

Multi-level decompression/fusions are as effective as single level lumbar spinal stenosis operations

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Introduction. A common hypothesis is that multi-level decompressions with/without fusion have worse clinical outcomes than similar single level operations. Our objective was to evaluate Patient Reported Outcomes (PROs), length of hospital stay and complication rates between two groups of patients: 1) 3-4 level decompressions with/without fusion and 2) single level decompressions with/without fusion.

Methods. We performed an observational cohort study using prospectively collected data from the Canadian Spine Outcomes and Research Network (CSORN). We included all patients diagnosed with stable lumbar spinal stenosis from 18 participating sites, operated on between 2008 and 2018. PROs were evaluated at 1-year post surgery. Length of hospital stay and complication rates were determined at hospital discharge.

Results. There were 1024 patients who met in/exclusion criteria (single level n=826, multi-level n=198); average age of the cohort was 65.9 (range 24-90, SD 11.4) with 63% males.

Unadjusted, adjusted and Propensity Score Matched analyses were performed to determine any significant differences.

The multi-level group had a statistically significant longer length of hospital stay (4.5 days vs 2.0; $p < 0.001$), intra-operative (12.6% vs 7.0%; $p < 0.009$) and peri-operative (20.2% vs 10.3%) adverse events.

Of the full cohort, 769 were eligible for 1-year follow up; 575/769 were successfully contacted (follow up rate =75%). At 12-month follow up, the multi-level group had a statistically significant smaller change in SF12 Mental Component Score between groups (2.9 vs 3.5). There were no statistically significant differences in PROs between groups for VAS back/leg pain, SF12 Physical Component Score, EQ5D or Oswestry score. Analyses using MCID change and Propensity Score Matching did not alter these findings.

Discussion. Length of stay and complication rates differ significantly, but long term, there were no statistically significant differences in PROs between multi and single level decompressions with/without fusion for stable lumbar spinal stenosis. Common assumptions that bigger surgery is worse long term, were not shown in this cohort.

Does the Concomitant Presence of Lumbar Scoliosis or Spondylolisthesis Affect Clinical Outcomes Following Decompression Surgery in Patients with Spinal Stenosis?

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Introduction: Lumbar stenosis can be accompanied by degenerative scoliosis or spondylolisthesis, which presents a challenge in surgical treatment decision-making. Once conservative measures fail, procedures can include: decompression alone, decompression with limited spinal fusion (fusion at the spondylolisthesis level alone), or long spinal fusion to regain acceptable alignment. The concern regarding an open decompression-only surgery in patients with lumbar stenosis and concurrent scoliosis and/or spondylolisthesis is the possibility of destabilizing the spine. However, little is known regarding the postoperative outcomes of patients with spinal stenosis that also present with concomitant scoliosis or spondylolisthesis. As such, the following study compared the postoperative clinical outcomes of patients who presented with stenosis alone to those that had concomitant scoliosis or spondylolisthesis.

Methods: We performed a retrospective analysis of patients who underwent a primary lumbar laminectomy between 2009-2015 by one of two senior orthopaedic spine surgeons. Patients were excluded from analysis if they had previous lumbar surgery, were under 18 years of age at the time of surgery, or had postoperative follow-up less than 3 months. Patients were divided into three groups; **Group 1:** patients diagnosed with lumbar stenosis alone (without concomitant scoliosis or spondylolisthesis); **Group 2:** patients with a concomitant scoliosis (>10 degrees of coronal angulation); **Group 3:** patients with stenosis and a concomitant spondylolisthesis at the level of decompression. Lumbar plain radiographs were evaluated to assess for concomitant scoliosis and spondylolisthesis diagnoses. Patient reported outcomes included Oswestry Disability Index (ODI) scores, Visual Analog Scales (VAS) scores for the back and leg, 12-Item Short Form Mental and Physical Survey (SF-12) scores, and the Veterans Rand 12-Item Health Mental and Physical Survey (VR-12) scores.

Results: Overall, 212 consecutive patients who fulfilled our inclusion criteria were assessed, with an average follow-up of 24.3 months (Table 1). All patients with a spondylolisthesis were found to be Meyerding Grade 1 and stable on flexion/extension lumbar plain radiographs. The scoliosis cohort (Group 2) had significantly more patients with an American Society of Anesthesiologists (ASA) grade of 3 or greater (48.8% vs 32.2%; p=0.001) compared to the stenosis-only cohort (Group 1). A herniated disc was present more often in the stenosis-only cohort (Group 1) compared to patients presenting with spondylolisthesis (Group 3) (p<0.001). Patients with scoliosis (Group 2) had a higher incidence of smokers (p=0.002) and had a lower duration of symptoms than patients with stenosis-alone (Group 1) (29.3±5.9 months vs 41.1 ± 53.8 months; p=0.042). There was no significant difference in any of the patient reported outcomes at all pre-operative and post-operative time points. Re-operation rates in stenosis-only patients (Group 1) (6.67%), scoliosis patients (Group 2) (10.26%), and spondylolisthesis patients (Group 3) (3.47%) did not differ significantly.

Discussion: At approximately two years after lumbar decompression alone, the presence of concomitant scoliosis or stable spondylolisthesis in lumbar spinal stenosis patients did not appear to impact clinical outcomes. Spinal stenosis patients that present with scoliosis or a stable spondylolisthesis can expect similar improvement of symptoms, following a stability-preserving lumbar decompression, as those that present with stenosis alone.

	Degenerative Stenosis alone	Scoliosis*	Spondylolisthesis~	All Patients	p-value
Overall	145	41	26	212	
Age	60.8 ± 14.9	62.9 ± 14.1	66.3 ± 9.5	61.9 ± 16.3	0.253
Female sex	26.67%	39.02%	38.46%	34.43%	0.087
BMI	29.3 ± 5.9	28.4 ± 6.2	30.9 ± 5.0	29.5 ± 6.5	0.404
Smoking	2.22%	10.17%	4.88%	8.02%	0.032
Diabetes	17.78%	24.39%	11.54%	15.57%	0.380
ASA ≥ 3	31.11%	48.78%	34.62%	27.83%	0.001
Percent with HNP	46.67%	51.22%	26.92%	41.21	<0.001
Duration of symptoms	41.1 ± 53.8	29.3 ± 5.9	33.4 ± 47.0	30.8 ± 46.1	0.042

*Stenosis in the presence of scoliosis with coronal angulation > 10 degrees

~Spondylolisthesis (all stable Meyerding Grade 1 in the presence of stenosis)

Early Surgery vs Prolonged Conservative Treatment for Sciatica - 10-year results of a Randomized Controlled Trial

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Introduction: The optimal timing for sciatica due to lumbar disc herniation is unclear. Early surgery results in faster recovery but long-term results appear similar to subjects treated with prolonged conservative treatment. Treatment outcome remains poor in a minority of patients regardless of the initial treatment policy, and recovery has been shown to vary with time due to subjects reporting intermittent periods of complaints. Randomized controlled trials have reported results up to 5 years. The current 10-year analysis will assess recovery, (re)operation incidence and results of treatment on health care costs and absenteeism among subjects randomly allocated to early surgery or prolonged conservative treatment.

Materials and Methods: The current study comprises the 10-year analysis of a multicenter, prospective, randomized trial among patients with 6 to 12 weeks of severe sciatica. Previously, the outcomes of 141 patients allocated to early surgery and 142 patients allocated to prolonged conservative treatment have been compared. Surgery was scheduled within 2 weeks after randomization. Conservative treatment was provided by the general practitioner and consisted of analgesics and physical exercises. In case disabling sciatica persisted for 6 months after the patient was randomized for conservative treatment, surgery was offered. Repeated standardized follow-up measurements were performed at 2, 4, 8, 12, 26, 38, 52, 78, 104, 156, 208, 260 and 520 weeks after randomization. Main outcomes are the Roland-Morris Disability Questionnaire for Sciatica (RDQ), Visual Analog Scale for leg pain and low-back pain, self-perceived recovery and reoperation incidence.

Results: After 10 years of follow-up 48% of subjects initially allocated to prolonged conservative treatment had undergone surgery. There was no clinically significant difference between early surgery or prolonged conservative treatment regarding the main clinical outcomes after 10 years of follow-up. RDQ scores at 10-years were 3.7 (95% CI 2.6 to 4.7) in the early surgery group and 3.3 (95% CI 2.3 to 4.3) in the prolonged conservative treatment group. The mean difference of 0.4 (95% CI -1.1 to 1.9) was not significant. Mean differences for leg pain and back pain were 2.9 (95% CI -3.3 to 9.1) and 3.0 (95% CI -4.9 to 10.9), respectively. 81% of patients allocated to early surgery reported good recovery of symptoms compared with 84% of patients allocated to prolonged conservative treatment ($p=0.65$). Among patients with unsatisfactory recovery leg pain decreased over the 10-year period (-29.1), whilst back pain increased (6.3). The reoperation rate was 11% in the early surgery group and 13% in the prolonged conservative treatment group ($p=0.66$).

Discussion: Long-term functional and clinical outcome did not differ between patients allocated to early surgery or prolonged conservative treatment, and the reoperation rate was similar in both treatment groups. These results do not differ from previously reported 5-year results. Determinants of poor recovery during short-term follow-up changed from predominant leg pain to predominant low back pain during long-term follow-up. This was not different for subjects treated surgically or non-surgically.

Mood disorders predict poor outcome of lumbar disc surgery - results from a clinical trial

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Introduction: Anxiety and depression are mood disorders that are frequently present in patients with chronic disorders. Approximately one third of patients undergoing lumbar surgery have symptoms of anxiety or depression. Previous studies have related anxiety and depression with increased pain and impaired functional disability in patients undergoing spine surgery. The aim of this study is to assess preoperative outcomes of the Hospital and Anxiety and Depression Scale (HADS) and postoperative surgical outcome in patients undergoing lumbar surgery for sciatica due to a lumbar herniated disc.

Materials and Methods: Data was derived from a double blind randomized controlled trial. 127 patients with a symptomatic lumbar disc herniation were randomly allocated to tubular discectomy (66 patients) or conventional microdiscectomy (61 patients). Repeated standardized follow-up measurements were performed at 2, 4, 6, 8, 12, 26, 38, 52, 78, 104, 156, 208 and 260 weeks after randomization. Main outcomes are the Roland-Morris Disability Questionnaire for Sciatica (RDQ), Visual Analog Scale for leg pain and low-back pain and self-perceived recovery. Depression and anxiety were assessed with the Hospital and Anxiety and Depression Scale.

Results: 11.9 percent of patients were preoperatively identified with a depression disorder (HADS depression score of 11 or more) and 20.7 percent with a possible depression disorder (HADS depression score 8-10). 19 percent of patients had an anxiety disorder (HADS anxiety score of 11 or more) and 39.2 percent had a possible anxiety disorder (HADS anxiety score 8-10). Postoperative Roland Disability during all consecutive follow-up moments was significantly associated with lower functional outcome (4.6, CI 1.1 to 8.1 at 5-years) in patients with a depression score of 11 or more. VAS leg pain (8.3, CI -6.2 to 22.9) and VAS back pain (3.0, CI -12.9 to 18.9) pain were not significantly associated with a depression score of 11 or more. Anxiety scores of 11 or more were not associated with significant worse functional outcome or increased leg or back pain. Moderate depression or anxiety scores of 8-10 were not significantly associated with worse outcome. 57% of subjects with depression (score of 11 or more) reported recovery of symptoms compared with 83% of subjects without depression ($p=0.02$). Anxiety scores were not significantly related with self-perceived recovery.

Discussion: A HADS score of 11 or more points for depression was a significant and strong predictor for worse functional disability and self-perceived recovery after lumbar disc surgery, whilst lower cutoff points and anxiety disorder were not related with outcome. Furthermore, the subjective reporting of functional disability and self-perceived recovery seem influenced more by mood disorders than measurements of pain. Results can be applied in a clinical tool to identify patients at risk for poor surgical outcome and for whom a reluctant surgical approach is warranted.

The indirect decompression effect of oblique lateral interbody fusion in the treatment of degenerative lumbar stenosis

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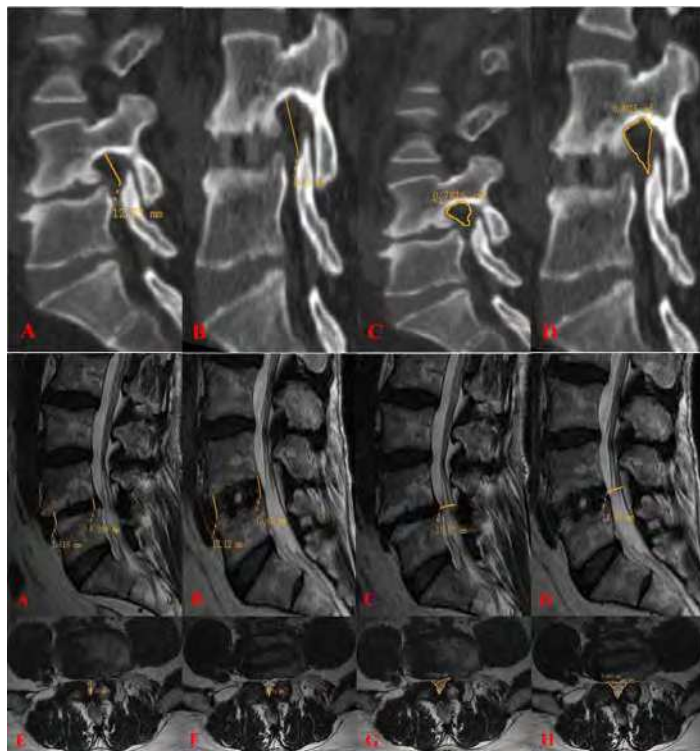
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Introduction Degenerative lumbar spinal stenosis is a reduction in the volume of the central spinal canal, the lateral recesses, and/or neuroforamina that decreases the space available for the thecal sac and/or exiting nerve roots. Traditionally, posterior approaches were usually used for direct decompression. However, it is well known that significant soft tissue injury were unavoidable in posterior lumbar approaches. In order to avoid the iatrogenic paraspinal muscle injury and the interferences of canal, mini-open anterior retroperitoneal lumbar interbody fusion methods, such as oblique lumbar interbody fusion (OLIF) have been applied recently. In theory, OLIF can achieve indirect decompression through restoring disc height and intervertebral stability, however the real effect has still controversies.

Methods From October 2014 to November 2017, 56 patients with mild to moderate lumbar spinal stenosis underwent OLIF combined with or without posterior pedicle screw fixation; 23 males and 33 females with average age 60.2 ± 17.6 years old; 18 cases at L3/4 segment and 38 cases at L4/5 segment. All cases were followed up for more than 1 year. Thin layer scanning of CT and two-dimensional reconstruction images were used to measure the vertical diameter and area of intervertebral foramen. Intervertebral disc height and spinal canal anteroposterior diameter were measured by on median sagittal MRI sequence, and the anteroposterior diameter and the cross-sectional area of the spinal canal were measured on cross-sectional MRI sequence. The clinical effects were assessed by the visual analogue score (VAS) and the Oswestry disability index (ODI) for low back pain, lower limb pain and lower limb numbness.

Results Compared with those measurements pre-operatively, the post-operative intervertebral disc height increased by $72.6 \pm 17.4\%$, and the post-operative left vertical diameter of intervertebral foramen increased by $34.3 \pm 11.6\%$, and the post-operative left area of intervertebral foramen increased by $32.6 \pm 12.2\%$, and the post-operative right vertical diameter of intervertebral foramen increased by $38.1 \pm 12.4\%$, and the post-operative right area of intervertebral foramen increased by $39.1 \pm 11.2\%$, and the post-operative anteroposterior diameter of sagittal spinal canal were increased $31.2 \pm 7.5\%$, and the post-operative anteroposterior diameter of cross-sectional spinal canal were increased $32.1 \pm 9.4\%$, and the post-operative cross-sectional area of the spinal canal were increased $51.2 \pm 13.6\%$. All of the differences were statistically significant between pre-operative and post-operative measurements. The VAS score for low back pain was 6.4 ± 2.3 pre-operatively, and 1.2 ± 0.4 post-operatively. The ODI for low back pain was $84.2 \pm 23.4\%$ pre-operatively, and $6.8 \pm 3.6\%$ post-operatively. The VAS score for lower limb pain was 5.3 ± 2.0 pre-operatively, and 0.7 ± 0.5 post-operatively. And the VAS score for lower limb numbness was 6.5 ± 2.9 pre-operatively, and 2.1 ± 1.0 post-operatively. All of the differences were statistically significant between pre-operative and post-operative evaluations.

Discussion There were obvious radiological evidences and remarkable clinical effect of indirect decompression used OLIF technique in treatment of mild to moderate lumbar spinal stenosis at early post-operative stage. However further long-term follow-up studies with multicenter large sample were still needed.



Efficacy of decompression surgery on walking ability and health-related quality of life in lumbar spinal stenosis patients with gluteus medius muscle weakness

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Introduction: We previously reported that weakness in gluteus medius muscle (GM) decreased walking ability and activities of daily living in patients with lumbar spinal canal stenosis (LSS) (ISSLS 2017). However, to the best of our knowledge, there is no study about the efficacy of surgical treatment on the weakened GM strength in patients with LSS. The objective of this study was to clarify whether decompression surgery could improve walking ability and health-related quality of life (HRQOL) in patients with GM weakness caused by LSS.

Methods: From July 2016 to March 2018, a total of 206 consecutive LSS patients (114 male, 92 female) who underwent single-level decompression surgery for LSS and followed at six months and at 1 year after the surgery were prospectively enrolled. The muscle strengths of GM were quantitatively measured using a hand-held dynamometer. To set a reference value of GM strength, that of 137 volunteers (75 male, 62 female) were assessed. We defined the value of GM strength under -2SD as GM weakness. Timed up and go (TUG) and two-step tests were used to evaluate the functional mobility. HRQOL of patients was assessed including JOABPEQ, RDQ, ODI and SF-36. Differences between the groups were analyzed using the Student's t-test and Mann-Whitney U-test (* $p < 0.05$).

Results: We identified 21 cases (10.2%) (14 male and 7 female) with GM weakness, of which 2 were diagnosed with canal stenosis at L3/4, 14 at L4/5, and 5 with extraforaminal stenosis at L5/S1, suggesting that GM weakness was mainly caused due to an L5 nerve root disorder (19 patients, 90.5%). The mean GM strength (Nm/kg) was 0.89 ± 0.48 preoperatively, 1.37 ± 0.51 at six months postoperatively ($p=0.01$), and 1.69 ± 0.30 at 1 year postoperatively ($p<0.01$), suggesting that the strength of GM was significantly improved by decompression surgery. The mean two-step test scores were increased from 0.90 ± 0.13 before surgery to 1.05 ± 0.22 ($p=0.35$) at six month, and 1.17 ± 0.18 at one year postoperatively ($p=0.03$). The mean TUG test scores had tendency to be shortened; 13.4 ± 3.9 seconds preoperatively, 11.2 ± 3.8 seconds at 1 year postoperatively, whereas they did not reach any statistical differences. The JOABPEQ scores for all domains, the ODI scores were significantly decreased at one year postoperatively, compared to those at preoperatively ($p<0.01$).

Discussion: This is the first study to reveal that decompression surgery could have a potential to improve the GM strength perioperatively, leading to increase functional morbidity in LSS patients with GM weakness. We also found that surgical treatment could have positive impact on HRQOL regardless of whether patients with LSS have GM weakness.

Nucleus pulposus-derived stem cells encapsulated in BMP7-based functionalized self-assembling peptide for alleviation of intervertebral disc degeneration in a rabbit model

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Introduction: Intervertebral disc degeneration (IDD), the primary cause of low back pain, is an irreversible disease with no effective treatment. Recently, nucleus pulposus-derived stem cells (NPSCs) have been considered as a potential cell source for intervertebral disc (IVD) regeneration. In our previous study, we established a novel functionalized self-assembling peptide RKP through conjugating a short bioactive sequence KPSSAPTQLN (KPS) derived from bone morphogenetic protein-7 (BMP7) to the C-terminus of RADA16-I and found that the functionalized peptide mixture RAD/RKP could form excellent scaffold for IVD tissue engineering [1, 2]. The aim of this study was to evaluate the regenerative effect of NPSCs encapsulated in BMP7-based functionalized self-assembling peptide RAD/RKP in a rabbit model of IDD.

Methods: Consecutive five lumbar IVDs from L2-L3 to L6-L7 in each of 20 New Zealand white rabbits were induced to degeneration using annulus fibrosus puncture. The intact disc L7-S1 was served as normal control. Four weeks later, the injured IVDs of each animal were treated differentially: L2-L3 were injected with 20 μ L phosphate-buffered saline (PBS), L3-L4 with 20 μ L RADA16-I, L4-L5 with 20 μ L RAD/RKP, L5-L6 with 20 μ L of 1×10^5 NPSCs, and L6-L7 with 20 μ L of 1×10^5 NPSCs loaded in RAD/RKP, respectively. Radiological measurements were performed pre-operation and post-operation at 4, 8, and 12 weeks, respectively, including disc height index (DHI) on plain radiograph, Pfirrmann grade and T2 relaxation time on magnetic resonance imaging (MRI). Then all animals were euthanized and the IVD samples were evaluated by histological analysis and enzyme-linked immunosorbent assay (ELISA). In addition, correlations between T2 relaxation time and other parameters were analyzed using Pearson's or Spearman's coefficients.

Results: Injection of NPSCs-laden RAD/RKP had the most satisfactory effects on the treatment of IDD in rabbits. %DHI decreased from 75.6% at 4 weeks to 64.2% at 12 weeks, demonstrating that the disc height in NPSCs-laden RAD/RKP group decreased significantly slowly ($P > 0.05$). The IVDs in NPSCs-laden RAD/RKP group had lower Pfirrmann grade as well as histological grade ($\chi^2 = 73.58$, $P < 0.001$; $\chi^2 = 82.38$, $P < 0.001$). In addition, T2 relaxation time in NPSCs-laden RAD/RKP group was significantly longer than that in other degenerative groups (92.58 ± 8.33 ms, $P < 0.001$). Similarly, the expressions of proteoglycan and collagen II in NPSCs-laden RAD/RKP group were significantly higher compared to other degenerative groups (5.75 ± 1.10 ng/mg, $P < 0.001$; 2.53 ± 0.98 ng/mg, $P < 0.001$). T2 relaxation time was negatively correlated with Pfirrmann grade ($r = -0.68$, $P < 0.001$) and histological grade ($r = -0.72$, $P < 0.001$), but positively correlated with the contents of proteoglycan ($r = 0.82$, $P < 0.001$) and collagen II ($r = 0.69$, $P < 0.001$).

Discussion: In the present study, we firstly incorporated endogenous stem cells within IVDs into RAD/RKP and explored the efficacy of this composite on prevention of IDD *in vivo*. Our results suggest that injection of NPSCs-laden RAD/RKP is effective in decelerating disc degeneration in the experimental model, providing a promising clinical application for the management of IDD in human in future. Furthermore, T2 mapping may serve as a non-invasive and quantitative monitoring tool to evaluate the effects of cell-based tissue engineering on IDD.

1. Tao H, Wu Y, Li H, Wang C, Zhang Y, Li C, Wen T, Wang X, He Q, Wang D, Ruan D (2015) BMP7-Based Functionalized Self-Assembling Peptides for Nucleus Pulposus Tissue Engineering. ACS applied materials & interfaces 7:17076-17087. doi: 10.1021/acsami.5b03605.
2. Tao H, Zhang Y, Wang CF, Zhang C, Wang XM, Wang DL, Bai XD, Wen TY, Xin HK, Wu JH, Liu Y, He Q, Ruan D (2014) Biological evaluation of human degenerated nucleus pulposus cells in functionalized self-assembling peptide nanofiber hydrogel scaffold. Tissue engineering Part A 20:1621-1631. doi: 10.1089/ten.TEA.2013.0279.

Expression of TRPV4 in human IVDs and its relevance in stretch-induced inflammation

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Introduction: Transient receptor potential (TRP) channels are cation selective transmembrane channels with diverse activation mechanisms and physiological function. Dysregulation of TRP channels is implicated in numerous pathologies. TRPV4 for example is involved in mediating inflammatory swelling in arthritic joints; in addition, TRPV4 regulates transduction of mechanical signals in various cell types¹. A first study from 2016 indicates that TRPV4 is expressed in the intervertebral disc (IVD) and seems to be associated with reduced osmolarity and pro-inflammatory cytokines².

The aim of this study was to (1) investigate TRPV4 expression patterns in a comprehensive manner and (2) determine whether TRPV4 plays a role in stretch-induced inflammation.

Methods: For the analysis of TRPV4 mRNA expression in human IVDs, a total of n=22 human degenerated (IVD degeneration/herniation) and n=12 non-degenerated IVD tissue samples (autopsies) were used. Gene expression was compared between degeneration and non-degeneration, NP and AF, as well as for various patient characteristics.

In a second step, the relevance of TRPV4 in stretch-induced inflammation (gene/protein), calcium flux and activation of the MAPK pathways was investigated in human AF cells *in vitro*, using a commercial bioreactor (n≥3, with/without pharmacological TRPV4 inhibition = GSK2193874, 20 – 500 nM).

Statistical analysis was conducted by Student t-tests, Aspin-Welch unequal variance tests or one-way ANOVA with Tukey correction, with a significance level of p < 0.05.

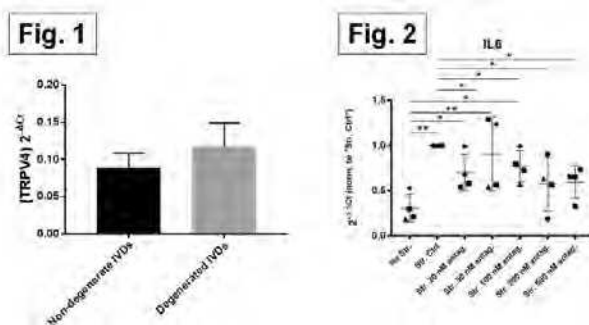
Results: TRPV4 mRNA was detected in all human IVD tissue samples. No statistically significant differences were found between the degenerated and non-degenerate samples (**Fig. 1**), IVD zones (NP vs. AF), degeneration grade (Pfirrmann grade), Modic changes, pain intensity and duration. Furthermore, its expression did not depend on whether a patient received a steroid treatment. Based on the constitutive expression of TRPV4, we subsequently investigated its role in IVD mechanobiology.

To determine the relevance of TRPV4 in mechanotransduction, 1 hour of stretching at 20% strain/1 Hz (= high physiological levels) was used based on initial experiments. These loading conditions resulted in a significant mRNA upregulation of inflammatory mediators, such as IL-6 (2.6 fold) and COX-2 (8.1 fold). First results confirm induction of inflammation on the protein level. Stretch-induced inflammation was accompanied by a significant MAPK activation (immunoblotting, 15 min) and calcium flux (live imaging with Fluo-4AM dye). Importantly, pharmacological inhibition of TRPV4 was able to reduce cytokine expression (**Fig. 2**) and MAPK activation.

Discussion: TRPV4 was consistently expressed in human IVD samples, indicating its fundamental function in IVD physiology and mechanotransduction. Our results suggest that stretch-induced inflammation may be mediated at least in part by TRPV4. TRPV4 may thus constitute a potential therapeutic target to tackle degenerative disc disease. Current work includes confirmation of results obtained with pharmacological TRPV4 inhibition by CRISPR/Cas9-based TRPV4 knockout.

Legends: Fig.1 Gene expression of TRPV4 in the non-degenerated (n=12, black bar) and degenerated (n=22, grey bar) IVD tissue.

Fig.2 Gene expression of IL-6 in human AF cells that were non-stretched (No. Str.), stretched or stretched with simultaneous TRPV4 inhibition with GSK2193874 (Str. antagon.) (n=4). *p<0.05, **p<0.01.



1. Krupkova et al., Eur Cell Mater 2017; 34: 180-201
2. Walter et al., Eur Cell Mater 2016; 32: 123-136

Pathological effects of cortisol on intervertebral disc cells and mesenchymal stem cells from low back pain patients.

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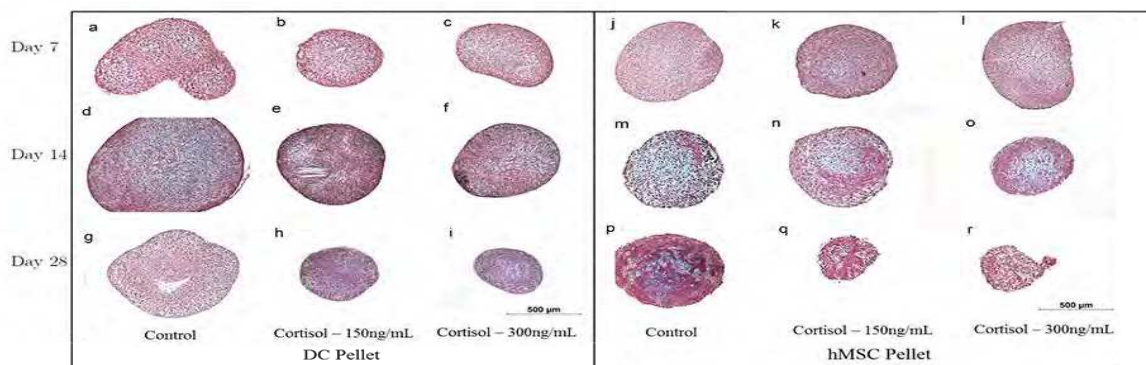
Background: In western countries, low back pain (LBP) is one of the most common disorders experienced by more than 80% of the population [1]. One of the main causes is reported to be disc degeneration involving the nucleus pulposus (NP) area with loss of proteoglycans and disorganization of the collagen structure. Chronic LBP has also been implicated to be linked to stress induced inflammation [2]. Psychological distress may aggravate pain symptoms, which in turn may cause excessive bodily stress leading to more pain [3]. Pain induces a stress response in the bodily systems and the body responds to stress by releasing cortisol (CORT) from adrenal cortex. CORT synthesis has also been reported to be induced by IL-1 β and tissue injury [4]. Physiological CORT level fluctuates between 10-250ng/mL within a day in healthy individuals [5]. However, it has been reported that CORT above physiological level induces apoptosis in chondrocytes both *in vitro* and *in vivo* [6]. Little is known about the impact of pain induced stress on IVD degeneration.

The aim was to explore the effects of stress mediated CORT at concentrations close to physiological concentrations *in vitro* on intervertebral disc cells (DCs) and human mesenchymal stem cells (hMSCs) isolated from patients with LBP in terms of chondrogenesis and proteoglycan accumulation. The objective was to further investigate cell proliferation, viability, cellular apoptosis, and expression of cytokine and chemokine receptors in DC and hMSCs as well as differentiation of hMSCs into chondrocyte-like cells.

Method: DC and hMSC pellet cultures (200,000 cells/pellet) were exposed to CORT at two concentrations, 150 ng/mL (CORT150) mimicking a normal healthy level and 300ng/mL (CORT300) an elevated pathological cortisol level for 28 days to simulate pain induced stress. The pellets were harvested at day 7, 14, and 28. Cell viability, histological staining with Alcian blue von Gieson, glycosaminoglycan (GAG), DNA along with TUNEL assays were performed. Detection of OCT4, SOX9, IL-1R and CXCR2 expressions was operated by immunohistochemistry.

Results: In this *in vitro* study, restricted cell proliferation and less GAG production in both DCs and hMSCs were observed with constant exposure of CORT at both physiological and elevated concentrations at two later time points. Higher number of apoptotic cells were detected especially at 300ng/mL CORT concentration in both DCs and hMSCs. Suppression of differentiation and immunomodulatory efficacy of hMSCs were also found with CORT treatment. Elevated expressions of IL-1R and CXCR2 were detected in both cell types when treated with CORT.

Conclusion: The findings from the present study suggest that increased concentrations of cortisol resulting from pain induced stress could be a contributing component of IVD degeneration and that further investigations both *in vitro* and *in vivo* are of interest to scrutinize the exact role and possibility to influence this factor for the large group patients suffering from LBP.



1. Airaksinen, O., et al., Chapter 4. European guidelines for the management of chronic nonspecific low back pain. Eur Spine J, 2006. 15 Suppl 2: p. S192-300
2. Hannibal, K.E. and M.D. Bishop, Chronic stress, cortisol dysfunction, and pain: a psychoneuroendocrine rationale for stress management in pain rehabilitation. Phys Ther, 2014. 94(12): p. 1816-25. Quinlan, J., et al., Protocol for a systematic review of the association between chronic stress during the life course and telomere length. Syst Rev, 2014. 3: p. 40.
3. Vukelic, S., et al., Cortisol Synthesis in Epidermis Is Induced by IL-1 and Tissue Injury. Journal of Biological Chemistry, 2011. 286(12): p. 10265-10275.
4. LaGow B et al., PDR Lab Advisor. A Comprehensive Point-of-Care Guide for Over 600 Lab Tests. 2007: PHYSICIANS DESK REFERENCE.
5. Nakazawa, F., et al., Corticosteroid treatment induces chondrocyte apoptosis in an experimental arthritis model and in chondrocyte cultures. Clin Exp Rheumatol, 2002. 20(6): p. 773-81.

Genetic lineage tracing of intervertebral disc cells in a neonatal regeneration model

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Introduction: Human intervertebral discs (IVDs) heal poorly, which can result in persistent pain. No regenerative strategies exist to promote cellular and functional IVD regeneration. We established a neonatal IVD regeneration model with complete functional healing and improved structure following nucleus pulposus (NP) herniation, contrasting degeneration and impaired function in adults [1]. The current study traced the fate of IVD cells and determined AF differentiation during neonatal regeneration. Identifying novel cell and molecular factors using lineage tracing in a regeneration model may inform therapies to promote adult IVD regeneration.

Methods: *Scx^{CreERT2}* (AF lineage), *Scx^{GFP}* (AF reporter) [2], *Shh^{Cre}* (NP lineage with *Shh^{EGFP}* reporter) [3], and Rosa26-TdTomato (Cre lineage reporter) [4] mice were used. Needle puncture injuries were induced *in vivo* at P5 [1] (n=5). Proliferation was assessed at day (d) 3 (EdU). Fluorescence detection of *Scx*-lineage (*Scxlin*) and *Shh*-lineage (*Shhlin*) cells was performed at d3 & d56. One-tailed Student's t-test determined differences in percentage of proliferating cells between control and injury with p<0.05 significance.

Results: Distinct repair cell populations observed in the highly cellularized d56 AF injury site included *ScxGFP*+ annulocytes of both *Scxlin* and non-*Scxlin* (Fig. 1). *Scxlin* cells that lost *ScxGFP* expression were observed, indicating AF cells were recruited into the defect but failed to restore AF phenotype. The injury site was disorganized at d56 despite the presence of AF cells. Co-localization of *Scxlin* cells with EdU at d3 determined whether AF healing occurred via annulocyte proliferation (Fig. 2). Most proliferating cells were *Scxlin* in controls (71.0±9.8%) and non-*Scxlin* after injury (57.2±1.3%). These results demonstrated neonatal AF healing was mediated by proliferation of extrinsic repair cells followed by AF cell recruitment and differentiation. Detection of *Shhlin* cells determined a population of *Shhlin* only (*ShhEGFP*-) cells with stellate morphology and elongated processes at d3 (Fig. 3), demonstrating a potential role for a population of *Shhlin* repair cells in the early AF injury response.

Discussion: AF differentiation occurred following neonatal herniation injury indicated by *ScxGFP* expression at d56. While phenotypic regeneration of the neonatal AF is possible, it occurs over a longer period than other tissues, e.g., neonatal tendon (d14) and neonatal heart (d21) that regenerate faster [5,6]. Neonatal IVD healing involved contributions from proliferating intrinsic annulocytes and extrinsic repair cells. The *Shhlin* cells in the injury site may appear to be cells recruited from a non-NP source since they have stellate morphology more similar to myofibroblasts. *Shh* has been implicated in myofibroblast accumulation [8] and may play a role in the acute injury response of the neonatal AF. We conclude that AF regenerative healing occurred and involved retention of intrinsic *Scxlin* cells, recruitment of extrinsic *Shhlin* cells, and restoration of AF cell phenotype.

References: [1] Torre+FASEB J,2018 [2] Pryce+Dev Dyn,2007 [3] Harfe+Cell,2004 [4] Madisen+Nat Neurosci,2010 [5] Howell+Sci Rep,2017 [6] Porrello+Science,2011 [7] Lehoczy+Proc Natl Acad Sci,2011 [8] Choi+Int J Biochem Cell Biol,2011

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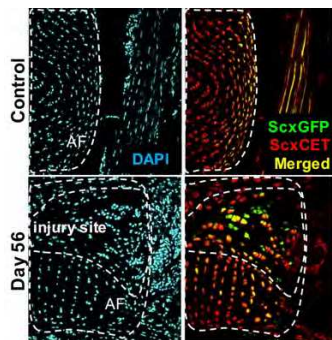


Figure 1: AF differentiation of *ScxGFP* annulocytes occurs at day 56. Most *ScxGFP* cells in the injury site derive from *Scxlin* cells (*ScxGFP* & *Scxlin*). A population of annulocytes is present in the injury site that derives from an extrinsic source (*ScxGFP* only). Mag=20X.

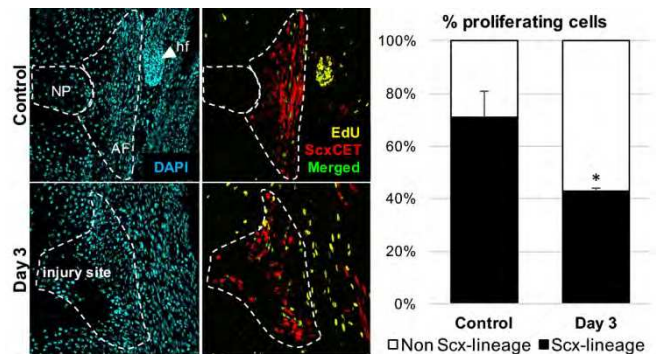


Figure 2: Proliferation of *Scxlin* cells (EdU & *Scxlin*) and non-*Scxlin* cells (EdU only) in neonatal AF is observed at day 3 in the injury site compared to uninjured controls. Mag=20X. *p=0.003 compared to control. hf = hair follicle.

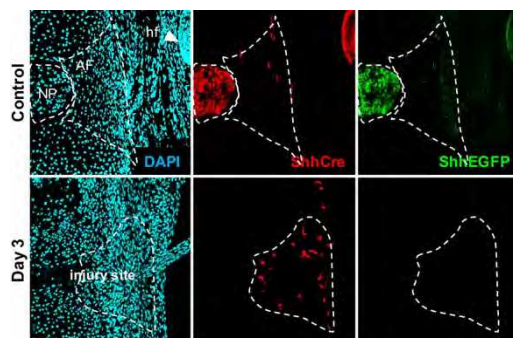


Figure 3: A population of *Shhlin* cells is present at day 3 in the injury site. *Shhlin* cells were observed in control NP at day 3, and in a small number of cells in the control AF. *Shhlin* cells at day 3 had elongated processes. Mag=20X.

A new rabbit model of intervertebral disc degeneration induced by intradiscal injection of monosodium iodoacetate

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Introduction: Establishing an optimal animal model for intervertebral disc (IVD) degeneration is important for developing new IVD therapies. Monosodium iodoacetate (MIA) injection, which is commonly used in animal models of osteoarthritis (OA), induces cartilage degeneration and progressive arthritis in a dose- and time-dependent manner. However, whether MIA injections into IVDs induce degenerative changes has not been evaluated. The purpose of this study was to determine the effect of MIA injections into rabbit IVDs on the progression of IVD degeneration evaluated by radiographic, micro-computerized tomography (μ CT), magnetic resonance imaging (MRI) and histological analyses.

Methods: 24 New Zealand White (NZW) rabbits (female, 16 weeks-old) were used in this study. Under general anesthesia, each disc from L1/2 to L4/5 had a posterolateral percutaneous injection of MIA in contrast agent (L1/2: contrast agent only; L2/3: MIA 0.01 mg; L3/4: 0.1 mg; L4/5: 1.0 mg; L5/6: non-injection control) (Fig. 1). Six rabbits were sacrificed at 2, 4, 8, and 12 weeks post-injection and processed for μ CT, MRI and histological analyses.

Radiography: Disc height was radiographically monitored biweekly from the day of injection to 12-weeks post-injection. IVD height was expressed as the disc height index (DHI) and the change in DHI for each disc was expressed as the percent disc height index (%DHI).

3D μ -CT: After CT-scanning of lumbar spinal columns, three-dimensional (3D) reconstructions and isolation of the endplates were performed using Mimics software (Materialize). The endplates were divided into 5 zones (Fig. 2), and the zonal 3D-disc height was calculated using a custom-written program.

MRI T2-quantification: Quantitative T2 mapping was performed in the sagittal plane. Signal intensity values within each regions of interest (ROI) were averaged and fit to a T2 decay equation.

Histology: Mid-sagittal sections of each IVD were stained with both hematoxylin and eosin or with safranin-O and graded using the previously established histology grading protocol.

Results: Change in disc height (Fig. 3): %DHI of each disc level gradually decreased time-dependently ($P < 0.01$). The discs injected with MIA (L2/3-L4/5) showed a significant decrease in %DHI compared to those of L1/2 and L5/6 (all $P < 0.01$). There were also significant differences in %DHI among the three MIA-injected discs (L2/3-L4/5, all $P < 0.01$). 3D-disc height: The 3D-disc height of posterior and NP zones gradually decreased significantly ($P < 0.01$). Change in T2 value: MRI T2-values of L3/4 (MIA 0.1 mg) and L4/5 (MIA 1.0 mg) significantly decreased compared to that of the L1/2 control ($P < 0.01$); that of L4/5 (MIA 1.0 mg) was significantly decreased compared to that of the L5/6 control. Histology: Histological analyses showed progressive time- and dose-degenerative changes in the discs injected with MIA ($P < 0.01$).

Discussion: The results of this study showed, for the first time, that the intradiscal injection of MIA induced degenerative changes of rabbit IVDs in a time- and dose-dependent manner. This study suggests that MIA injection into rabbit IVDs could be used as an animal model of IVD degeneration for developing future treatments.

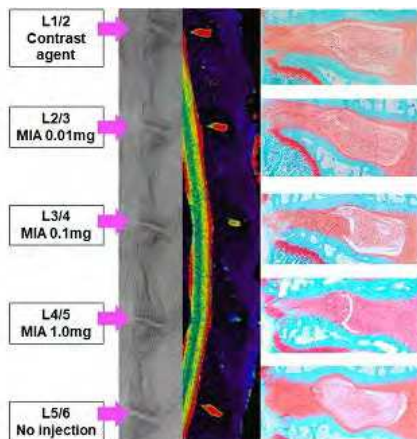


Fig. 1. Radiography and MRI T2-mapping and histology at 12weeks post-injection

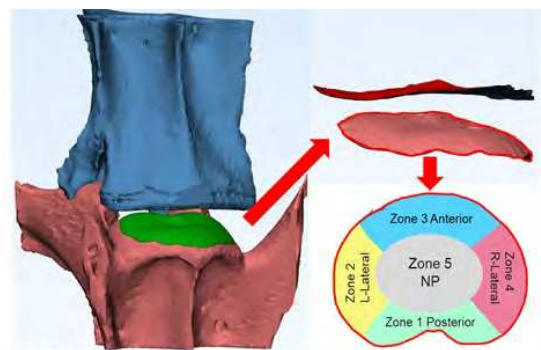


Fig. 2. Isolation of endplates and 5zones (Posterior, L-Lateral, Anterior, R-Lateral, NP)

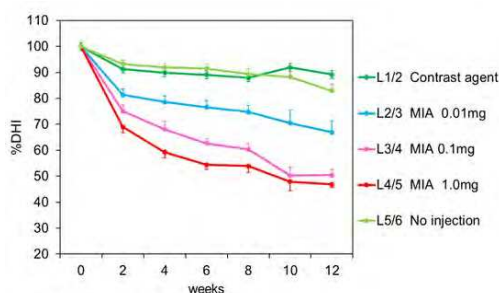


Fig. 3. Change in disc height

Identification of two natural compounds as new senolytics in intervertebral disc degeneration and back pain.

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Introduction: Intervertebral discs (IVDs) degeneration is one of the major causes of back pain. Upon degeneration, the IVDs tissue become inflamed, and this inflammatory microenvironment may cause discogenic pain. Cellular senescence is a state of stable cell cycle arrest in response to a variety of cellular stresses including oxidative stress and adverse load. The accumulation of senescent IVDs cells in the tissue suggest a crucial role in the initiation and development of painful IVD degeneration. Senescent cells secrete an array of cytokines, chemokines, growth factors, and proteases known as the senescence-associated secretory phenotype (SASP). The SASP promote matrix catabolism and inflammation in IVDs thereby accelerating the process of degeneration. In this study, we quantified the level of senescence in degenerate and non-degenerate IVDs and we evaluated the potential of natural compounds to remove senescent cells and promote overall matrix production of the remaining cells.

Methods: Human IVDs were obtained from organ donors. Pellet or monolayer cultures were prepared from freshly isolated cells and cultured in the presence or absence of two natural compounds: Curcumin and its metabolite vanillin. Monolayer cultures were analyzed after 4-days and pellets after 21 days for the effect of senolysis. A cytotoxicity study was performed using Alamar blue assay. Following treatment, RNA was extracted, and gene expression of senescence and inflammatory markers was evaluated by real-time q-PCR using the comparative $\Delta\Delta C_t$ method. Also, protein expression of p16, Ki-67 and Caspase-3 were evaluated in fixed pellets or monolayer cultures and total number of cells was counted on consecutive sections using DAPI and Hematoxylin. Proteoglycan content was evaluated using SafraninO staining or DMMB assay to measure sulfated glycosaminoglycan (sGAG) and antibodies were used to stain for collagen type II expression.

Results: We observed 40% higher level of senescent cells in degenerate compare to the non-degenerate discs from unrelated individuals and a 10% increase when we compare degenerate compare to the non-degenerate discs of the same individual. Using the optimal effective and safe doses, curcumin and vanillin cleared 15% of the senescent cells in monolayer and up to 80% in pellet cultures. Also, they increased the number of proliferating and apoptotic cells in both monolayer and pellets cultures. Following treatment, mRNA expression levels of SASP factors were decreased by 4 to 32-fold compared to the untreated groups. Senescent cell clearance decreased, protein expression of MMP-3 and -13 by 15 and 50% and proinflammatory cytokines levels of IL-1, IL-6 and IL-8 by 42, 63 and 58 %. Overall matrix content was increased following treatment as validated by an increase in proteoglycan content in pellet cultures and surrounding culture media.

Discussion: This work identifies novel senolytic drugs for the treatment of IVD degeneration. Senolytic drugs could provide therapeutic interventions that ultimately, decrease pain and provide a better quality of life of patients living with IVDs degeneration and low back pain.

Identification through movement analysis of chronic low back pain pathological spinal movements patterns and their sensibility to change during exercise treatment

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Introduction: Chronic low back pain (CLBP) is a bio-psycho-social syndrome causing disability. While there are multiple imaging systems for the anatomical structures, in vivo movement evaluation has scarcely been performed.¹ Our aim was to pilot in a CLBP population a movement analysis protocol developed in healthy participants², and verify correlations with pain, disability and treatment effects.

Methods: We recruited a convenience sample of 10 CLBP patients who were referred for a group exercise therapy (strengthening, core stability, active stretching and postural re-education)^{3,4} We used a non-invasive optoelectronic full spine evaluation according to a previously developed protocol². We analyzed anterior flexion, lateral bending and rotation movements, and collected Numerical Rating (NRS) and Oswestry (ODI) scales before and after treatment. We performed a qualitative analysis to identify possible abnormal movement patterns, that have been quantified through 3 or 4 points Likert scales: their inter-observers repeatability has been checked comparing three operators (1 expert and 2 students). A total score for each movement has then been calculated as well as its variations with treatment, and correlations with ODI and NRS.

Results: Comparing normal to pathological patterns (fig 1) we identified the following parameters: for all movements total Range of Motion, fluidity, symmetry, and pelvis center; we also added for lateral bending the lumbopelvic rhythm, for flexion and rotation the arrival overdrive, and for flexion the altered Anticipatory Postural Adjustments. Inter-operators repeatability resulted in a Cohen k 0.21-0.4 in 13% of parameters, 0.41-0.6 in 47%, 0.61-0.8 in 32% and 0.81-1 in 9%. With treatment, ODI and NRS improved and the total score decreased in all movements: flexion (p<0.01), bending (p<0.01) and rotation (p<0.0005). We did not find any correlation with ODI and NRS.

Discussion: In this study we have identified some reliable qualitative patterns of pathological movement in CLBP that showed to be sensible to treatment, even if not correlated to subjective scales like ODI and NRS. Future studies should check these preliminary results in wider populations and different treatments, while a quantification of these qualitative parameters is under development. Negrini, S. et al. Trunk motion analysis: a systematic review from a clinical and methodological perspective. Eur. J. Phys. Rehabil. Med. 52, 583–592 (2016)

Barbara, P. et al. Functional assessment of the spine through an optoelectronic system. Gait & Posture Volume 57, Supplement 1, Pages 347-348 (2017)

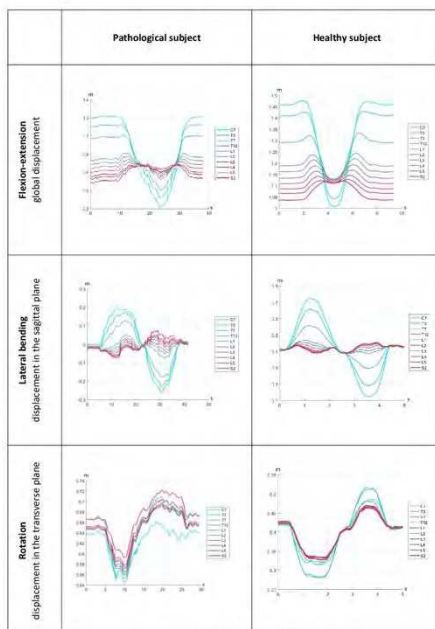


Figure 1: Pathological vs Healthy pattern, in time (s)

1. Sahin, N. et al. Effectiveness of back school for treatment of pain and functional disability in patients with chronic low back pain: a randomized controlled trial. J. Rehabil. Med. 43, 224–229 (2011)
2. Pflugsten, M. et al. Multidisciplinary treatment program on chronic low back pain, part 3. Psychosocial aspects. Schmerz Berl. Ger. 10, 326–344 (1996)

Male gender and initial job demand predicts successful re-integration and return to work: results from 20-years of Experience with a Multidisciplinary Programme for Rehabilitation of Chronic Low Back Pain

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Introduction: Low back pain (LBP) is highly disabling with significant healthcare burden worldwide. Rehabilitation and reintegration of this group of patients back to the working population, is paramount to alleviating medical and social costs. Since 1996, we have adopted a 14-week intensive multidisciplinary programme targeting patients with chronic LBP, providing functional rehabilitation aiming at re-integration back to the society. This study aims to review its outcomes, as well as to identify factors predicting successful return to work.

Methods: This was an analysis of a prospectively collected cohort of chronic LBP patients consecutively enrolled into the programme. Rigorous pre-admission assessment was performed to identify patients with functional deficits while excluding patients with surgically treatable diseases or psychological disorders. These patients all failed to return to work previously despite a prolonged period of conservative treatment. Assessments were performed at baseline, 8-weeks and 14-weeks. Sitting, standing and walking tolerance, and straight leg raise test were studied. Pain was assessed by Visual Analogue Scale (VAS) and functional assessment was performed by Oswestry Disability Index (ODI), Acceptance of Illness Scale (AIS), Bradburn Affect Balance Scale (BABS) and Spinal Function Sort Score (SFSS). Final capacity for returning to work was defined by matched achieved work strength level with the job demand. Wilcoxon signed-rank test and paired t-tests were performed to determine differences in parameters before and after the programme. Spearman's correlation analysis and chi-square test of independence were used to delineate any significant associations between different factors and the ability to return to work. Based on these tests, a multivariate logistic regression model was generated to ascertain the effect of factors on predicting ability to return to work.

Results: 191 patients (26.2% female) with mean age 40.2 years were recruited. Up to 89.0% of patients had an injury on duty. There was significant improvement in ODI (46.9 to 43.9, $p<0.05$), SFSS (98.3 to 108.1, $p<0.05$), sitting (50.3 to 60.7, $p<0.001$), standing (40.2 to 46.6, $p<0.001$) and walking tolerance (50.7 to 59.1, $p<0.001$), and straight leg raising test (Right: 73.3 to 77.1, $p<0.01$; Left: 74.3 to 76.7, $p<0.001$). Psychological parameters also improved (AIS: 21.4 to 22.6, $p<0.05$; BABS: 0 to 4.3, $p<0.001$). However, their mood deteriorated (BDI: 17 to 19.5, $p<0.05$). After the programme, 41.9% of patients met their work demand. Our model showed that male patients were 5.9 times ($p=0.17$) more likely to meet work demand level as is initial job demand ($p=0.002$). Factors including change in sitting tolerance, VAS under exertion, mood, general psychological wellbeing and injury on duty status did not affect the ability to return to work.

Discussion: This programme is effective in improving outcomes of patients with chronic LBP. There was significant improvement in physical tolerance of daily activities despite persistent negative cognitions and low mood. However, they were more accepting towards chronic LBP, and enjoyed better general wellbeing. Male patients with higher job demand were more likely to return to their work. From our data, we have constructed a viable tool to determine patients most suitable for this intensive rehabilitation programme.

Exercise for the intervertebral disc: a 6-month RCT

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Introduction: While exercise has anabolic effects on bone, muscle and tendon, any benefits on the lumbar intervertebral disc (IVD) are not well characterized. Rodent IVD benefitted from running exercises [1]. In humans, positive associations were reported between running exercise [2], physical activity [3] and the IVD. However, an interventional study in humans to examine whether exercise leads to anabolic adaptation in the human IVD had yet to be performed.

Methods: A 6-month randomised clinical trial (ACTRN12615001270505; [4]) was conducted of 40 people (19 women, 21 men) aged 25-45yrs with chronic low back pain. Inclusion criteria included baseline physical inactivity (less than 150min moderate to vigorous physical activity per week). The experimental intervention group received progressive spinal loading, spine-specific physical activity as part of a general strength and conditioning (GSC; 1-2 treatment sessions per week over 6 months) program. The control group received low intensity non-weight bearing motor control exercises and manual therapy (MCMT; 12 treatment sessions over 6 months). Magnetic resonance imaging quantified lumbar central (nuclear) and whole IVD T2-time using sagittal spin-echo multi-echo sequences. Vertebral body fat fraction (VFF) and multifidus muscle volume (from L1 to L5) were measured using axial mDIXON sequences. Scans were performed at baseline prior to randomisation, at 3 months and at 6 months. The primary analysis compared averaged data from all lumbar levels (T2-time and VFF), or in the case of multifidus muscle size, the volume of this muscle from L1 to L5. An intent-to-treat analysis approach was implemented.

Results: A significant increase in multifidus muscle volume was seen in the GSC group at 6-months (mean[SD] +4.4[6.9]%, $p=0.012$), but not in the MCMT group (+1.2[7.2]%, $p=0.52$). Despite this, no significant change was seen in nucleus or whole IVD T2-time over the time course in either group: nucleus 3 months GSC -2.1[5.7]% vs MCMT +0.5[5.3]%; nucleus 6 months GSC -1.0[5.8]% vs MCMT -0.4[6.1]%; whole IVD: GSC 3 months -1.2[4.8]% vs MCMT +0.2[4.6]%; whole IVD 6 months GSC -1.6[4.3]% vs MCMT -0.8[5.9]% (all $p>0.05$). Similarly, no significant change was seen in lumbar vertebral fat fraction was seen in either group: VFF 3 months GSC -1.3[3.1] percentage point vs MCMT +0.2[3.0] percentage point; VFF 6 months GSC -1.0[4.0] percentage point vs MCMT -1.7[6.2] percentage point (all $p>0.05$).

Discussion: Prior cross-sectional data suggested better IVD markers in runners compared to inactive people. This first prospective interventional study, whilst showing muscle hypertrophy due to the experimental intervention, failed to identify such an anabolic impact of spine-specific loading and exercise on IVD or lumbar vertebrae adipose marrow after 6 months in inactive people with chronic low back pain. Different protocol or study population may identify anabolic effects of exercise on IVD.

[1] Brisby et al (2010) Spine 35:1429-36

[2] Belavý et al (2017) Scientific Reports 7:45975

[3] Bowden et al (2018) J Orthop Res 36:1313-1323

[4] Simson et al (2017) Trials 18(1):184

Can Preoperative Rehabilitation Improve the Surgical Outcome in the Patients with Adult Spinal Deformity?; A retrospective cohort study

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Introduction; Postoperative rehabilitation plays an important role to improve the surgical outcomes for the patients with adult spinal deformity (ASD). There are, however, no studies to verify the necessity of preoperative rehabilitation (POR). The purpose of the current study was to evaluate the efficacy of the POR program on the improvement of surgical outcome in the ASD patients.

Methods; This is a retrospective cohort study. There were 106 patients with symptomatic ASD treated surgically from 2011 through 2016. The ASD was defined based on SRS-Schwab ASD classification. Twenty-six patients with a minimum of 1-year follow-up were investigated. There were 3 males and 23 females with a mean age of 68 year. All patients were operated by the same orthopaedic spine surgeon, and were fixed to ilium using S2AI screws. The subjects were divided into 2 groups; **Group 1(control group)**; the patients had no POR before the surgery. **Group 2(the POR group)**; the patients had undergone the POR program at outpatient for more than 2 months. The POR protocol consisted of a 40-minute exercise session per week at the outpatient and home-exercise for more than 3 days/week. It aims to improve muscle strength, endurance, and range of motion (ROM) of trunk and lower extremities. Primary outcome measure was SRS-22 at the 1-year postop. Secondary outcome ones included muscle strength and ROM of trunk and hip joints. Walking speed was also measured. All outcomes were measured at baseline before the surgery and at 1-year postoperative follow-up. Statistical analysis was conducted using multiple regression analysis. The confounding factors were age, sex, height, weight, sagittal vertical axis (SVA), pelvic tilt (PT), pelvic incidence (PI), and lumbar lordosis (LL). Statistical significance was defined as a *p*-value of less than 0.05.

Results; The POR group showed the significantly higher values than the control one in the SRS-22 at the 1-year postop. Multiple regression analysis on SRS-22 scores at 1-year postop showed that the presence or absence of the POR was an independent influencing factor ($b=0.54$, $R^2 = 0.29$) on the surgical outcome. Significant improvement was found in the POR group in terms of trunk extension ROM, lumbar extension ROM, hip joint extension ROM, hip extensor muscle strength, and walking speed. There were no major adverse events in the POR group.

Discussion; This study demonstrated that the POR program can improve the surgical outcome without any complications in the patients with ASD. It can be attributed to the improvement of physical function such as muscle strength and ROM. Further investigation in the fashion with randomized controlled study was needed to verify the true efficacy of the POR in the patients with ASD.

What factors differ between individuals with either good or poor outcome following microdiscectomy for lumbar disc herniation: an investigation of inflammatory and muscle regeneration markers in the lumbar multifidus muscle

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Introduction: Persistent low back pain (LBP) and disability following microdiscectomy for lumbar disc herniation (LDH) has been reported to be about 30% and revision surgery rate was nearly 20% in follow-up ¹. According to the results of different studies, disturbed back muscle innervation and loss of muscular support may be an important cause for the dissatisfaction following microdiscectomy. Reported changes in the paraspinal muscles after surgery include a loss of muscle thickness, edematous and fatty changes observed in magnetic resonance imaging, but underlying molecular changes and mechanisms are poorly understood. In animal models ^{2,3} these structural alterations have been proposed to be promoted by molecular pathways regulating inflammation, such as interleukin-1 β (IL-1 β) and regeneration, such as brain-derived neurotrophic factor (BDNF). However, is it unknown if the expression of these molecules is dysregulated following LDH and if their expression may differ between individuals with good and poor outcome following microdiscectomy for LDH. This prospective cohort study is to evaluate the difference of inflammatory and muscle regeneration markers in lumbar multifidus muscle (LMM) between individuals with good and poor outcome following microdiscectomy for LDH.

Methods: LDH patients undergoing microdiscectomy surgery (n=21) for LBP with sciatica participated. 33% or more of visual analogue scale (VAS) pain improvement (VAS LBP +) and 25% or better of physical functioning scale (PFS +) improvement were used as threshold for good recovery rate for clinical outcomes. Tissues obtained during microdiscectomy had mRNA extracted and inflammatory and muscle regeneration transcripts profiled using quantitative polymerase chain reaction (qPCR). Paired sample T-test, Spearman's rank correlation coefficient and Mann-Whitney U test were performed using SPSS v24.

Results: VAS LBP improvement rate had a strong positive relationship with PFS improvement rate (r=0.781, P<0.001). Expression of IL-1 β (r=0.674, P<0.01) and TNF (r=0.678, P<0.01) in sub-cuticular fat have a strong association with post-operative VAS LBP. BDNF expression was 70% (P<0.01) increased in the VAS LBP+ group than the VAS LBP- group in LMM (Fig.1). Conversely, the expression of IL-1 β in VAS LBP- group was 1.9 times (P<0.05) greater compared to VAS LBP+ group in sub-cuticular fat (Fig.2). None of the investigated inflammatory and muscle regeneration markers in muscle or fat had an obvious effect on the improvement of PFS.

Conclusions: This study provides evidence that molecular pathways that regulate inflammation and regeneration are associated with patient outcomes following microdiscectomy for LDH. This supports a role for these molecules in regulating the pathophysiology of LDH.

Fig 1. BDNF

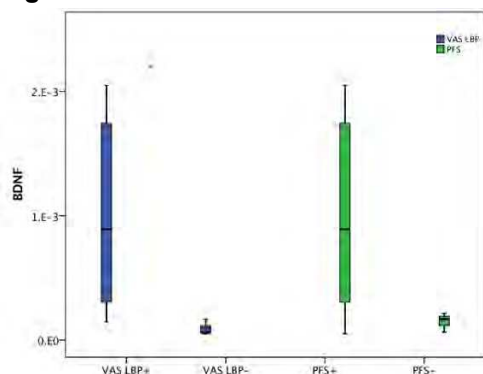
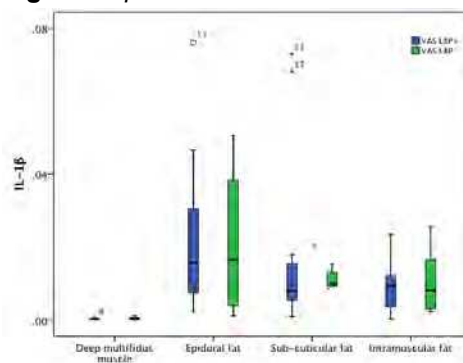


Fig 2. IL-1 β



Reference

- 1 Silverplats K, Lind B, Zoëga B, et al. Clinical factors of importance for outcome after lumbar disc herniation surgery: long-term follow-up. *European Spine Journal* 2010;19:1459-67.
2. James G, Sluka KA, Blomster L, et al. Macrophage polarization contributes to local inflammation and structural change in the multifidus muscle after intervertebral disc injury. *Eur Spine J* 2018;27:1744-56.
3. Yu T, Chang Y, Gao XL, et al. Dynamic Expression and the Role of BDNF in Exercise-induced Skeletal Muscle Regeneration. *Int J Sports Med* 2017;38:959-66.

The tasks effect in low back pain movement patterns

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Introduction: Aetiology of low back pain (LBP), in the majority of cases, is complex and multifactorial. However, there is a recognised causative role between posture and movement and the development of LBP. For this reason, examining movement during functional and challenging activities is important. However, LBP has been mostly studied during range of motion (ROM) manoeuvres. A limitation of the existing literature is its concentration on the lumbar spine only viewed frequently as single rigid segment despite the spine multi-segmental nature and its connection and dependence on other body regions. The aims of this study were to analyse the full body 3D kinematics in people with and without LBP during functional tasks and to investigate if differences between groups were equally observed in the lumbar spine when considered as both rigid and multi-segmental entity.

Methods: Twenty healthy controls and 20 participants with non-specific chronic LBP participated in the study. 3D kinematics of the spine segments and lower limbs joints were measured with a 3D motion capture system operating at 100Hz. A multi-segmental approach was adopted for the spine by considering the upper and lower segments in each the thoracic and lumbar region of the spine. Participants performed walking, sit-to-stand and lifting (5kg), each repeated 3 times. 3D ROM of the upper (T1-T6) and lower (T7-T12) thoracic segments, upper (L1-L3) and lower (L3-L5) lumbar segments, whole lumbar segment (L1-L5), pelvis, hip, knee and ankle joints were calculated for each task. Data normality was assessed with the Shapiro-Wilk test. Independent t-tests or Mann-Whitney tests, depending on data normality, were performed to assess differences between groups. Significance levels were set at $p < 0.05$.

Results: During walking, compared to controls, participants with LBP displayed greater (mean difference=2.7°) lower thoracic rotation ($p=0.03$), upper ($p=0.01$) and lower lumbar flexion ($p=0.04$). During sit-to-stand significant differences were observed in hip rotation ($p=0.02$), knee ab/adduction ($p=0.01$), lower thoracic flexion ($p=0.03$), and upper lumbar lateral flexion ($p < 0.01$). During the lowering phase of the lifting task, participants with LBP showed greater ROMs in the hip ($p < 0.01$), knee ($p < 0.01$) and ankle ($p < 0.01$) joints but smaller upper lumbar flexion than controls (-4.7°, $p=0.03$). The same trend was observed in lower lumbar flexion (-1.2°) but the difference was not significant. For the picking phase of the lifting task significant differences were observed in knee ab/adduction ($p=0.03$) and rotation ($p < 0.01$), upper thoracic rotation ($p=0.02$), lower thoracic lateral flexion ($p=0.03$) and lower lumbar rotation ($p=0.01$). No differences were observed between groups with the lumbar segment represented as one rigid segment.

Discussion: This is the first study looking at the full body 3D kinematics in people with and without LBP during different functional tasks and adopting a multi-segmental approach for the analysis of the spine. As the task difficulty was increased more, so statistically significant differences were observed between the two groups (3 in walking, over 5 for lifting) highlighting that participants with LBP adopted different strategies, particularly in the lower limbs. Finally, when assessing people with LBP, regional differences in the lumbar spine should be considered.

In vitro biomechanical testing of an innovative antero-posterior fixation for A3 lumbar fracture

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Introduction: Mechanically unstable A3 type compression fractures at the lumbar spine require surgical fixation. Several approaches and techniques are currently used with no consensus. The goal of the study was to assess the spine mobility with various posterior minimally invasive techniques, including the use of a novel technique combining anterior and posterior treatment (SpineJack, VEXIM).

Methods: Seven cadaver lumbar spine segments were used in this study. Calibrated CT-scans were acquired to estimate Bone Mineral Density (BMD). Burst fracture was induced at L1 following a standardized protocol. Cut notches were generated in L1 to weaken this specific vertebra before impaction with a drop tower.

The instrumental configurations were: 1) bilateral pedicle screws and rods fixation at T12 and L2; 2) bilateral pedicle screws and rods fixation at T12 and L2 with bilateral SpineJack at L1 connected to the rods with no cement; 3) bilateral pedicle screws and rods fixation at T12 and L2 with bilateral SpineJack at L1 connected to the rods with cement at L1.

Instrumented spine mobility was tested by imposing incremental pure moments on T11 in flexion / extension (FE), lateral bending (LB) and axial torsion (AT). The EOS® system was used for recording the 3D displacement of T12 in the coordinate system of L2.

Results: Two groups were distinguished according to range of motion, bone mineral density (BMD) and maximal force at impaction : group A (5 specimens; average BMD 111 mgHA ; average maximal force at impaction 7595 N, average range of motion in configuration 1 : 16.9° in FE, 16.7° in LB, and 22.8° in AT) and group B (2 specimens; average BMD 76 mgHA ; average maximal force at impaction 5545 N, average range of motion in configuration 1 : 6.3° in FE, 4.6° in LB, and 7.3° in AT).

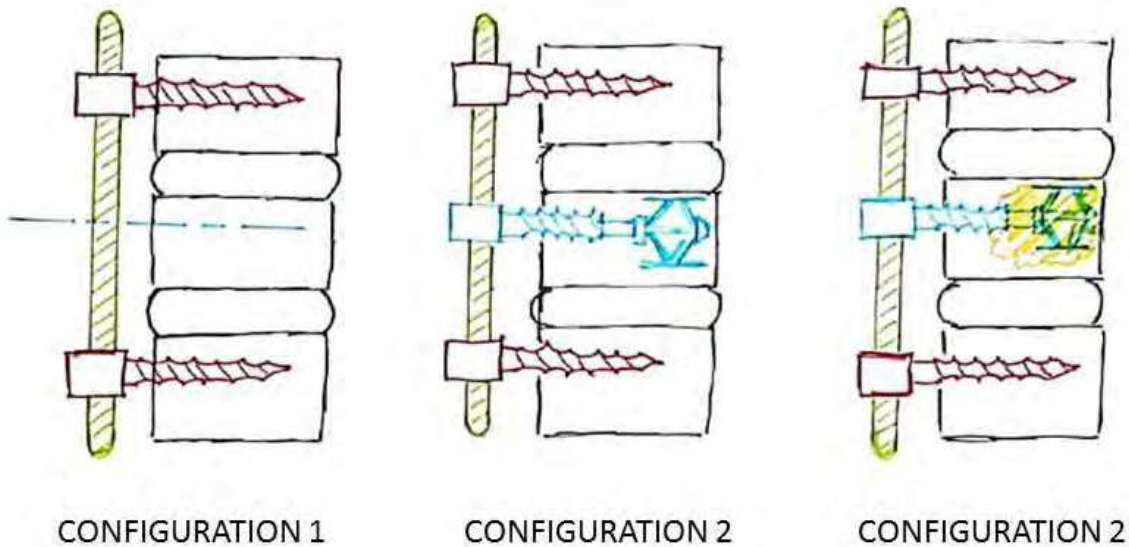
The range of motion significantly decreased between configuration 1 and configuration 2 for all specimens:

- FE : average decrease -51,7% (-3,3°) for group A and -27,9% (-4,7°) for group B
- LB: average decrease -25% (-1,1°) for group A and -5,6% (-0,9°) for group B
- AT: average decrease -37,2% (-2,7°) for group A and -18,2% (-4,1°) for group B

The range of motion decrease between configuration 2 and configuration 3 was not significant for any group: group A (-0.3° in FE; -0.2° in LB and -0.3° in AT) ; group B (-0.3° in FE ; -0.9° in LB and -1.8° in AT)

Conclusion: A significant decrease in mobility in all directions was noted using additional anterior fixation at the fractured level compared to rods and screws fixation only. The adjunction of cement increased furthermore the rigidity of the fixation construct with very little influence on spine mobility.

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Enhanced spinal fusion by combination of NELL-1 and ultra-low dose of BMP-2 in a rat model

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Introduction: BMP-2 is being used to argument spinal fusion. However, *in vivo* administration can lead to various complication such as seroma, ectopic bone formation. NELL-1 is more specific than BMP-2 which selectively effects on osteochondral lineages. A few reports have shown combining BMP-2 and NELL-1 is beneficial for bone regeneration. From our previous rat posterolateral spinal fusion model study, polyelectrolyte complex (PEC) can required BMP-2 dosage to 20-fold lower than conventional dosage used in a rat model. With addition of NELL-1, the required dosage of BMP-2 would be further reduced. Therefore, we hypothesized that NELL-1 and ultra-low dose of BMP-2 delivered by PEC can achieve solid spinal fusion at lower dosage.

Methods: Bone mesenchymal stem cells (BMSCs) were treated with 0-10 µg/ml NELL-1 with 0-10ng/ml of BMP-2 for 14 days. BMSCs mineralization was visualized by alizarin red staining. Uptake and release profiles of NELL-1 and BMP-2 from PEC were monitored through 14 days. Animal study was approved by the NUS Institutional Animal Care and Use Committee. Twenty-five rats were allocated to five group: Gp 1) PEC+20µg NELL-1+0.25µg BMP-2(N=7) Gp 2) PEC+0.25µg BMP-2(N=6); Gp 3) PEC+20µgNELL-1 (N=4); Gp 4) absorbable collagen sponge+10µg BMP-2(N=4); 5) PEC blank control (N=4), and underwent L4-L5 posterolateral spinal fusion procedures. Rats were euthanized at 8 weeks post-operation. Fusion was evaluated by microcomputed tomography(micro-CT) and biomechanical test. Fusion mass was analyzed by Bruker CTan software. Biomechanical test was performed by a cantilever method.

Results: NELL-1 and ultra-low dose of BMP-2 (5ng/mL) significantly enhanced BMSCs mineralization compared to any of the single growth factor treatments (Fig1.A and B), suggesting NELL-1 and BMP-2 had synergistic effect on BMSCs differentiation. The capacity of PEC to uptake NELL-1 and BMP-2 was 95.86±1.21% and 89.90±1.72%, respectively. NELL-1 and BMP-2 were released from PEC in a controlled manner, cumulative release rate through 14 days of which reached 20.14±0.63% and 18.76±6.48%, respectively (Fig1.C). Micro-CT (Fig2.A) revealed that both Gp 1 and 4 achieved 100% fusion compared with 33% fusion was observed in Gp 2. In Gp 3, the fusion rate further reduced to 25%. Gp 1 had highest BV/TV compared with the other four groups (p<0.001, Fig.2B). Notably, ACS with the conventional dose of BMP-2 (10µg) induced bony shell formed outside of the scaffold and sparse ossicles representing inside the scaffold, which was confirmed by the semi-quantitative result that Gp 4 had the highest volume of ectopic bone (Fig2.C). Biomechanical result (Fig3) also revealed that Gp 1 showed a better biomechanical property, indicating by significantly higher stiffness in extension and flexion compared to Gp 2, Gp 5 and intact spine, and in lateral bending compared to Gp 2, Gp 3, Gp 5 and intact spine.

Discussion: NELL-1 and ultra-low dose of BMP-2 enhanced BMSCs mineralization *in vitro*. Co-delivery of NELL-1 and BMP-2 with PEC carrier can further reduce BMP-2 efficacy dose to induce fusion in rat posterolateral spinal fusion model by 50%. In the future, large animal studies should be conducted to obtain more clinically relevant data.

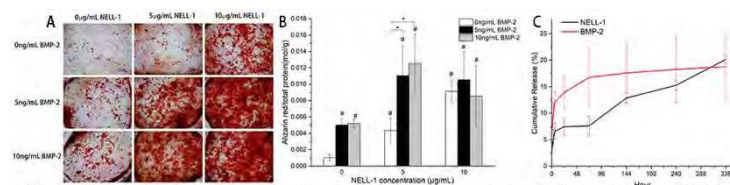


Fig1. Combined effect of NELL-1 and ultra-low dose of BMP-2 on BMSCs mineralization. A) alizarin red staining of BMSCs after 14 days of treatment under NELL-1 and/or BMP-2. B) Quantification of stained area by extracting alizarin red. Amount of alizarin red was normalized by the amount of total protein. C) release pattern of NELL-1 and BMP-2 from PEC through 14 days. # denotes the group is significantly different with blank control group. *denotes there is significant difference between the two compared groups.

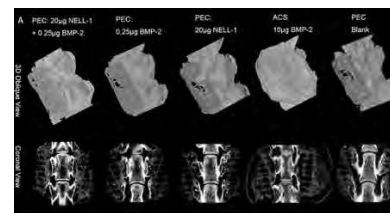


Fig2. Micro-CT of spinal fusion at 8 weeks post-operation. A) representative 3D reconstructions (top panel) and coronal view (bottom panel); B) ratio of bone volume and total volume (BV/TV, %); C) volume of ectopic bone formed outside the implanted scaffold (ectopic bone volume, mm³). ** denotes p value less than 0.001 between the two compared groups.

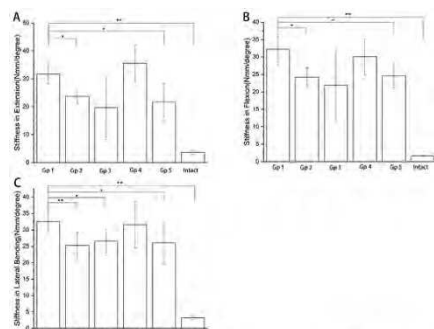


Fig. 3 Stiffness of fusion mass regarding extension (A), Flexion (B) and lateral bending (C). * denotes p value less than 0.05 between the two compared group, ** denotes p value less than 0.001 between the two compared groups. Intact indicates intact spine without any surgical procedures.

Remaining systemic treatment options: a valuable predictor of survival and functional outcomes after surgical treatment for spinal metastasis.

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Introduction: Deciding whether to perform surgery for malignant spinal metastasis is a complicated task for oncologists and surgeons, and multiple factors need to be considered. Recent studies have indicated that systems developed to aid this decision-making process showed decreased accuracy over time, especially for certain malignancies, probably due to their inability to reflect recent advances in systemic treatment and improvement in overall survival.

Methods: In an effort to identify novel prognostic factors affecting survival and functional outcomes, the current study reviewed 100 consecutive patients who received surgical treatment for spinal metastasis in a single center from March 2012 to June 2016. Patient outcomes were assessed by survival time and functional status during the follow-up period. The functional status of patients during the follow-up period was assessed using the Eastern Cooperative Oncology Group performance status (ECOG PS) scale. The cohort was divided into two groups according to their postoperative function. The good outcome group was defined as a group of patients who maintained a functional status better than ECOG PS 3 (= ECOG PS 0-2) for more than 3 months postoperatively, and the poor outcome group as a group of patients who were unable to do so. The proportion of patients with loss of ambulation and the causes for the loss of ambulation were also evaluated.

Results: Comparative and logistic regression analyses found that the availability of remaining options for systemic treatment at the time of decision-making for surgery was associated with improved postoperative functional performance status. Survival analyses using Kaplan-Meier curves and a Cox proportional hazards model also found that the availability of remaining systemic treatment options was associated with improved survival and functional outcomes. This finding was statistically more significant in a group of patients with a low revised Tokuhashi score, for whom conservative treatment was previously recommended. As for the functional outcome, the most common cause for loss of ambulation was deterioration of the general condition due to the progression of the malignancy at the primary site or metastasis to an organ other than the spine, in both the total patient cohort (73.0%) and the poor outcome group (71.4%). Epidural spinal cord compression due to the progression of the spinal metastatic lesion was the cause of loss of ambulation in 11/74 (14.9%) patients for the total cohort and 3/21 (14.3%) patients for the poor outcome group.

Discussion: Since the occurrence of spinal metastasis itself in spite of previous systemic treatment can be considered a treatment failure, a prognosis of a patient is likely to be more dependent on the remaining options, rather than the history of or response to the previous treatment. The results of the current study emphasize the importance of the availability of remaining options for systemic treatment when deciding on surgical treatment for spinal metastasis. The current study also described the specific causes of loss of ambulation and analyzed the factors associated with functional outcomes in patients with spinal metastasis.

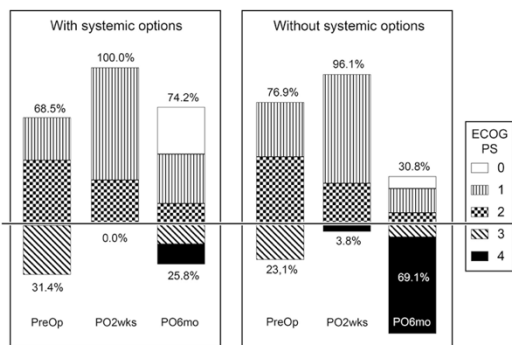


Figure 1. Effect of remaining systemic treatment options on functional outcomes. Note the proportion of patients with poor functional performance status (ECOG PS 3 and 4) is similar between groups, with and without systemic options, at preoperative and immediate postoperative period, but distinguishable at 6 months postoperative. (Abbreviations: ECOG PS, Eastern Cooperative Oncology Group performance status; PreOp, preoperative; PO2wks, 2 weeks postoperative; PO6mo, 6 months postoperative.)

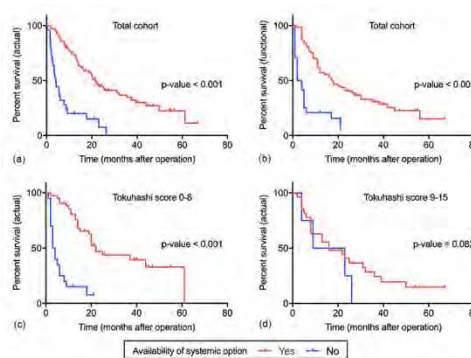


Figure 2. Survival curves for actual and functional survival stratified by remaining systemic treatment options. Figure 2a. Curve for actual survival of total cohort. Figure 2b. Curve for functional survival for total cohort. Figure 2c. Curve for actual survival of the patients with Tokuhashi score of 0-8. Figure 2d. Curve for actual survival of the patients with Tokuhashi score of 9-11 and 12-15 combined. (All p-values in the Kaplan-Meier curves are derived from log-rank test)

Cervical Epidural Steroid Injections: Incidence and Determinants of Subsequent Surgery

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Introduction: CESIs are increasingly used in the nonsurgical management of cervical disorders despite narrowing indications. Patients may delay or avoid surgery following CESIs, however the rate and determinants of subsequent surgery remain uncertain. Therefore, we used a retrospective analysis of nationally-representative administrative claims data to determine: 1) the proportion of patients having surgery following cervical epidural steroid injection (CESI), and 2) the timing and factors associated with subsequent surgery.

Material and Methods: Survival analyses were performed using the Truven Health MarketScan® databases from 2007-2015. Inclusion criteria were CESI for cervical disc herniation, stenosis, or radiculopathy, age ≥18, and active enrollment for 1 year prior to CESI to screen for exclusions. Patients were followed until they underwent cervical surgery or their enrollment lapsed. Rates of surgery were assessed with Kaplan-Meier survival curves. Factors associated with subsequent surgery were assessed with multivariable Cox proportional hazard models, $\alpha=0.001$ due to large sample size.

Results: A total of 192,777 CESI patients were included (age 50.9 ± 11.3 years, 55.2% female). Within 6 months of CESI, 11.2% of patients underwent surgery, increasing to 14.5% by 1 year and 22.3% by 5 years (Figure 1). Ages 35-54 and male sex were associated with increased likelihood of subsequent surgery (Figure 2). Patients with radiculopathy were less likely to undergo surgery following CESI than stenosis or herniation; those with multiple diagnoses were more likely (Figure 3). Patients with comorbidities including CHF, other cardiac comorbidities or chronic pain or northeast US region location were less likely. Some 40.2% of patients underwent >1 CESI, 84.6% within 1 year. Additional injections were associated with reduced rates of subsequent surgery.

Conclusion: Following CESI, 22.3% of patients underwent surgery within 5 years. Multiple patient-specific risk factors for subsequent surgery were identified, and patients undergoing repeated injections were at lower risk. Determining which patients may progress to surgery will improve resource utilization and inform shared decision-making.

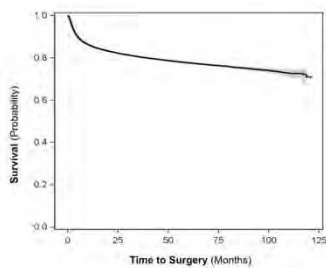


Figure 1. Kaplan Meier survival curves and 99% confidence intervals (shaded areas) for progression from CESI to surgery. Survival is defined as time from CESI to subsequent surgery.

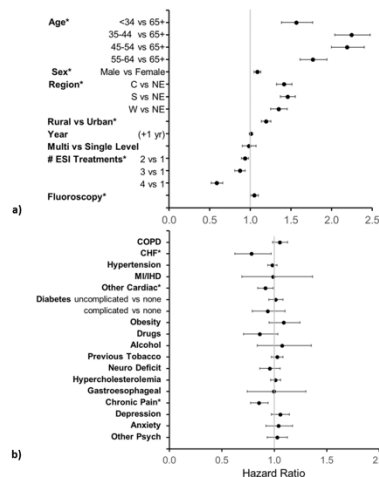


Figure 2. Hazard ratios and 99% confidence intervals for the rate of surgery following CESI for a) demographic and treatment factors and b) patient comorbidities included in the multivariable Cox proportional hazard model. Regions include Central (C), South (S), West (S) and Northeast (NE). Factors with CIs not overlapping a hazard ratio of 1.0 indicates significance at $p < 0.001$. * denotes significance.

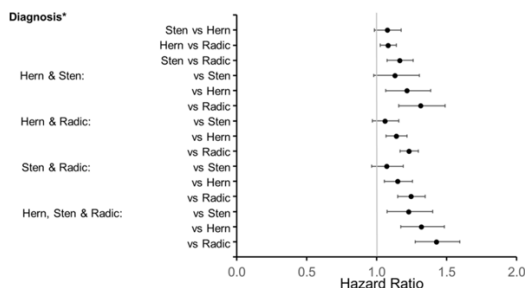


Figure 3. Hazard ratios and 99% confidence intervals for the rate of surgery following CESI by diagnosis. Factors with CIs not overlapping a hazard ratio of 1.0 indicates significance at $p < 0.001$. * denotes significance.

A Study on Sports Activities of Non-union Adolescent Lumbar Spondylolysis Patients

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Introduction: For adolescent lumbar spondylolysis patients, we generally treat them with bracing and pausing sports activity in order to achieve bone union. However some of them unfortunately can't achieve bony healing, and some can't pause sports activities. There were few papers on sports activity of non-union patients or terminal stage of lumbar spondylolysis. The purpose of this study was to examine non-union patients' sports activities.

Subjects and Methods: We included 228 patients who were diagnosed as lumbar spondylolysis using both CT scans and MRI, besides followed until bony healing or non-union (Apr.2013-Dec.2017). One hundred and eighty of 228 patients consented conservative treatment with bracing. Remaining 48 patients continued sports activities. Forty-three of 180 patients with bracing could not achieve bone union. We evaluated their sports activity at final follow-up. We rated their clinical outcomes into four ranks: 1) Excellent; no pain, full activities, 2) Good; occasional pain, full activities, 3) Fair; occasional pausing of sports activities due to low back pain, 4) Poor; pain during sports activities, or quit sports.

RESULTS: We were able to follow the total of 51 non-union patients. In which, 26 of them were unfortunate non-union patients in spite of bracing, and 25 patients were continuing sports activity. There were 44 men and 7 women. The average age was 15 years (10-18). Mean follow-up periods was 8months (5-32months). Nine patients were rated "excellent", 21 "good", 20 "fair" and 1 "poor". There was no significant difference as to age and level of affected laminae among these groups. According to these results, 30 of 51 non-union patients (58.8%) returned to sports activities completely without disturbing pain. Twenty patients (39.2%) paused their sports activities occasionally, however they were able to resume sports activities. Only one patient quit sports activity. In terms of unilateral or bilateral, 4 unilateral spondylolysis patients were rated excellent and 5 were good. Meanwhile, in bilateral spondylolysis patients, 5 "excellent", 16 "good", 20 "fair" and 1 "poor".

Discussion:

In this study, the half of the bilateral spondylolysis patients returned to sports with occasional pausing due to low back pain. Meanwhile, for unilateral spondylolysis patients, there seemed to be few disadvantages of non-union, because they resumed sports activities almost unchanged. Therefore, don't we have to aim bony healing of unilateral spondylolysis? We believe not. Because we have reported that unilateral spondylolysis had a tendency to proceed to pseudo-bilateral spondylolysis; this type of bilateral spondylolysis had the fracture following the pre-existing contralateral side unilateral spondylolysis. And unilateral lumbar spondylolysis had higher rate and shorter period for bone union compared to bilateral and pseudo-bilateral spondylolysis. When they become bilateral spondylolysis, the half of them occasionally pause sports activities. So we believe we have to aim bony healing at unilateral spondylolysis. On the other hand, bilateral spondylolysis had difficulty in bony healing; It needed over 5 months and union rate was 61% (2018 ISSLS). Therefore, for bilateral spondylolysis patients and their parents, we had better inform them benefit and disadvantage of bracing to select their treatments.

Quantitative evaluation of motor function of the lower extremity using the foot tapping test: Part 2. Five-year follow-up.

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Background: The foot tapping test (FTT, Numasawa et al, Spine 2012) is one of the tests for long tract disorders of the lower extremities. It reflects not only compression myelopathy, but also motor function of the lower extremities in L4, 5 associated radiculopathies (Kobayashi et al, JSSR 2017). The purpose of this study was to investigate postoperative recovery of the motor function of the lower extremities in lumbosacral disorders using the FTT.

Method: A total of 288 feet from 163 cases (92 men, 71 women; mean age 63.7 years, most common age group 70-79 years old) who underwent surgery for lumbosacral disorders, having pathology causing L4 or L5 motor dysfunction, were enrolled in this study. Exclusion criteria were, preoperative manual muscle testing score ≤ 3 , tumor, and re-operation. A total of 101 cases of lumbar spondylosis, 34 cases of degenerative spondylolisthesis, 10 cases of lumbar disc herniation, and 7 cases of lumbar spondylolysis and lumbar spondylolytic spondylolisthesis were included. Injured levels were L1/2 in 1 case, L2/3 in 13 cases, L3/4 in 73 cases, and L4/5 in 142 cases (including overlap). Neurologic impairment types: radicular type, 78cases; cauda equina type, 27 cases; and mixed type, 58 cases. Longitudinal changes of FTT were examined before surgery, 3 months, 1 year, 3 years, and 5 years after surgery. Statistical analysis was performed by analysis of variance (ANOVA) ($p < 0.05$).

Results: On the FTT, the average \pm SD numbers of taps (before surgery/3 months/1 year/3 years/5 years) were 19.3 \pm 6.5/23.9 \pm 5.7/25.5 \pm 5.9/24.9 \pm 5.1/26.0 \pm 5.5 in total, 19.9 \pm 5.8/24.5 \pm 5.0/26.8 \pm 4.3/25.6 \pm 5.2/27.4 \pm 4.7 in the radicular type, 19.2 \pm 6.6/22.8 \pm 4.5/25.5 \pm 5.8/24.7 \pm 3.3/26.2 \pm 1.8 in the cauda equina type, and 18.8 \pm 6.9/23.9 \pm 5.0/24.5 \pm 6.8/24.3 \pm 5.2/24.4 \pm 6.3 in the mixed type. Significant recovery was observed at one year after surgery in all the neurologic impairment types. However, no significant changes were observed more than 1 year after surgery among all neurologic impairment types.

Discussion: From the present study, recovery of motor function of the lower extremity in lumbosacral disorders was observed until 1 year after surgery in all neurologic impairment types, and this recovery was continued for 5 years.

Is the terminal complement complex a possible target for therapeutic intervention in intervertebral disc degeneration?

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Introduction: Inflammation is known to contribute to disc degeneration (DD), but there is limited knowledge regarding a possible involvement of the innate immunity. Terminal complement complex (TCC) immunopositivity was previously observed in human pathological intervertebral discs (IVD).¹ The present work focuses on i) correlation of TCC deposition in different IVD regions with patient age and tissue degree of degeneration, and ii) characterization of isolated cells.

Methods: Disc tissues were collected *post-mortem* from healthy donors (Healthy, n=6, age 12±7, 3F/3M), and from patients with scoliosis (Sc, n=10, age 16±5, 7F/3M) displaying no signs of disc degeneration, or with DD (n=36, age 60±13, 22F/14M, Pfirrmann grade 3-5), with ethical approval and patients' informed consent. TCC deposition was investigated in nucleus pulposus (NP), annulus fibrosus (AF) and endplate (EP) tissues. Randomly selected Sc and DD patients' AF, NP and EP expanded cells (passage 2-5) were analyzed for gene expression of TCC-inhibitors *CD46*, *CD55* and *CD59*, as well as for apoptosis (*Bax1*), inflammation (*IL-6*, *IL-8*), ECM composition (*COL1A1*, *COL2A1*, aggrecan, elastin, fibrillin-1) and degradation (*MMP1* and *MMP3*) markers. Cellular TCC deposition was determined by a cell-based ELISA, after stimulation with 5% human serum (containing the components C5 to C9, necessary for TCC formation). Serum-free medium was used as control. An erythrocytes lysis test was performed to the culture supernatants to confirm TCC's lytic activity. Statistical analysis was performed with Man-Whitney or Kruskal-Wallis test.

Results: TCC immunopositivity was identified in all donor groups, with high variability between single donors specially in Healthy and DD, though these 2 groups are very different in age range (Figure 1A). Although no significant differences were observed in the different tissue locations for each group, a significantly higher frequency of TCC+ cells was found in the EP from Healthy and DD, when compared to Sc (Figure 1B,C; p<0.05). No correlation with age or degeneration degree in DD were found. Sc samples, more homogeneous regarding age and without degenerative features, presented low TCC deposition (<30% TCC+ cells). After cell expansion, *CD46*, *CD55* and *IL-8* were significantly up-regulated in the EP versus AF of DD patients (p<0.05). The expression of *CD46* and aggrecan was significantly down-regulated in the NP of DD compared to Sc (p<0.05). In presence of human serum, TCC was formed (about 2-fold higher than in serum-free medium) and cell lysis occurred, but no significant differences were observed between DD and Sc groups in AF, NP or EP expanded cells regarding TCC deposition and cell lysis.

Discussion: The data suggests that TCC is formed in IVD cells both in very young or strongly degenerated samples, which might correlate with vascularization. Moreover, TCC deposition can be induced *in vitro*. Further studies are ongoing to understand which microenvironmental factors can activate TCC deposition and if there is a possible functional relevance of the complement system in DD, being a target for new therapeutic approaches for these patients. **Acknowledgement:** DFG (NE_549/6-1, BR_919/12-1) and Ulm University (L.SBN.0157).

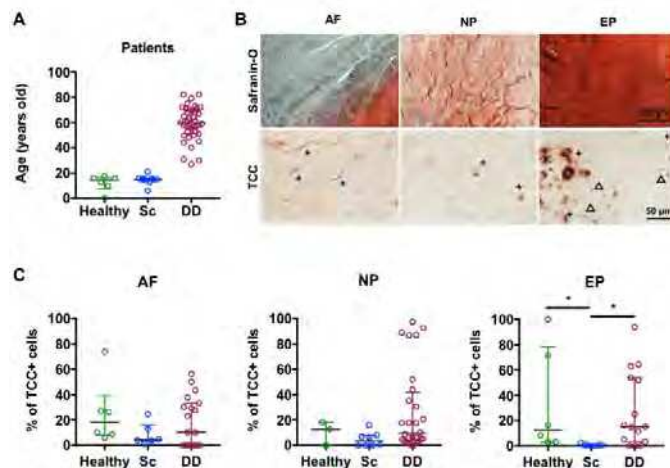


Figure 1. Histopathological analysis of IVD tissue. (A) Donor age distribution. **(B)** Representative images of IVD tissue collected during surgery, from patients suffering from disc degeneration (DD), stained for safranin-O (proteoglycans are stained red, while Fast Green counterstains the non-collagen sites) and for TCC, displaying cells positive (+) and negative (Δ) for TCC deposition, in the different IVD regions: annulus fibrosus (AF), nucleus pulposus (NP) and endplate (EP). **(C)** Percentage (%) of TCC+ cells in healthy IVD tissue collected *post-mortem*, and in tissues collected during surgery from patients suffering from Sc and DD. *P<0.05. Kruskal-Wallis test.

Endplate damage is heritable, is independently associated with low back pain and may trigger intervertebral disc degeneration: a longitudinal study from TwinsUK

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Introduction: Endplate defect is an MRI trait, found to be associated with intervertebral disc degeneration. There is a lack of understanding regarding the mechanism underlying lumbar disc degeneration (LDD). This large-scale longitudinal population-based study aimed to determine the order of appearance of degenerative change in the vertebral body and intervertebral disc, the influence of endplate degeneration on LBP and whether there is a genetic influence on endplate damage.

Methods: Individuals from the TwinsUK spine study having longitudinal T2-weighted lumbar MRI scans at baseline (n=996) and a decade later (n=438) were included. LDD, vertebral endplate defect expressed as a total endplate (TEP) score and Modic change (MC) were assessed using standard techniques. Mixed-effects models were used to determine the association between spine pathology features adjusted for covariates. Endplate defect heritability was estimated using variance component analysis.

Results: The mean TEP score at baseline rose progressively higher going down the lumbar spine. TEP was seen to progress over time, with a statistically significant lower score observed at baseline compared with follow up ($p < 0.001$) at each lumbar level, with the highest rates of progression at L3–4 of 65.2%. Significant association between endplate defect, LDD (Pfirrmann), MRI features of LDD (4-point grading classification) and MC was observed, with changes in TEP score between baseline and follow-up significantly associated with change in LDD and MC size at all lumbar levels ($p < 0.0002$). Considering severe and disabling LBP at baseline, we found a significant association between endplate defect and severe disabling LBP ($p \leq 0.013$) at every lumbar level even after adjustment for risk factors age, sex and BMI.

An association between LDD at baseline and MC at follow-up was shown at upper lumbar levels. TEP score was heritable with estimated additive genetic component $A = 55.3\%$ (95% CI 43.0-65.4).

Discussion: Endplate defect, LDD and MC are all independent risk factors for episodes of severe and disabling LBP. Longitudinal analysis showed LDD is followed by MC. Endplate defect has significant heritability. However, whether endplate defect triggers LDD or these pathological changes occur concurrently could not be determined conclusively.

Causes of low back pain in different populations –The Wakayama Spine Study

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Purpose: Causes of low back pain (LBP) may differ for the elderly and non-elderly population, and may vary between men and women. Taking this into account, the related factors of LBP in the general population were stratified and then analyzed.

Methods: A cross-sectional study using an established population-based cohort in Japan was conducted. Of the 952 subjects who participated in the second survey of the Wakayama Spine Study, 812 completed sagittal whole-spine radiography in a standing position, whole-spine magnetic resonance imaging (MRI), and bioelectrical impedance analysis (BIA). The pelvic incidence-lumbar lordosis (PI-LL, °) was measured as an index of spino-pelvic alignment in the radiograph. Lumbar disc degeneration (Phirrmann's classification: grade 1-5) and endplate changes (Modic type 1, 2, and 3) were evaluated by sagittal MRI. The fatty infiltration ratio (FIR, %) in the erector spinae and multifidus at the L1 upper end-plate level and cross-sectional area (CSA, mm²) of the dural tube at the L1/2-L5/S1 levels were measured on the axial MRI using DICOM software. Appendicular skeletal muscle mass index (ASMI) was calculated from the sum of the muscle masses of the four limbs after adjusting for height (kg/m²). Information on the presence of LBP within 1 month was obtained via interviews.

Statistics: Participants were divided into four groups based on age (over 65 years or not) and sex. The prevalence of LBP was compared among the groups. The associated factors of low back pain were then determined by multiple logistic regression analysis after the consideration of multicollinearity and over fitting in each group.

Results: The prevalence of LBP was 36% for non-elderly men (n=130), 38% for non-elderly women (n=274), 39% for elderly men (n=117), and 39% for elderly women (n=291). There were no significant differences between the groups. The disc degeneration index (DDI: sum of the Phirrmann's grade from L1/2 to L5/S), and PI-LL mismatch ($\geq 10^\circ$) in men, and the DDI in women were significantly related to LBP in the non-elderly participants. On the other hand, the FIR of the erector muscle in men and the PI-LL mismatch in women were significantly related to LBP in the elderly subjects.

Discussion: The prevalence of low back pain was almost identical among the groups, irrespective of age and sex. However, the related factors of low back pain were different between elderly and non-elderly individuals, and between men and women. We have previously reported that disc degeneration was a common condition affecting more than 80% of the elderly population. Together with the results of this time, the disc degeneration may not be a cause of low back pain in the elderly individuals.

Conclusion: Physicians may need to alter the treatment strategy for LBP based on sex and age group. Similarly, researchers must take care in choosing variables and interpreting results when analyzing their cohort populations.

Cost-effectiveness of balloon kyphoplasty for patients with acute osteoporotic vertebral fractures in a super-aging society.

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Introduction: Osteoporotic vertebral fracture (OVF) is a common disease in elderly people. In Japan, the incidence of painful OVF in 2008 was estimated as 880,000, and approximately 40% of patients with painful OVF are hospitalized due to the severe pain. Japan is the front-runner of super-aged societies and rising health care costs are an economic problem. There have been no reports of the cost-effectiveness comparing with nonsurgical management (NSM) in Japan. Therefore, the purpose of this study was to reveal the cost effectiveness of VAP in Japan and investigate the factor related to increase of ICER.

Methods: This was a propensity score matching study. From April 2015 and September 2017, 116 consecutive patients who underwent BKP were enrolled in this study. Ten hospitals participated in the study. BKP and nonsurgical management (NSM) for acute/ subacute OVF were performed in 116 cases and 420 cases, respectively. Quality Adjusted Life Years (QALY) and increment cost was calculated based on a propensity score matching study. QALY was evaluated by SF-6D. Seventy-one cases were matched. Incremental Cost-Effectiveness Ratios (ICERs) were calculated using a Markov model.

Sensitivity Analysis: The uncertainty of the results was explored by stochastic and qualitative sensitivity analyses of important factors. The impact of uncertainty on the estimated ICER due to the stochastic nature of sampled data was analyzed by applying a non-parametric bootstrap resampling technique to both costs and effectiveness. Also, cost-effectiveness acceptability curve (CEAC) analyses were performed.

Results: In the comparison between BKP study and NSM therapy, the mean age was 78.3 years and 77.7 years, respectively ($P=0.456$). The difference of costs is 402,988 JPY and the gained QALY for 6-month follow-up was 0.153 and 0.120, respectively (difference = 0.033). ICERs for 3 years and 20 years were 4,404,158 JPY and 2,416,406 JPY, respectively. According to sensitivity analysis, ICERs ranged from 652,181 JPY to 4,896,645 JPY (4,418–33,168 GBP). The 60s and 70s gained substantial QALY compared with 80s (0.51, 0.41, and 0.07, respectively). CEAC showed 87% acceptable below 5,000,000 JPY. The CEAC plot shows that BKP has a 87% likelihood of having a cost per QALY below 5,000,000 JPY.

Discussion: This study demonstrated that BKP provides a cost-effectiveness treatment for osteoporotic vertebral fracture in Japan. On the other hand, the effect might be blunt in patients aged > 80 years. However, the instruments such as SF-6D and EQ-5D were all designed for self-completion, but there are strong arguments in favor of interviewer administration to reduce cognitive burden and help in promoting understanding, particularly in frail older people, which might affect this result. Further research is necessary to elucidate the cost-effectiveness in this population.

Teriparatide Neoadjuvant Therapy Targeting the Osteoporotic Spine: Influence of Administration Period from the Perspective of Bone Histomorphometry

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Introduction: Many osteoporosis drugs have been developed for reducing the risk of osteoporotic fractures, but it is difficult to expect that their effects will be observable within a short-term. To date there has been little debate regarding effective neoadjuvant therapy regimens. As teriparatide (TPTD) offers a powerful early stage osteogenesis-promoting effect, it has recently come to be expected to offer not only a fracture prevention but also the capacity to promote improvement in spinal implant fixation, contribute to prevention of proximal junctional kyphosis (PJK), and promote bone fusion. In this study, we evaluated various aspects related to bone histomorphometry in spinal fusion patients also presenting with osteoporosis and examined the impact of preoperative administration of TPTD on cancellous bone as well as the effect of different periods of administration.

Methods: The subjects were 43 spinal fusion patients with osteoporosis who consented to undergo an iliac biopsy (TPTD administration group (TPTD group): 30 patients, non-administration group (NTC group): 13 patients). The TPTD administration periods and the number of subjects treated for each period were: 1 month (5 patients), 2 months (8 patients), 3 months (8 patients), 4 months (6 patients), and 6 months (3 patients). All patients were double-labeled with tetracycline preoperatively, and iliac biopsies were performed during spinal fusion surgery. Non-decalcified thin-sliced specimens were prepared from a block of iliac bone, then static and dynamic histomorphometric analyses were performed using osteomeasure analytic system. Specimens were classified based on TPTD administration period and then compared against the NTC group using the Dunnett method after performing one-way ANOVA testing.

Results: Regarding the baseline breakdown between both groups, P1NP (change rate 181% vs. 48%) and TRACP 5b (22% vs. -30%) were significantly increased in the TPTD group compared to the NTC group at the time of biopsy; however, no other data points showed a significant difference between the groups. Regarding the dynamic bone morphometry parameter, an increase in mineralizing surface (MS/BS) was observed 1 month after TPTD administration; this increase became significant when TPTD was administered for 3 months, and when administered for 4 months, was 5.6 times the MS/BS value observed in the NTC group, gradually decreasing afterward. The bone formation rate (BFR/BS) and activation frequency (Ac.F) also exhibited similar tendencies. Regarding static parameters, osteoid surface (OS/BS) also increased with increases in osteoblast surface (Ob.S/BS) when TPTD was administered for 1 month, and peaked after 3 months, gradually decreasing afterward. The eroded surface (ES/BS) bone resorption parameter exhibited no significant increase regardless of TPTD administration period.

Discussion: After starting TPTD administration, the osteogenic parameters peaked after 3-4 months, demonstrating a more rapid effect than previously anticipated. However, responsiveness to TPTD may diminish after 6 months. When considering TPTD neoadjuvant therapy, an administration period of ≥ 3 months is believed to be advantageous to prevent implant loosening and PJK onset during the early postoperative period.

Do osteoporosis and spinal degenerative disorders affect low back pain and related disorders? The Wakayama Spine Study

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Introduction: Osteoporosis and spinal degenerative disorders are both important clinical conditions that affect elderly individuals. However, little is known about the coexistence of these conditions. The purpose of this study was to clarify how the coexistence of osteoporosis and spinal degenerative disorders affect lower back pain (LBP) and related disorders in the general population.

Methods: This cross-sectional study was performed as part of a large-scale population-based cohort study in Japan. A total of 1011 subjects (335 men, 676 women; mean age 66.1±13.3 years) were recruited. We assessed cervical cord compression, lumbar spinal stenosis, lumbar disc degeneration, and lumbar Schmorl's nodules using total spinal magnetic resonance imaging (MRI). Furthermore, the vertebral fracture in the thoracolumbar spine was evaluated using sagittal MRI with a semi-quantitative method, and we evaluated the presence or absence of diffuse idiopathic skeletal hyperostosis on total spinal standing radiographs. Bone mineral density was measured using the dual-energy X-ray absorptiometry method; we determined that 70% or less of the young adult mean had spinal osteoporosis. These items were set as image evaluation items. The following items were then measured and evaluated as clinical conditions: the presence or absence of LBP within the last month, visual analog scale (VAS) of LBP, Oswestry Disability Index (ODI), one-leg standing time, 5 times stand-up time (5SUT), maximum walking speed, and maximum stride. In the multiple regression analysis, we used clinical conditions as objective variables and image evaluation items as explanatory variables, in addition to basic characteristics, such as age, sex, and body mass index (significance level, p<0.05).

Results: Lumbar spinal stenosis, lumbar disc degeneration, and thoracolumbar vertebral fracture were associated with the prevalence and VAS of LBP. Furthermore, cervical cord compression and thoracolumbar vertebral deformity were significantly associated with the ODI, 5SUT delay, and maximum walking speed prolongation. On the other hand, spinal osteoporosis alone was not significantly related to LBP.

Discussion: This study has a limitation due to the cross-sectional design. However, we believe there is clinical relevance because the data are based on the general population with a sample size greater than 1000. We elucidated that spinal osteoporosis is not significantly associated with LBP and related activity of daily living (ADL) disorders (ex. ODI) and that thoracolumbar vertebral fracture is a factor related to LBP, ADL disturbance, and decline in agility. These results suggest that the prevention of osteoporotic vertebral fracture is important.

Local mechanical environment plays a role in spinal bone mineral density measured by quantitative computed tomography: A study on lumbar lordosis

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Introduction: One of the principles of bone biology is Wolff's law that states bone will adapt to loads under which it is placed. Patients with a spinal deformity have a different weight load distribution compared to healthy individuals. There have been some reports on the association between spinal balance parameters and regional bone mineral density (BMD), but the results are controversial. One possible reason for the inconsistent results in previous studies is the use of standard dual X-ray absorptiometry (DXA) which can result in inaccurate BMD measurements for patients with degenerative spondylosis. The purpose of this study is to evaluate the relationship between spino-pelvic parameters and regional volumetric bone mineral density (vBMDs) measured by QCT in the lumbo-sacral region among patients undergoing lumbar fusion surgery.

Materials and Methods: Institutional ethics board approval was obtained for this study. The data of consecutive patients undergoing posterior lumbar spinal fusion between 2014-2017 was reviewed. We included patients with preoperative computed tomography of the lumbar-spine and standing whole spine radiographs. Patients with Cobb >20° scoliosis, CVA >3 cm coronal imbalance, or any ongoing anti-osteoporotic treatment were excluded. 145 patients were included in the final analyses. QCT measurements were conducted in L1 to S1 vertebral trabecular bone. The associations between each spino-pelvic sagittal parameters (SVA, LL, TK, PI, PT, SS) and vBMDs from L1 to S1 were evaluated utilizing multivariate regression analyses adjusted by age, gender, race, and BMI. The statistical significance level was set at p<0.05.

Results: Mean age (\pm SD) was 65.4 (\pm 11.7). 55.2% of the patients were female. Mean vBMD in L1 (\pm SD) was 118.3 \pm 37.4 mg/cm³. After adjusting by age, gender, race, and BMI, LL was negatively associated with vBMDs in all levels from L1-L5 (% coefficient and R-square: L1: -0.442, 0.269; L2 -0.551, 0.297; L3 -0.611, 0.363; L4 -0.554, 0.228; L5 -0.431, 0.196), but not in S1. SS was negatively associated with vBMD only at L4 (% coefficient -0.586). SVA, PI, PT, TK were not associated with vBMDs at any levels.

Discussion: We demonstrated that LL independently affected local vBMDs in the lumbar spine. Higher LL was associated with lower vBMDs in all levels. Our results suggest that BMD is affected not only by metabolic factors, but also by the mechanical environment. It is also implied that local mechanical forces have different loading effects on vertebral bodies that affect bone density. The effect of LL on vBMD was most significant at L3. L3 is usually located at the apex of the lumbar curve. Due to this anatomical characteristic, LL change might influence the weight load distribution and regional vBMD in L3 more than other lumbar vertebrae.

An Effect Comparison of Denosumab and SERM on Spinal Instrumentation in Patients with Osteoporosis

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Introduction: Spinal instrumentation is commonly used to treat various Spinal disorders. One of the advantages of spinal instrumentation is the biomechanical stability it provides; however, a common complication of this procedure is the risk of implanted screw loosening. To overcome this problem, several studies have investigated the effects of osteoporosis treatment in patients undergoing spinal instrumentation. However, evidence supporting the use of other treatment options such as Denosumab and SERM to treat osteoporosis is still lacking. The objective of this study was to investigate the effects of Denosumab and SERM (Bazedoxifene) on spinal instrumentation surgery using Finite Element Analysis (FEA).

Methods: Twenty-six patients [age: 68.4 ± 6.5 years (mean \pm SD)] with postmenopausal osteoporosis were selected for this prospective study. Patients were divided into two groups: [Denosumab group (Dmab group) N=13, and SERM group (SERM group) N=13]. All patients were evaluated using DXA, and CT at baseline and 12 months after treatment. Each 3D-FEA model of L4 vertebra was constructed from the CT data. The 3D-FE models of the pedicle screw were developed separately from high resolution micro-CT and inserted in the vertebra model using traditional trajectory. In each model, nonlinear analysis was performed. The pull out strength (POS) of the screw and compression force of the vertebra were assessed at baseline and 12 months after treatment.

Results: Twenty-two patients (84.6 %: 11 denosumab, 11 SERM) completed this study. There was a significant decrease in TRACP-5b and total-P1NP from the initial baseline to 12 months post treatment for both the Dmab and SERM groups ($P < 0.05$, vs baseline: Wilcoxon). The percent LS BMD changes increased significantly in both treatment groups from baseline (Dmab group: 6.1%, $P < 0.01$ vs baseline / SERM group: 3.4%, $P < 0.05$ vs baseline), but no significant difference was observed between both groups. In the FEA analysis, the percent change in compression force for both treatment groups was not significant in contrast to baseline and there was no between-group difference. However, the percent change in POS increased significantly from baseline in the Dmab group (Dmab group: 18.5%, $P < 0.01$ vs baseline / SERM group: 0 %, ns vs baseline) compared to the SERM group ($P < 0.05$: Mann-U).

Conclusion: In summary, our results showed that both treatment groups had a significant increase in LS BMD. However, in biomechanical studies using FEA, Dmab had a stronger effect on improving screw fixation. This study suggests that the effects of spinal instrumentation is different in each treatment. This is an important fact to take into consideration when designing a treatment plan for patients with spinal disorders. Denosumab may be useful for reducing loosening of pedicle screws after spinal instrumentation.

Clinical and radiological impact of adjacent vertebral fracture after balloon kyphoplasty: Development of a scoring system for predicting adjacent vertebral fracture occurrence

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Introduction: The incidence of adjacent vertebral fractures (AVFs) after balloon kyphoplasty (BKP) is reported to be 10%-38%. However, only a few studies elucidated the risk factors of AVF after BKP. Unlike vertebroplasty, BKP aims not only to secure fracture fixation and stabilization, but also to reconstruct the vertebral anatomy and correct the kyphotic spinal deformity. In addition, the clinical impact, including the patients' quality of life (QOL), and the radiological impact, including upper and lower spine units, have not been elucidated formally. Thus, the purpose of this study was to investigate in detail the clinical and radiological impact of AVFs after BKP for the treatment of OVF and to establish a scoring system for the prediction of AVF.

Methods: This prospective cohort study included 116 consecutive patients from 10 participating hospitals who underwent balloon kyphoplasty from 2015 to 2017. Each patient underwent plain X-ray imaging and computed tomography before and after surgery. Severity of pain was subjectively assessed using a visual analog scale (VAS). QOL was evaluated using SF-36. Patients were followed up for at least 6 months. Odds ratio (OR) of each variable for AVF was calculated using a logistic regression model adjusted by age, gender, site of fracture (thoracic or thoracolumbar spine/lower lumbar spine), the presence of old OVF, wedge angle before surgery ($<20^\circ$ / $20-25^\circ$ / $>25^\circ$) and $>10^\circ$ of correction. Selection of independent predictors for inclusion in the AVF risk score was based on their relative prognostic contribution in the logistic regression model. For each patient, the AVF risk score was calculated as the simple arithmetic sum of point values assigned to each risk factor based on the multivariate-adjusted risk relationship: 1 point for OR 1.0 to 10 and 2 points for OR >10 .

Results: A total of 109 patients were analyzed. Thirty-two patients (29%) showed AVFs. No significant difference was observed in each clinical outcome at 6-month follow-up, although greater VAS score for back pain at 1-month follow-up was observed in the AVF group than in the non-AVF group ($p<0.001$). The multiple logistic regression model showed increased odds ratio (OR) of thoracic or thoracolumbar spine, old OVF presence, $>25^\circ$ kyphosis before surgery, and $>10^\circ$ correction for AVF. Based on this result, a simple scoring system for predicting AVF occurrence was determined. The total AVF score varied from 0 to 6. All patients with 5-6 points showed AVF.

Discussion: In conclusion, AVFs have no impact on the clinical outcome, except for back pain at 1-month follow-up. More severe wedge angle before surgery, correction degree, presence of old OVF, and thoracolumbar level were predictive factors of AVF. All patients with AVF risk score 5 or more showed AVF. Therefore, if the patients have an AVF risk score of 5 or more and needed correction of kyphosis, correction surgery with implantation should be selected for them.

Factors related to low back pain among elderly population in suburban area Japan -The Shiraniwa Study-

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Introduction: In a super aged society, low back pain of the elderly population is one of the most important problems to be solved. Considering the current situation that the real number of elderly people and the rate of increase of elderly people are large in suburban areas, we need to investigate the actual condition of elderly residents living in suburban areas. Therefore, the purpose of this study was to clarify the factors related to low back pain among elderly people in suburban area Japan .

Methods: This study was based on the results obtained from cross-sectional measurements of participants who enrolled in the Shiraniwa study. The Shiraniwa study, which began in a suburban community from 2016, is a population-based prospective cohort study that aims at investigating locomotive syndrome, sarcopenia, frailty, and low back pain. It was also designed to elucidate risk factors for these conditions.

We enrolled 409 people aged 65 years or older (164 males, 245 females, mean age: 73.5±5.4 years) and investigated Visual Analogue Scale of low back pain (VAS), body mass index (BMI), skeletal muscle mass index(SMI: using bioimpedance analysis machine: MC780A, TANITA, Japan), handgrip strength, gait speed, Hospital Anxiety and Depression Scale (HADS), presence of exercise habit at age 20 to 50 (Past Exercise), C7 sagittal vertebral axis (SVA), and prevalent vertebral fractures (OVF) from lateral view of whole spine radiograph.

We defined the people whose VAS \geq 30mm as LBP group, and LBP < 30mm as normal group. Each item was compared between two groups using Mann-Whitney U test and chi-squared test. Factors related to low back pain were assessed using multivariate logistic regression analysis. The explanatory variables were as follows; Age (+1yr.), sex, slime (BMI<18.5kg/m²), obesity (BMI>25.0kg/m²), low SMI (male:<7.0kg/m², female:<5.7kg/m²), low handgrip strength (male:<26kg, female:<18kg), slow gait speed (<0.8m/s), OVF, sagittal imbalance (SVA>95mm), depression, anxiety (HADS score +1pt.), and Past Exercise.

Results: Low back pain of VAS 30mm or more was present in 38.9% (159 people) of the study population. There was no significant difference in sex, SMI, handgrip strength, gait speed and Past Exercise between two groups. Age (74.7years vs 72.7years), BMI (23.6kg/m² vs 22.6kg/m²), HADS score (depression: 4.55 vs 3.55, anxiety:4.84 vs 3.66), SVA (51.9 vs 24.4) and the ratio of OVF (22.6% vs 9.6%, p<0.01) were significantly higher in low back pain group (p<0.01).

Multivariate logistic regression analysis revealed that obesity (aOR: 1.75, 95% CI 1.04-2.93), OVF (aOR 2.21, 95% CI 1.14-4.28), anxiety (aOR 1.14, 95% CI 1.05-1.24) and sagittal imbalance (aOR 3.24, 95% CI 1.44-7.33) were independently related to low back pain. On the other hand, Age, sex, Sarcopenia, depression and past exercise habit were not independently related to low back pain.

Discussion: Factors related to low back pain of VAS 30mm or more were obesity, prevalent vertebral fractures, anxiety, and sagittal imbalance . It is not clear the causality due to the cross-sectional nature. However, this study supported that obesity and anxiety might be effective targets for treating low back pain among elderly patients living in suburban area.

Pelvic compensation accompanying spinal malalignment and back pain-related factors -The Wakayama Spine Study

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Background: When the center of gravity of elderly people with decreased trunk flexibility moves forward, it often takes posture to maintain standing by pelvic compensation. Therefore, it is not enough to evaluate global alignment with only the sagittal vertical axis (SVA), but it is also important to simultaneously evaluate pelvic tilt (PT).

Purpose: In this study, we focused on the combination of C7 SVA and PT and aimed at evaluating the standing posture of elderly people and investigating the factors related to postural abnormality.

Methods: This was a cross-sectional study using an established population-based cohort in Japan. Of the 814 subjects who participated in the second survey of the Wakayama Spine Study, 747 (220 men, 527 women, mean age 64 y.o.) underwent sagittal whole-spine radiography in a standing position, whole-spine magnetic resonance imaging (MRI), and bioelectrical impedance analysis (BIA). The C7 SVA (mm) and PT were measured from the radiographs. The fatty infiltration ratio (FIR, %) in the erector spinae and multifidus at the L1 upper end-plate level was measured by axial MRI using Digital Imaging and Communications in Medicine software. The appendicular skeletal muscle mass index (ASMI) was calculated from the sum of the muscle masses of the four limbs after adjusting for height (kg/m²).

Statistics: The participants were divided into the following four groups on the basis of PT and SVA: normal group (PT<20°; SVA<50mm), compensated group (PT≥20°; SVA<50mm), noncompensated group (PT<20°; SVA≥50mm), and decompensated group (PT≥20°; SVA≥50mm). The latter three categories were defined as malalignment, and the characteristics of and factors related to each group were examined.

Results: The prevalence of malalignment was increased by age group as follows: less than 50 y.o., 17%; 50s, 26%; 60s, 38%; 70s, 49%; over 80 y.o., 62%. This prevalence was also significantly higher in women under 50 y.o. and over 70 y.o. The number of people in each group and the average age per group were 466 and 61 y.o. in the normal group; 187 and 65 y.o. in the compensation group; 37 and 73 y.o. in the noncompensation group; and 57 and 75 y.o. in the decompensation group, respectively. The prevalence of low back pain (66%) and pain intensity measured by visual analogue scale (average 30 mm) in the decompensated group was significantly higher than those of the other three groups. On multivariate analysis, it was found that female sex and the FIR of the erector spinae were significant factors.

Conclusion: This study reveals that pelvic compensatory function for the postural abnormality changes with age. Some of the characteristics of people with no pelvic compensation include mild exacerbation of back pain and limited degeneration of the erector spinae muscle. These results suggest that spinal muscles are important for preventing low back pain in the elderly with spinal malalignment.

Association of vertebral bone marrow edema with low back pain in degenerative lumbar scoliosis in the elderly

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Introduction:

The underlying pathophysiology of low back pain (LBP) in degenerative lumbar scoliosis (DLS) is unclear. The objective of this study was to examine if bone marrow edema (BME) adjacent to the vertebral endplate on magnetic resonance imaging (MRI) was associated with LBP in elderly DLS patients.

Methods:

This study is a cross-sectional observational study. One hundred and twenty DLS patients over 65 years were enrolled. Of these patients, 64 with LBP were allocated to LBP group, and 56 without LBP to control group. DLS was defined as de novo DLS with a Cobb's angle > 10°, developing after bone maturation without previous history of scoliosis. Lumbar radiography, computed tomography, MRI, and tender point examination in the lumbar spine were performed in all patients. On MRI, coronal T2-weighted fat-saturated images were used to score the size of BME. We defined BME as the areas of increased signal intensity adjacent to vertebral endplates and its corresponding bone marrow of the vertebral body (Figure). The prevalence of BME in LBP group and in control group was compared. The radiographic and MRI findings were evaluated by two spine specialists. The intra- and inter-reader kappa value was 0.80 (p<0.001) and 0.79 (p<0.001).

Results:

The two groups were similar at baseline data of clinical characteristics. There was no significant difference between LBP group and control group for the radiographic parameters; Cobb angle, laterality of scoliosis, location of intervertebral vacuum phenomenon and endplate osteosclerosis. BME was found in 62 of 64 (96.9%) patients in LBP group compared with 21 of 56 (37.5%) patients in control group (P<0.001). BME located more frequently on the concave side than on the convex side of scoliosis (P<0.001). Among patients in LBP group, BME score was associated with LBP severity (r=0.724; P<0.001). Lumbar tenderness was found in 52 (81.3%) patients in LBP group compared with 4 (7.1%) patients in control group (P<0.001).

Discussion:

BME on MRI was closely associated with the presence and severity of LBP in the elderly DLS patients. In DLS patients, the biomechanical stress loaded on the vertebral endplate at the concave side of scoliosis might be the causes of LBP.



Lifestyle and lifetime occupational exposures may not play a role in the pathogenesis of Modic Changes on the lumbar spine MRIs

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Introduction: Modic Changes (MCs), signal variations of the endplate and bone marrow on magnetic resonance (MR) images, have long been suspected as a pathological cause of back pain. While much attention has been focused on the clinical perspectives of MCs, the etiology of MCs remains unclear. A variety of theories, such as mechanical stress alteration, infection, autoimmune inflammation, and gene determination, have been proposed to explain the pathogenesis of MCs. Although some studies have reported that gender, body mass index (BMI), cigarette smoking, and physical loading may associate with MCs, the observed associations are not consistent among studies. Using a sample of general population, the goal of this study was to determine the magnitude of associations between MCs with lifestyle and lifetime exposures, if any.

Methods: The study was extended on the Hangzhou Lumbar Spine Study, a population-based study of mainland Chinese focusing on lumbar degenerative changes. The study sample was randomly selected from a typical Chinese community. Demographics, lifestyle, and lifetime exposures were measured using a structured questionnaire, including smoking history, alcohol consumption, vehicle vibration, exercise history, and occupational history. Moreover, each job in lifetime was further reviewed to evaluate occupational physical demands, sitting, vibration, and injury. The presence and type of MCs were evaluated on T1W and T2W sagittal MRIs. Univariable and multivariable logistic regressions were used to examine the associations of MCs with various environmental exposures.

Results: There were 486 subjects (53.5 ± 14.4 yrs; range, 20-88 yrs) included in this study. MCs were found in 46.5% of subjects studied, in which 14 (2.9%) and 168 (34.6%) had exclusively type I changes and type II changes, respectively, and 42 (8.6%) had mixed I/II changes. In univariable regression analyses, greater age (OR=1.10, $P<0.001$), higher BMI, vehicle vibration and exercise, but not male gender and cigarette smoking were associated with greater likelihood of presenting MCs in the lumbar spine. Greater age was also associated with a greater number of endplates affected by MCs ($P<0.001$). Except occupation vibration exposure, all occupational loading measurements were statistically associated with the occurrence of MCs. In multivariable regression analyses, no statistically significant association between the occurrence of MCs with gender, BMI, cigarette smoking, vehicle vibration, exercise and each category of occupational exposures was observed after age was adjusted for. Given different types of MCs, gender (OR=0.55, $P=0.008$) and BMI (OR=1.10, $P=0.017$) were found significantly associated with type II changes, but not type I changes.

Discussion. Age is an important determinant for MCs. Lifestyle and occupational factors may play a minor role in the pathogenesis of MCs in the lumbar spine, if any. Such etiological pattern for MCs is similar to that of lumbar disc degeneration, suggesting that MCs are degenerative findings that determined by genes.

Results of conservative protocol in management of 403 patients of Lumbar Disc Herniation: Are we operating more than we should?

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Introduction: The ideal management of lumbar disc herniation (LDH) still remains unresolved. An initial conservative management is recommended for symptomatic LDH patients with an exception for cauda equina syndrome. However what constitutes an ideal conservative protocol is yet to be established. Previous large-scale trials in this regard (Weber, Maine and SPORT) have investigated the role of rest, exercises, physical therapy, non-steroidal anti-inflammatory drugs (NSAIDs), opioids and muscle relaxants, but have failed to reach a guiding consensus. The routine use of certain drugs from class of antiepileptics and antidepressants have been found to be efficacious in this condition but their optimum duration and dose, especially their progressive dose escalation, has not been extensively studied. The primary aim of this study was to establish the role of conservative protocol, its appropriate constituents, duration as well as response rate and also the actual need for surgery in LDH patients.

Methods: A hospital-based prospective study was carried out including 403 patients of age-range 14 to 65 years presenting with typical symptoms of LDH (radiculopathy) in whom a conservative treatment was proposed at initial presentation. All patients were managed by a multimodal conservative protocol including pharmacological therapy consisting of NSAIDs, progressive dose escalation of antiepileptic and antidepressants like pregabalin (maximum 600mg), oxcarbazepine (maximum 600 mg), duloxetine (maximum 120mg) and amitriptyline (maximum 75mg), oral, intravenous or epidural steroids, deep heat therapy, local hot/ice packs, counter-irritants, exercises as well as posture counseling. Outcome measures included Visual Analog Scale (VAS) score for leg and back pain, Oswestry Disability Index (ODI), recurrence rate and patient-reported satisfaction. The patients were followed at 3, 6 and 12 months.

Results: There was significant reduction in ODI ($p < 0.0001$), VAS scores for both back pain ($p < 0.001$) and leg pain ($p < 0.0001$) at initial follow-up visit (3 months). This reduction continued or was maintained till the final follow-up at the end of 1 year. Only 60 (14.8%) had recurrence. 269 (66.8%) patients were either satisfied or very satisfied with final outcomes. Only 22 patients (5.4%) required surgery, even though 277 (68.7%) had been advised for it elsewhere.

Discussion: Patient satisfaction was higher in our study (66.8%) as compared to 60.06% in Weber's and 46% in Maine study. Requirement of surgery was least in our study (5.4%) as compared to 25.7% in Weber's study, 8.2% in Maine and 22% in SPORT trial. Most of the patients advised surgery elsewhere responded to our conservative protocol. Our conservative protocol has thus shown encouraging results with good outcomes and better patient satisfaction, low recurrence rate as well as lower requirement of surgery as compared to literature. This study provides suitable evidence based conservative management protocol for LDH patients. However, a larger randomized multicentre study is required to draw a final conclusion in this regard.

Range of motion and local sagittal alignment of lumbar spine in 627 healthy volunteers - Age-related changes and gender difference -

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Introduction: Several researchers have tried to establish normal alignment and kinematic behavior of the lumbar spine, using plain radiographs. There have been few studies using a large and gender-balanced cohort with a balanced age distribution. The aim of this study was to evaluate lumbar sagittal alignment and range of motion (ROM) using radiographs in large asymptomatic cohort, and elucidate those gender differences and age-related changes.

Methods: A total of 627 healthy volunteers (at least 50 men and 50 women in each decade from 3rd to 8th) underwent the whole spine radiographs in a standing position, and the lumbar spine radiographs in a recumbent position. Lumbar lordosis (T12-S1) and ROM during flexion and extension were measured using a computer digitizer.

Results: Mean lumbar lordosis (LL) was $36.8^\circ \pm 13.2^\circ$ in the recumbent position and $49.8^\circ \pm 11.2^\circ$ in the standing position. The LL was larger in standing position and in female, than that in recumbent one and in male. Local lordosis at each disc level increased incrementally with distal progression through the lumbar spine in both positions. Local lordosis at L4-S1 was $29.8^\circ \pm 8.0^\circ$ in the recumbent position and $34.2^\circ \pm 8.3^\circ$ during standing, and occupied 85.1% and 70.8% of total LL respectively. However local lordosis in the standing position decreased with age at L2-3, L3-4 and L4-5 levels. Total lumbar ROM (T12-S1) decreased with age. Female ROM was larger than male one.

Conclusion: The standard value and age-related changes in lumbar alignment and ROM in each decade were established in asymptomatic subjects. These data will be useful as normal values for the sake of comparison in clinical practice, and elucidate gender differences and age-related changes of them.

Differences in Surgical Practices Between Salaried and Fee-for-Service Surgeons for Degenerative Lumbar Conditions in a Universal Health Payer System

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Introduction. Optimal surgical treatment for some spinal disorders remains controversial. By offering different procedures, surgeons are a central driver of health care costs. Even within a universal health payer system, surgeons may offer different treatments for similar conditions on the basis of their compensation mechanism. The purpose of this study was to examine differences in surgical practice, for two common degenerative spine conditions, between fee-for-service and salaried physicians. The second goal was to investigate if there were any differences in baseline characteristics between patients based on surgeon remuneration.

Methods. Differences in operative practices based on remuneration scheme (fee for service or salaried) were assessed among registered surgeons in the Canadian Spinal Outcomes Research Network (CSORN) for 2 lumbar conditions: stable spinal stenosis and degenerative spondylolisthesis. The primary outcome was the difference in type of procedures performed between the two groups. Other studied variables included use of minimally-invasive surgery, operative time, and baseline patient characteristics (age, BMI).

Results. Sixty-four surgeons across 8 Canadian provinces were examined in this study; 39 surgeons were fee for service and 25 were salaried.

For stable spinal stenosis (n=2141), salaried surgeons performed significantly more decompressions only (p<0.05), and statistically less interbody fusion procedures (p<0.05) than fee-for service surgeons. Salaried surgeons tended to operate on fewer spinal levels (p<0.01) and performed less minimally invasive procedures (p<0.001) than their fee-for-service counterparts.

For degenerative spondylolisthesis (n=1228), salaried surgeons performed significantly more instrumentation plus interbody fusions (p<0.05), endured significantly longer operative times (p<0.001) and performed less MIS procedures (p<0.001).

Baseline patient characteristics were similar for both groups.

Discussion. Surgeon compensation was associated with different approaches to stable lumbar spinal stenosis and degenerative lumbar spondylolisthesis. Salaried surgeons tended to treat spinal stenosis more conservatively, and degenerative spondylolisthesis more aggressively. More than just patient related factors seem to influence surgical decision-making and should be thoroughly explored.

Can Minimally Invasive Spinal Fusion Surgery Provide the Better Surgical Outcome than Conventional One in the Treatment of Degenerative Lumbar Spinal Diseases? A minimum of one-year follow-up study

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Introduction: The true effectiveness of minimally invasive spinal fusion (MISF) surgery has not been adequately clarified for the treatment of degenerative lumbar spinal diseases. The purpose of the current study was to investigate whether the MISF can provide the better outcomes than conventional fusion surgery in the treatment of degenerative lumbar spinal diseases.

Methods: One hundred and twenty-five patients who had undergone single-level fusion surgery for unstable degenerative spondylolisthesis or foraminal stenosis were examined with a minimum of one-year follow-up (mean period of 28 months). There were 61 men and 64 women with a median age of 70s ranging 47-88. The main pathology was degenerative spondylolisthesis in 94 patients and foraminal stenosis in 31. The following 3-types of fusion surgery were performed; minimally invasive transforaminal interbody fusion after microscopic decompression through a unilateral approach with percutaneous pedicle screwing (PTLIF), transforaminal interbody fusion after microscopic decompression through a unilateral approach (TLIF), and posterior lumbar interbody fusion with posterolateral fusion after open decompression through a bilateral approach (PLIF). PTLIF was performed using percutaneous pedicle screwing with a guidance of CT-based navigation system. TLIF was performed same decompression method as PTLIF. However, pedicle screws were inserted through the open method for approach side and the transfascial method for the opposite side. PLIF was performed by the posterior lumbar interbody fusion combined with posterolateral fusion after open decompression through a bilateral approach. The screws were inserted with a freehand method. Two board-certified spine surgeons operated all patients. One junior surgeon performed PTLIF in 46 patients and TLIF in 34 patients. The other senior surgeon performed PLIF in 43 patients. There were no statistically significant differences among 3 groups in terms of age, gender, preoperative severity, and follow-up period. Outcome measures were as follows; Visual analogue scale (VAS) for low back pain, lower limb pain and numbness, Roland-Morris Disability Questionnaire (RDQ), and Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ). The status of intervertebral bony union was also evaluated using X-ray CT. Kruskal-Wallis test was used for statistical analyses. Statistical significance was defined as a p-value of less than 0.05.

Results: The estimated blood loss (EBL) and operating time were significantly higher in the TLIF group. There were no statistically significant differences among 3 groups in terms of VAS scores, RDQ scores, and all of the domains of the JOABPEQ scores at the baseline before the surgery. There were also no statistically significant differences in terms of improvement in three VAS scores, RDQ scores, and all of the domains of the JOABPEQ scores. The intervertebral union rate was 91% in PTLIF group, 92% in TLIF, and 94% in PLIF. No statistically significant difference was found in the union rate among 3 groups.

Discussion: The current study demonstrated that there were no statistically significant improvements of VAS and HR-QOL among three groups with different surgical invasiveness. The degree of proficiency or skillfulness for each surgical method might be attributed to the outcome in the treatment of degenerative lumbar spinal diseases.

Application study of ERAS in perioperative period of fusion surgery of patients with degenerative lumbar diseases

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Introduction: Spine surgery is often combined with large operation trauma, long operation time, and many postoperative complications and how to accelerate postoperative rehabilitation of fusion surgery has become an important clinical problem. We have tried the Enhanced Recovery After Surgery (ERAS) regimen in the perioperative period of fusion surgery. The details of this paper are as follows:

Methods: 236 patients with lumbar degenerative disorder whose fusion segments were no more than 3 (88 male patients and 148 female) were enrolled in the study from January 2015 to August 2015. They were divided into control group and ERAS group according to their will. The control group adopted traditional perioperative interventions while the ERAS group adopted ERAS scheme in perioperative period and the follow-up time were 13.4 ± 0.9 months. We collected Visual Analogue Score (VAS) at different time, The Oswestry Disability Index (ODI), the length of stay, postoperative complications, opioid doses, the readmission rate, and degree of satisfaction to the treatment and explored implementation experience of ERAS in lumbar fusion surgery.

Results: There was no statistical significance in age, gender, BMI, the number of surgical segment, VAS scores, ODI scores and anesthesia grade of American Society of anesthesiologists (ASA grade) between ERAS group (119 cases) and control group (117 cases) ($P > 0.05$). VAS scores of ERAS group were lower than that of control group during 3 days after surgery, at discharge, and 1 month after operation ($P < 0.05$) while there was no statistical significance at follow-up ($P = 0.251$). Compared with control group, ERAS group had short length of postoperation stay, few postoperative complications, little opioid dose during 2 days after surgery, and superior degree of satisfaction ($P < 0.05$). There was no statistical significance in rate of readmission during 1 month after surgery ($P = 0.339$).

Conclusion: The implementation of ERAS in perioperative period of lumbar fusion surgery can alleviate postoperative pain, accelerate functional recovery, reduce the use of opioids, reduce postoperative complications, improve patients' degree of satisfaction, and ultimately achieve the purpose of rapid rehabilitation without a concomitant increase in readmission rate.

Effects of restoration of sagittal balance on adjacent segment degeneration in instrumented lumbar fusions

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Introduction: Adjacent segment degeneration (ASD) is one of the consequences following fusion surgery, and various confounding factors are known to be related to the pathomechanism of this consequence. Recently, global sagittal alignment has been reported to have significant implications on clinical outcomes following fusion surgery. Therefore, this study was designed to investigate the effects of surgical restoration of sagittal balance on adjacent segment degeneration after long level lumbar fusion.

Methods: From 2003 to 2015, patients who underwent more than 4 level lumbar fusion surgery with L2 as an upper level and sacral± iliac as a lower fusion level were recruited. Exclusion criteria was following; surgery for infection, trauma and tumors, high grade degeneration (Kellgren-Lawrence> grade 3) at the upper level (L1-2) and lack of data. A total of 73 patients were finally enrolled, and according to postoperative restoration of sagittal balance (PI-LL <±9), 44 patients (group I, including 10 pedicle subtraction osteotomy (PSO)) showed matched sagittal balance and 29 (group II) showed mis-matched one. General demographics, sagittal radiographic parameters and clinical outcomes were recorded. Preoperative disc degeneration at L1-2 was evaluated with Pfirmann grade and K-L grade. Postoperative 2 years disc degeneration at index level was evaluated with K-L grade. More than grade 3 degeneration and increase of 1 grade in K-L grade compared to preoperative one at the index level were defined as a radiologic ASD following surgery. Statistical analysis to investigate the clinical and radiological outcomes between the groups and factors related to ASD was done.

Results: Incidences of radiological ASD (group I, 11 patients (25%); group II, 16 (55%)) and ODI score (group I, 36.9±19.9; group II, 49.4±20.7) at postoperative 2 years were significantly higher in group II. And there were no significant differences in other demographics including age, sex and preoperative Pfirmann/ K-L grade and back and leg pain scores between groups. Since group II presented relative higher pelvic tilt and lower lumbar lordosis compared to those of group I, subgroup analysis was done between the PSO patient and group II.

In this subgroup analysis, even there was no significant differences in pelvic incidence, pelvic tilt and preoperative degeneration of the index level, group II showed higher incidence of radiological ASD (PSO group, 1 patients (10%); group II, 16 (55%)) and worse clinical outcomes (ODI, 47±20.7 in PSO and 49.7±20.5 in group II). In univariate analysis, age, preoperative Pfirmann and K-L grade and postoperative lumbar lordosis and PI-LL mismatch were related to the radiological ASD. In multivariate analysis, preoperative Pfirmann grade (OR 4.2, 95% CI 1.75-10.1) and PI-LL mismatch (OR 4.9, 95% CI 1.5-15.4) showed significant relationship with radiological ASD at postoperative 2 years.

Discussion: Restoration of sagittal balance even with PSO may provide positive effect on the adjacent segment degeneration although other factors such as preoperative degeneration grade are also related to.

Open versus Minimally Invasive Transforaminal Lumbar Interbody Fusion in Obese Patients. A systematic Review and Meta-analysis

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Introduction: Obesity is still considered a significant burden on the current health care system. The surgical outcome for the obese patient is always less optimal compared to healthy weight patients. Lumbar spine degenerative disease is prevalent. Transforaminal lumbar interbody fusion (TLIF) is the treatment of choice for lumbar spinal stenosis and spondylolisthesis and can be done through traditional open approach (O-TLIF) with extensive damage to the spinal muscle or through minimally invasive techniques (MI-TLIF) through a small incision and dilators. This review aims to report the published difference between MI-TLIF and O-TLIF in an obese patient in regards to complications rate, functional outcome, blood loss and hospital stay.

Methods: Out of 17 studies identified through the search, only four studies were included in the meta-analysis. There were two prospective, and two retrospective cohorts, 430 obese patients, the average age was 53.5 years, 153/203 male/female ratio, and the average BMI was 33.6. The primary outcome was complications rate (Total, infection, Dural tear), whereas secondary outcomes were functional outcomes (VAS pain score and ODI), blood loss and hospital stay. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, several databases including PubMed, EMBASE, Web of Science, Cochrane Library were searched through January 2018 to identify any observational and experimental studies comparing the outcomes of O-TLIF versus MI-TLIF for lumbar spondylolisthesis or spinal stenosis in obese patients.

Results: The total number of complications was significantly higher in O-TLIF compared to MITLIF (OR = 0.420 [95% CI: 0.199, 0.887]; I2 = 45.20%) and same in Dural tear (OR = 0.255 [95% CI: 0.102, 0.636]; I2 = 0%) whereas no significant difference in infection rates between the two groups (OR = 0.899 [95% CI: 0.192, 4.204]; I2 = 32.37%). Although some studies reported significant improvement in the functional outcome early on after surgery, no difference was detected between the two groups for VAS and ODI between pre-op and last follow up (SMD = -0.034 [95% CI: -0.695, 0.627]; I2 = 62.14%) and (SMD = 0.617 [95% CI: -1.082, 2.316]; I2 = 25%) respectively. The blood loss was significantly less in MITLIF comparing to O-TLIF (SMD = -426.736 [95% CI: -490.720, -362.752]; I2 = 70.53%), and similar statistical significance was detected between two group in regards to hospital stay (SMD = -1.079. [95% CI: -1.591, -0.208]; I2 = 84.3%).

Conclusions: Early literature suggests that the complications rate, blood loss, and hospital stay are less in MI-TLIF compared to O-TLIF and no difference in the functional outcomes for an obese patient with a degenerative lumbar disease. Longer-term studies with larger sample size are warranted to examine the clinical outcomes of obese patients.

Risk factors for readmission and complications in obese and severely obese patients undergoing elective posterior lumbar spine fusion

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Background context: Obesity is an important risk factor for complications after lumbar spine fusion, and poses unique challenges regarding safety and quality of care. Nonetheless, this patient population is not well studied. The purpose of this study was to determine risk factors for readmission in this specific patient population.

Methods: This was a retrospective case control study. Adult patients age >18 undergoing primary posterior lumbar fusion were identified using ICD-9 codes in the State Inpatient Databases of New York, Florida, North Carolina, Utah, and California. Independent analyses were performed for three separate groups of patients: patients were identified as *obese* using codes for obesity or BMI >30, but not morbid obesity or BMI > 40, *severely obese* using codes for morbid obesity or BMI > 40, and *normal* if they had none of the above codes nor codes for overweight or underweight. Data were queried for demographics, comorbidities, surgery characteristics, and 90-day hospital readmission. Logistic multivariate regressions were performed to determine risk factors for readmission.

Results: We analyzed 24,349 obese, 9,835 severely obese patients and 257,986 normal patients. The 90-day hospital readmission rate was 14.5%, 17.5%, and 12.1% in the obese, severely obese, and normal groups, respectively. In the obese group, risk factors for readmission included female gender, Black/Hispanic race, Medicare/Medicaid insurance, the addition of anterior or lateral interbody fusion, >3 Levels treated, cerebrovascular disease, chronic pulmonary disease, congestive heart failure (CHF), diabetes without and with chronic complication, myocardial infarction, peptic ulcer disease, peripheral vascular disease, renal disease, and mental health disease. In the severely obese group, risk factors for readmission included female gender, Medicare/Medicaid insurance, >3 levels, CHF, diabetes without and with chronic complication, hemi/paraplegia, mild liver disease, and renal disease. In the normal group, all studied variables were risk factors for readmission.

Conclusion: Ninety-day hospital readmission rates in obese and severely obese patients undergoing elective posterior lumbar fusion are high. Risk factors include demographic variables such as race and insurance status, as well as various comorbid conditions, but not age. Similar risk factors were seen in normal weight patients, however with less magnitude, suggesting a synergistic effect of obesity with other risk factors. This study provides valuable insight into modifiable risk factors that may be potential targets for preoperative optimization and guidance on risk adjustment in this unique patient population.

One-third of postoperative scoliosis patients pursue a career path in a healthcare-related field.

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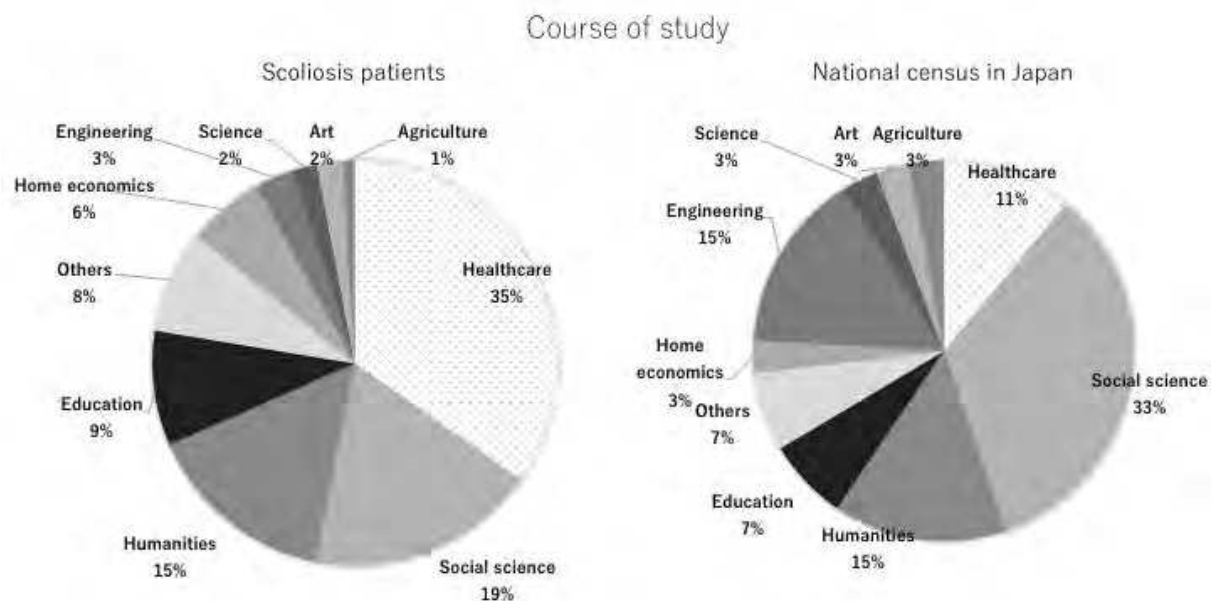
Introduction: Although scoliosis surgery early in life may affect career choice in favor of healthcare fields, no study has analyzed this relationship. We investigated the career paths of postoperative scoliosis patients.

Methods: A total of 212 patients with scoliosis who underwent corrective surgery between 12 and 17 years of age were mailed a questionnaire, and 132 patients (mean age: 21.2±2.0, range: 19–28 years, at the time of the survey) responded. Mean age at time of operation was 15.1±1.5 years (range: 12–17 years). Choice of study major was determined using the same questions used in the Japanese national population census. Clinical outcomes were evaluated using Scoliosis Research Society-22 questionnaire (SRS-22) and the Short Form 36 Health Survey (SF-36).

Results: 35% of scoliosis patients chose a career in healthcare compared with 11% of people the same age based on the population census. Healthcare was the most popular career choice in patients, while it ranked fourth in the population census. The mean age at which a career direction decision was made in scoliosis patients was 17.8±2.6 years, and 87% of patients reported that their decision to pursue a healthcare-related career was affected by their own medical experiences. Among various occupations chosen by patients pursuing a healthcare-related career, nurse ranked 1st and accounted for 35% of all healthcare professionals. Compared with patients that chose a non-healthcare career, the mean age at which a career decision was made was significantly lower among patients pursuing a healthcare-related career. There were no significant differences in SRS-22 and SF-36 scores between patients pursuing healthcare- and non-healthcare-related careers.

Discussion: Scoliosis surgery had an appreciable impact on patients' career path toward the healthcare field. Both intrinsic and interpersonal factors provide support for these results. In particular, patients' gratitude for being treated for their illness may have inspired them to seek a career that involved helping others suffering from illnesses. Moreover, patients may have been influenced by healthcare professionals during their own courses of treatment. Our results showed that younger age at the time of career direction decision was factor in pursuing a healthcare-related profession. A younger age at the time of career direction decision can be explained by the fact that early socialization experiences, e.g., interactions with nurses and healthcare settings, have a strong influence on an individual's perspective on nursing, self-identification with nurse attributes and the decision to enter the profession. Similar SRS-22 and SF-36 scores among patients pursuing healthcare- and non-healthcare-related careers suggest that quality of life is not a factor in choosing a healthcare-related field of study.

These findings suggest that patients' experiences in hospitals can affect the future direction of their lives. Medical staff can think of their work as not only to treat patients' diseases, but also to foster future medical staff.



Impact of Previous Lumbar Spine Surgery on Outcome of Lumbar Total Disc Replacement: Analysis of Prospective 5-year Follow-up Study Data

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Introduction: FDA-regulated prospective trials evaluating lumbar total disc replacement (LTDR) in the United States have included patients with previous lumbar surgeries. One of the largest insurers in the United States recently issued a positive coverage policy for LTDR that disqualifies patients with previous lumbar surgeries of any kind from treatment with LTDR. The purpose of this study was to compare LTDR outcomes in patients with vs. those without prior lumbar spine surgery.

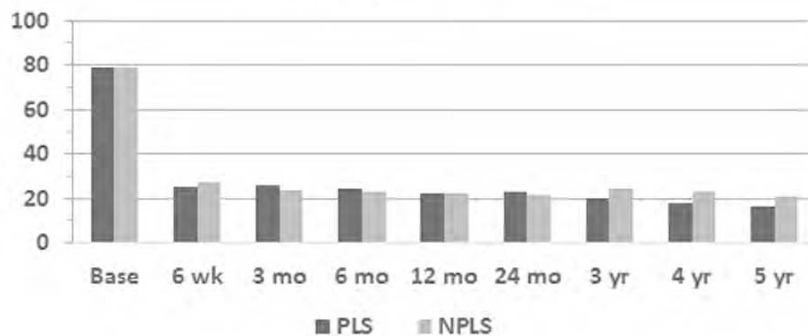
Methods: This is a post hoc analysis of an FDA-regulated trial of single-level LTDR for degenerative disc disease. 376 patients from the activL® IDE study population were divided into Prior Lumbar Surgery (PLS) (n=92) and No-Prior Lumbar Surgery (NPLS) (n=284) groups. PLS patients had undergone one or more of the following procedures: intradiscal electrothermal annuloplasty (IDET) (n=5), percutaneous nucleoplasty (n=4), microdiscectomy (n=81), hemilaminectomy (n=17), laminotomy (n=36) or other (n=1) prior to receiving a LTDR. Patients with prior lumbar fusion were excluded from the IDE study. All patients received LTDR at either L4-L5 or L5-S1. Baseline characteristics, functional and pain outcomes, serious adverse events and re-operations were statistically compared between the groups at time points up to 5 years post-operation.

Results: 24% of patients had one or more lumbar surgeries prior to LTDR. Patient baseline demographics were the same between groups. Baseline ROM (5.0 ± 4.0 vs. 7.2 ± 5.1 degrees) and translation (0.4 ± 0.5 vs. 0.6 ± 0.7 mm) were significantly lower in the PLS group. VAS back pain and leg pain, ODI and the SF-36 Physical Component Score improved significantly ($p < 0.05$) from baseline in both groups and were maintained through 5 years after LTDR (VAS back pain and ODI scores provided in the graphs below). There were no significant differences in clinical outcome measures between groups at any time point.

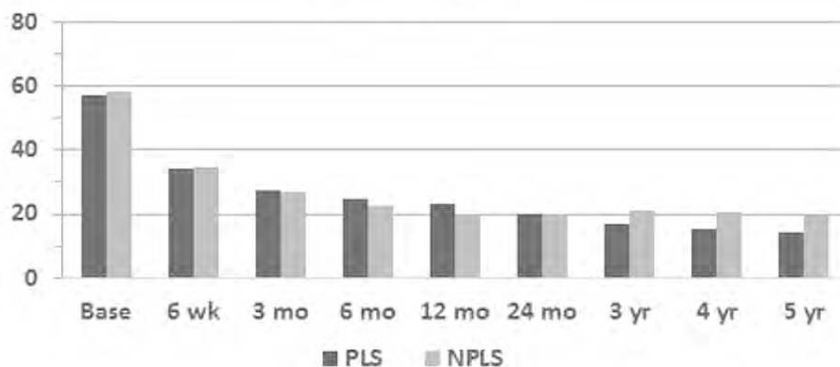
Flexion-extension ROM was maintained at or above baseline values for the PLS group, but was lower in the NPLS group; significantly at 6 weeks, 3 months and 3 years. AP ROM and translation were similar between PLS and NPLS groups at all time points. Serious device (6.5% vs. 9.5%) and procedure (9.8% vs. 16.9%) related events were numerically lower in the PLS group, though not statistically lower. Similarly, index (5.4% vs. 6.7%) and adjacent (2.2% vs. 2.5%) level re-operation rates were lower in the PLS group.

Discussion: Prior lumbar spine surgery was not related to compromised outcomes among patients undergoing LTDR. There were no statistically significant differences in ODI, SF-36, pain scores, or safety rates between PLS and NPLS patients. PLS patients had numerically fewer safety events than NPLS patients. These results are in line with findings from earlier studies that prior surgery is not a contra-indication for LTDR provided that other selection criteria are met. These results do not support the denial by an insurer to give patients and providers the option of receiving LTDR for DDD unresponsive to non-operative care as described in the FDA approved device usage labeling.

Mean VAS Back Pain Scores



Mean ODI Scores



Adjacent segment degeneration versus disease after lumbar spine fusion for degenerative pathology: A Meta-analysis of the Literature

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Introduction : Arthrodesis remains a common intervention for the surgical treatment of degenerative spinal disease. Clinical studies have demonstrated variability in the rates of adjacent segment pathology after lumbar fusion. The objective of this study was to review the published literature and to estimate rates and risk factors for adjacent segment degeneration (ASDeg) and adjacent segment disease (ASDis) after lumbar fusion.

Methods : A Systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines on the incidence of fusion for lumbar degenerative pathology at the adjacent segment after previous surgery. We searched MEDLINE, EMBASE, Cochrane Library, and CINAHL databases for articles through to May 2012. Thirty one articles with 4206 patients were selected. Extracted data included average patient age, average time to follow-up, type of intervention, potential risk factors and ASDeg and ASDis incidence. Funnel and forest plots were used to describe heterogeneity and meta regression to estimate pooled incidence of ASDeg and ASDis.

Results : A total of thirty one articles with 4206 patients were included for analysis. Combining all extractable data, the overall pooled incidence of ASDeg was 5.9% per year (95% CI- 4.8%, 7.2%), and ASDis was 1.8% (95% CI-1.3%, 2.4%) per year. The incidence of ASDeg is higher with more motion segments. Gender, age, segmental sagittal alignment, fusion methods and instrumentation were not associated with an increased risk of ASDeg or ASDis. Radiographic ASDeg did not show strong correlation to clinical outcomes.

Discussion: The prevalence of ASDeg and ASDis has been variably reported in the literature, and fusion length is the factor most significantly associated with adjacent segment pathology. In guiding surgical strategies to avoid adjacent segment pathology, limiting the number of levels fused may have a greater impact than motion sparing approaches or changes in fusion strategies.

Nucleus replacement gets a new chance with annulus sealing

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Introduction: The surgical standard treatment for disc herniation is usually the nerve decompression by partial nucleotomy. This leads to a reduction in disc height and intradiscal pressure (IDP) and an increased range of motion (ROM) which can result in an accelerated degeneration process. Nucleus replacement implants are intended to prevent from this, but are associated with the risk of extrusion. The aim of this study is to investigate biomechanically whether the combination with an annulus closure is a promising concept for the treatment of disc herniations.

Methods: In 6 human lumbar spinal specimens (L3-4, L5-S) a prolapse was provoked by a box defect (6x7 mm) in the annulus. The herniated nucleus material was removed and replaced by a novel collagen-based nucleus implant. An annulus closure sealed the defect. In the intact state, after creating the defect, postoperatively and after dynamic loading (n = 100000 cycles), ROM and IDP were measured in a quasistatic universal spine tester. Therefore, pure moments of ±7.5 Nm were applied in flexion-extension, lateral bending and axial rotation. Disc height was determined using an Instron materials testing machine by axial loading with 100 N. Significant differences were assessed using the Friedmann and Bonferroni Post-Hoc Test with a significance level set to $\alpha = 0.05$.

Results: The initially provoked prolapse with partial nucleotomy led to a significant increase of the ROM in lateral bending ($p = 0.035$) and axial rotation ($p = 0.014$). The implantation of the nucleus replacement and annulus closure reduced the ROM again. IDP and disc height values decreased due to the defect and increased after implantation. Macroscopically, neither the nucleus replacement nor the annulus closure device migrated during cyclic loading.

Discussion: None of the many concepts for nucleus replacement developed so far were able to assert themselves due to the high risk of extrusion. In this study, the biomechanical properties of the intact intervertebral disc could be nearly restored after a postoperative prolapse. There was no extrusion of the implant nor nucleus material. In combination with an annulus closure device, nucleus replacement implants could have a new chance.

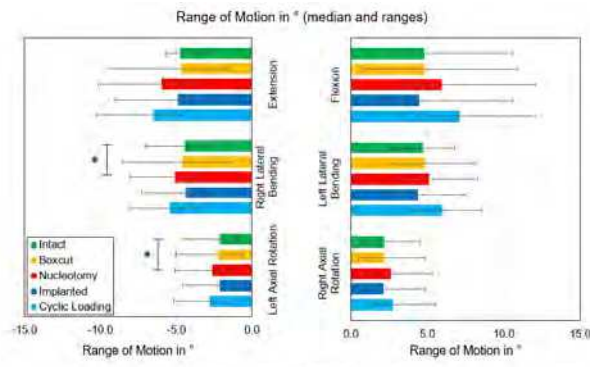


Figure 1: Median and ranges for the range of motion in all motion planes flexion/extension, left/right lateral bending and right/left axial rotation for pure moments of ±7.5 Nm assessed with the spine tester.

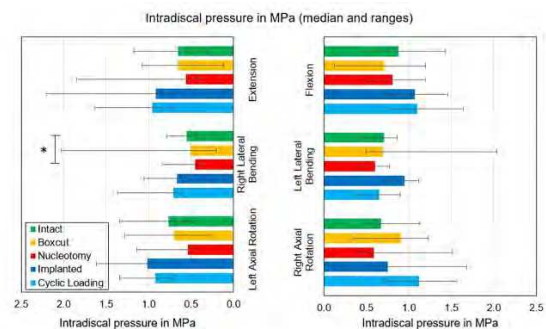


Figure 2 Median and ranges for the intradiscal pressure in all motion planes flexion/extension, left/right lateral bending and right/left axial rotation for pure moments of ±7.5 Nm assessed with the spine tester, * $p < 0.05$



Figure 3: Left) Transverse section through a disc following 100 000 cycles of loading. Right) Both the nucleus replacement (tweezer tip) as well as the annulus repair device are still contained within the disc periphery on the posterior right hand aspect of the annulus.

Low-intensity Pulsed Ultrasound Far-field Exposure Increases Matrix Synthesis in Annulus Fibrosus Cells

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Introduction: Damage and tears in the intervertebral disc (IVD) are associated with back pain and disability and are related to risk of disc herniation and degeneration. Current therapies for stimulating healing such as intradiscal growth factor and stem cell injections are invasive and have shown limited success rates. Our group is exploring noninvasive delivery of Low-intensity Pulsed Ultrasound (LIPUS) mechanical energy to repair disc tissue defects and reduce the rate of disc degeneration and back pain by stimulating matrix metabolism. While previous *in-vitro* studies have demonstrated LIPUS-induced effects in disc cells with near-field exposure, far-field exposure – which is more relevant for targeting deep tissues – has not been investigated. Aims: (1) Develop and characterize an *in-vitro* system for far-field LIPUS exposure at relevant frequencies for targeting deep tissues; (2) Evaluate stimulatory effects of far-field LIPUS exposure on annulus fibrosus (AF) cells cultured in alginate or hyaluronic acid (HyA) scaffolds.

Methods: Acoustic simulations were performed for 0.5, 1.0, and 1.5MHz operating frequencies while varying transducer diameter and standoff distance to optimize beam exposure area and minimize intensity field heterogeneity. Simulations were validated by hydrophone measurements, and beam uniformity at the cell culture location was quantified by intensity gradient. Bovine AF cells were encapsulated in alginate or HyA beads. One group received media supplemented BMP-7, a well-known anabolic growth factor. The other group was exposed to a LIPUS waveform (1.5MHz, $I_{SPTA}=120mW/cm^2$) for 20 minutes each treatment day. Control and BMP-7 samples were placed in the LIPUS system (**Fig. 1**) for 20 minutes with ultrasound off. After 5-8 treatments, matrix synthesis was assessed via hydroxyproline and DMMB assay for total collagen and sulfated glycosaminoglycan (GAG) concentration, respectively, and normalized by DNA. Histological sections were stained with Alcian Blue.

Results: Acoustic field measurements demonstrated uniform, broad exposure within the beam's diverging far-field, with a 93% reduction in intensity gradient magnitude compared to typical near-field configurations (**Fig. 2**). When cultured in alginate, AF cells demonstrated greater collagen concentration than controls when treated with BMP-7 (3.3-fold) or LIPUS (2.6-fold), with no significant difference between the BMP-7 and LIPUS groups (**Fig. 3a**). While there was no significant difference in collagen content when cells were cultured in HyA, sGAG concentration was significantly greater than controls with both BMP-7 (2.3-fold) and LIPUS (3.8-fold) treatment, with LIPUS treatment significantly outperforming BMP-7 (**Fig. 3b**).

Discussion: We observed an upregulation in collagen and sGAG synthesis in AF cells with far-field LIPUS exposure that is of similar or greater magnitude to growth factor treatment, suggesting that LIPUS may be a safer alternative for stimulating AF repair. Our findings indicate that cellular scaffold material properties may be important for cell response to LIPUS stimulus, suggesting that tissue properties may be important considerations for future *in-vivo* application. Ongoing *in-vitro* studies using harvested human surgical tissue will improve understanding of tissue stiffness and degeneration stage effects on LIPUS-induced cell response. Additional parametric studies are underway to identify which LIPUS parameters cells are sensitive to and ultimately an optimal dose for stimulating matrix synthesis.

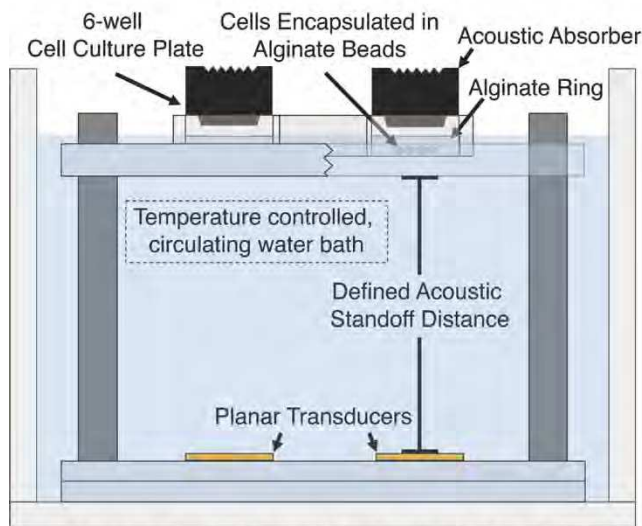


Figure 1. Generalized schematic representing our custom *in-vitro* system designed to deliver uniform acoustic energy to cells cultured in monolayer or in 3D scaffolds. Cell culture targets are placed at a predetermined acoustic standoff and well-plates are sealed apically with an acoustic absorber. The system is placed in a degassed, temperature-controlled water bath.

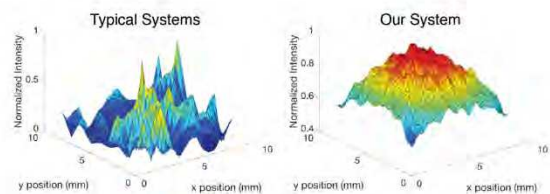


Figure 2. Surface plots of measured intensity across the cell culture position demonstrate improved beam uniformity with our far-field system compared to typical near-field systems. Mean gradient is reduced by 93% (0.014 ± 0.011 vs 0.001 ± 0.001 Vpp^2/mm).

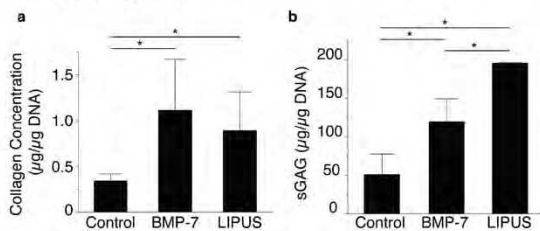


Figure 3. (a) Collagen concentration assessed by hydroxyproline content demonstrates significantly upregulated collagen synthesis in both treatment groups when cells are cultured in alginate, and (b) sGAG concentration assessed by DMMB assay demonstrates significantly upregulated GAG synthesis in both treatment groups when cells are cultured in HyA.

Osteomacs: may be a key factor in the development of Modic changes

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Introduction: Lumbar degenerative diseases are not uncommon clinically. Modic changes (MCs) are one of the main radiographic manifestations of lumbar degenerative diseases, but its etiology is remaining unclear. Recent researches suggest that apart from structural and mechanical properties changes in the bony endplates, regional bone resorption and sclerosis coexist simultaneously in histology, suggesting a re-balance of osteogenesis and osteoclastogenesis in MCs. Osteomacs play an important role in the balance of destruction and regeneration of bone, but no research has focused on the effects of Osteomacs on MCs yet.

Methods: 30 patients suffering from low back pain, exhibiting MCs on MRI (Modic type 1, n = 9; Modic type 2, n = 18; Modic type 3, n = 3) and undergoing 1- or 2- level lumbar interbody fusion were included. 3 patients with lumbar vertebral burst fractures were used as the normal control. Surgical patients also had a transpedicular vertebral body biopsy taken of subchondral bone under Intraoperative X-ray examination. Tissue collected from the biopsies corresponding to the MCs was first examined by micro-CT. Then, samples underwent Immunohistochemical or TRAP staining and real-time PCR. We define F4/80⁺CD169⁺ for Osteomacs by immunohistochemical staining and based on the number of Osteomacs observed in different types of MCs and burst fractures samples, we reclassified the biopsies into Osteomacs+ group (≥ 3 Osteomacs/ 40X view) and Osteomacs- group (< 3 Osteomacs/ 40X view). Subsequently, data was performed on the results of Micro-CT, immunohistochemical/TRAP staining, and real-time PCR between the two groups.

Results: Osteomacs+ groups accounted for 5 of 9 cases of Modic type 1, 2 of 18 cases of type 2, 3 of 3 cases of type 3 and 1 of 3 cases of vertebral burst fractures, respectively. Micro-CT analysis revealed significantly higher BV/TV and Tb.Th in Osteomacs+ groups compared to Osteomacs- groups. Immunohistochemical staining showed Osteomacs+ group had significantly more Osteocalcin⁺ osteoblast in comparison to Osteomacs- group, whereas the number of TRAP⁺ osteoclast was higher in the Osteomacs- group. Real-time PCR showed significantly increased osteogenic-related gene expression in Osteomacs+ group and increased osteoclastogenic-related genes expression in the Osteomacs- group.

Discussion: Our data demonstrate that Osteomacs can regulate osteogenesis and osteoclastogenesis in different types of MCs. Osteosclerosis in regional bony endplate can be considered as an indication of excessive bone repair related to Osteomacs.

In the past few decades, multiple studies have declared that different types of MCs are different stages of a same continuous process, but few studies elaborate the pathologic process of MCs. Our study provides a new perspective on the development of MCs. We believe that : In the early stage (Modic type 1), localized micro fracture of the endplate initiates the distribution of Osteomacs, while the acute inflammation and the following osteoclastic activity attenuates the osteogenesis process, resulting in low bone formation and high bone resorption in type 2; At Modic type 3 stage, the inflammation tends to be chronic, accompanied by the initiation of organization, providing a good matrix for Osteomacs and osteoblasts to start an osteogenesis process.

Autophagy plays protective roles against human disc cellular apoptosis and senescence, but not affect extracellular matrix degradation

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Introduction: The intervertebral disc is the largest avascular organ. Autophagy is an important cell survival mechanism by self-digestion and recycling damaged components under stress, primarily nutrient deprivation. Thus, resident cells may utilize autophagy to cope with the stressful conditions (low nutrition, pH, and oxygen concentration). However, the extent to which autophagy affects disc cells is unknown. Pharmacological inhibition difficult to provide specific mechanistic explanations of autophagy due to diverse crosstalks in the pathway. Therefore, our objective was to elucidate roles of autophagy in human disc cells using the RNA interference technique.

Methods: Human disc cells obtained from lumbar surgery were used. Cells were cultured in DMEM with or without 10% FBS under 2% O₂ for 0–48 hours to assess serum starvation-induced autophagy. Expression of autophagy marker LC3 and substrate p62/SQSTM1 as well as autophagy-related gene 5 (ATG5), essential for autophagy execution, was assessed by WB. Next, we conducted experiments for autophagy induction or inhibition in human disc cells. ATG5 small interfering RNA (siRNA) was transfected to suppress autophagy. Since autophagy is negatively regulated by the mammalian target of rapamycin complex 1 (mTORC1), RAPTOR, a component of mTORC1, was knocked down using siRNA to enhance autophagy. Cells after transfection of each siRNA were cultured in DMEM with or without 10% FBS for 24 hours. Knock-down efficacy were assessed by WB. To assess mTOR signaling affected by RAPTOR siRNA, phosphorylation levels of Akt and p70/S6K were also evaluated by WB. Then, in no serum-containing DMEM with 10 ng/ml interleukin-1 β (IL-1 β) to induce inflammation, the incidence of apoptotic and senescent cells was determined by WB for cleaved PARP, cleaved caspase-9 and senescent p16/INK4A. Further, matrix metabolism was evaluated by WB for MMPs and TIMPs in supernatants and real-time RT-PCR for *aggrecan-1* and *collagen type 2- α 1* normalized to *GAPDH*.

Results: (1) Time-dependent increases in LC3-II and decreases in p62/SQSTM1 in response to serum starvation, consistent with autophagy induction. (2) ATG5 siRNA decreased LC3-II and increased p62/SQSTM1, showing autophagy inhibition. On the other hand, RAPTOR siRNA increased LC3-II and decreased p62/SQSTM1, showing enhanced autophagy. (3) Pro-inflammatory IL-1 β induced apoptotic and senescent stimuli. Cleaved caspase-9 and cleaved PARP increased by ATG5 siRNA, but decreased by RAPTOR siRNA. Senescent p16/INK4A also increased by ATG5 siRNA, but decreased by RAPTOR siRNA. (4) IL-1 β -induced MMP-3, -13 releases were unaffected by ATG5 siRNA, but decreased by RAPTOR siRNA. In addition, ATG5 siRNA was less sensitive to *aggrecan-1* and *collagen type 2- α 1* mRNA expression, but RAPTOR siRNA promoted *collagen type 2- α 1* mRNA expression.

Conclusion: Knock down of ATG5 led to increased cell death and aging under stressful conditions, indicating the importance of autophagy in maintaining disc cell homeostasis. mTORC1 suppression by RAPTOR siRNA showed protective effects against human disc cellular apoptosis, senescence, and matrix degradation. Suppressed mTORC1 and p70/S6K lose the p70/S6K-mediated negative feedback loop, leading to Akt induction. Activated Akt provides pro-survival and anti-catabolic effects. Autophagy modulation is a potential molecular treatment strategy preventing degenerative disc disease, which depends on induction of Akt as well as autophagy.

Viable allograft as a supplemental therapeutic for disc regeneration

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Introduction: Degenerative changes of the lumbar spine are common and can contribute to chronic back pain. Mechanisms of intradiscal degeneration have been linked to genetic, metabolic, and mechanical imbalance and previous investigators have shown that degenerative changes of the intervertebral disc can be positively influenced by meaningful repair of the annulus and nucleus.^{1,2,3} A protocol was developed to determine whether supplemental cellularized allograft disc matrix could be used to repair degenerative disc tissue in one to two levels. After IRB approval, a study of 224 patients was initiated (ClinicalTrials.gov NCT03709901). This study assesses the first 24 subjects for safety as a preliminary to the larger study.

Methods: Subjects were randomized to receive either allograft, saline placebo, or to continue conservative treatment. The primary outcome of the study evaluated Oswestry Disability Index (ODI) at 6/12 months after transplant, and the Visual Analogue Scale of Pain Intensity (VASPI) at 6/12 months following allograft supplementation. Structural outcomes were assessed by x-ray and Magnetic Resonance Image (MRI) at 12 months. Safety was assessed by the incidence and severity of adverse events (AEs) and clinically relevant changes in laboratory tests. The first 24 subjects returned one month after transplant. Subjects consisted of 5 females and 19 males; demographics of age 35.7 (27-62), and BMI 27(17.7-35.4) were similar between the groups. The safety committee evaluated complications including infections, inflammation, additional interventions and reviewed MRI studies up to 12 months following tissue implantation.

Results: The assessment at 30 days showed no incidents reported. All 24 subjects were followed for the subsequent 12 months. There were no reports of infection or inflammation, none of the subjects withdrew from the study, and no subject required a surgical intervention during the 12-month study. A few subjects reported transient pain after the injection that was managed with appropriate medication. MRI evaluation demonstrated anatomic improvement of the disc and enhanced nucleus signal as represented in **Figure 1**. This subject experienced significant reduction in pain and improvement in ODI. While the data presented to the endpoints in the study is preliminary, the lack of adverse incidents and the initial clinical improvements are encouraging.

Discussion: The target of this safety study was to assure that prescriptive intervention that is clinically efficient and effective could be delivered without risk. Although the data is preliminary, it shows that cellular allograft administration is safe and that attaining clinical improvement for painful degenerative disc disease may be possible.

12-Month Follow-Up, Safety Cohort



VAST Subject Entry

Visual Analogue Scale: 70
Oswestry Disability Index: 58%



12-Month Post Safety

Visual Analogue Scale: 15
Oswestry Disability Index: 22%

Safety of intradiscal condoliase in the treatment of lumbar disc herniation

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Introduction: Chemonucleolysis with condoliase is an effective alternative of surgery for patients with sciatica caused by lumbar disc herniation (LDH). Condoliase reduces the swelling pressure of the herniated nucleus pulposus (NP) by degrading glycosaminoglycans chains that imbibe water, comprising proteoglycans abundant in the NP, thereby providing relief of sciatica. It has long been argued, however, that degradation of NP can accelerate disc degeneration and may lead to clinical symptoms including low back pain (LBP).

We have conducted two randomized clinical trials to verify the efficacy of condoliase for LDH, and have observed imaging changes including decrease of the disc height and signal changes in the vertebral body adjacent to the cartilaginous endplate (Modic changes), although these changes have also been frequently found with aging and after discectomy. The present study was undertaken to investigate the relationship between patients preoperative background factors, and the occurrence of post-treatment adverse events and to elucidate the possible risk factors that may cause such adverse events.

Methods: The safety data of 357 patients (229 receiving condoliase versus 128 placebo) obtained at two previously conducted randomized trials were reviewed retrospectively. Pretreatment background factors included age and gender, disc height, Modic changes, and Pfirrmann grades before condoliase injection. Newly-developed LBP and/or leg pain, decrease of disc height ($\geq 30\%$), posterior vertebral body angle in flexion ($\geq 5^\circ$), vertebral body translation (≥ 3 mm), and changes in Modic classification were defined as post-treatment adverse events.

Results: Newly-developed LBP, decrease of disc height $\geq 30\%$ and posterior vertebral angle $\geq 5^\circ$ were found most frequently in the 20- to 29-year age group patients. Incidence of newly-developed LBP in 20- to 29-, 30- to 49-, and 50- to 70-year age groups after condoliase injection was 41.5%, 32.4% and 25.6%, that of decrease of disc height was 26.8%, 13.8%, and 11.6%, and that of posterior vertebral angle was 19.5%, 8.3%, and 0%, respectively. When the patients were divided into two groups by the median value of disc height at baseline, those with higher disc heights had more prominent disc height decrease than those with lower disc heights (18.8% vs 12.8%). Three out of four patients (75%) whose Pfirrmann grade of the injected disc was rated zero at baseline had disc height decrease and developed LBP. Difference in Modic changes at baseline did not affect the occurrence of adverse events.

Discussion: In this study, patients in their twenties and those with none or mild disc degeneration (higher disc height, Pfirrmann grade 0) are more likely to develop adverse events such as LBP and disc height decrease. The results of the present study would help selecting optimal candidates for condoliase treatment among a variety of patients with LDH.

1. Chiba K, Matsuyama Y, Seo T, Toyama Y: Condoliase for the treatment of lumbar disc herniation: a randomized controlled trial. *Spine (Phila Pa 1976)*,43(15): E896-876, 2018.
2. Matsuyama Y, Chiba K, Iwata H, Seo T, Toyama Y: A multicenter, randomized, double-blind, dose finding study of condoliase in patients with lumbar disc herniation. *J Neurosurg Spine* 28(5): 499-511, 2018.

Clinical importance of trunk muscle mass for low back pain, spinal balance, and quality of life: A multicenter cross-sectional study

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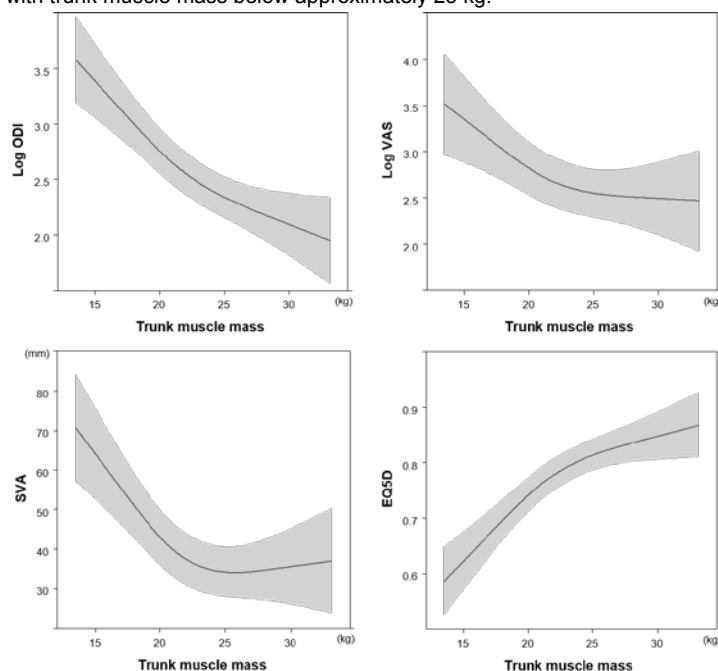
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Objectives: Elucidating the mechanisms of low back pain and spinal sagittal imbalance and taking preventive measures are considered important solutions to the increase in healthy life expectancy in the elderly population. Few reports have investigated the relationship of trunk muscle mass with lumbar spine function and spinal balance, and the clinical significance of trunk muscle mass remains unclear. If trunk muscle mass was a reliable index of low back pain and spinal sagittal imbalance, it could serve as a useful indicator in clinical practice. Therefore, we conducted a large-scale multicenter study to clarify the relationship between trunk muscle mass and low back pain, spinal sagittal balance, and quality of life, and to elucidate the significance of trunk muscle mass in patients with spinal diseases.

Methods: Patients attending spinal outpatient clinics at 10 different medical institutions were enrolled in this study. Data on patients with metals in the body, such as spinal implants or artificial joints, and patients younger than 30 years were excluded. Patient demographics, trunk muscle mass and appendicular skeletal muscle mass (ASM) measured by bioelectrical impedance analysis (BIA), body mass index (BMI), Charlson Comorbidity Index (CCI), the Oswestry Disability Index (ODI), visual analog scale (VAS) for low back pain, sagittal vertical axis (SVA), and EuroQol 5 Dimension (EQ5D) score were investigated. Multivariate nonlinear regression analysis was used to investigate the association of trunk muscle mass with the ODI, VAS score, SVA, and EQ5D score.

Results: Of 2551 eligible patients, 1738 (mean age 70.2 ± 11.0 years; 781 men and 957 women) were enrolled. The average trunk muscle mass was 22.2 ± 4.4 kg, which had a significant negative correlation with age, and the decrease accelerated at approximately 70 years of age. Trunk muscle mass was significantly correlated with the ODI, VAS score, SVA, and EQ5D score ($p < 0.001$) when adjusted by age, sex, BMI, ASM, CCI, and history of lumbar surgery. Patient deterioration was associated with a decrease in trunk muscle mass, and the deterioration accelerated from approximately 23 kg. Meanwhile, ASM was not related to the ODI, VAS score, SVA, and EQ5D ($p > 0.05$).

Conclusions: Trunk muscle mass was significantly associated with the ODI, VAS score, SVA, and EQ5D score, and it was found that trunk muscle mass was more important than appendicular skeletal muscle mass as a factor in spinal pathology. Trunk muscle mass may assume an important role to elucidate and treat lumbar spinal dysfunction and spinal imbalance that may deteriorate with trunk muscle mass below approximately 23 kg.



Physical activity attenuates fibrotic alterations to the multifidus muscle associated with intervertebral disc degeneration

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Introduction: Chronic low back pain causes structural remodelling and inflammation in the multifidus muscle. Collagen expression is increased in the multifidus of humans with lumbar disc degeneration. However, the extent and mechanisms underlying the increased fibrotic activity in the multifidus are unknown. Physical activity reduces local inflammation that precedes multifidus fibrosis during intervertebral disc degeneration (IDD) but its effect on amelioration of fibrosis is unknown. This study aimed to assess development of fibrosis and its underlying genetic network during IDD and the impact of physical activity. This study aimed to examine the effect of intervertebral disc degeneration and its treatment with physical activity on fibrosis in the multifidus muscle.

Methods: Wildtype and SPARC-null mice were either sedentary or housed with a running wheel, to allow voluntary physical activity. At 12 months of age, IDD was assessed with MRI and multifidus muscle samples were harvested from L2-L6. In SPARC-null mice, the L1/2 and L3/4 discs had low and high levels of IDD, respectively. Thus, multifidus samples from L2 and L4 were allocated to low and high-IDD groups compared to assess the effects of IDD and physical activity on connective tissue and fibrotic genes.

Results: High-IDD was associated with greater connective tissue thickness and dysregulation of Collagen-III, Fibronectin, CTGF, Substance P, TIMP1 and TIMP2 in the multifidus muscle. Physical activity attenuated the IDD-dependent increased connective tissue thickness and reduced the expression of Collagen-1, Fibronectin, CTGF, Substance P, MMP2 and TIMP2 in SPARC-null animals and wildtype mice. Collagen-III and TIMP1 were only reduced in wildtype animals.

Discussion: These data reveal the fibrotic networks that promote fibrosis in the multifidus muscle during chronic IDD. Furthermore, physical activity is shown to reduce fibrosis and regulate the fibrotic gene network.

Biomechanical changes in dynamic sagittal balance and lower limb compensatory strategies following realignment surgery in adult spinal deformity patients

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Introduction: Current outcomes for adult spinal deformity (ASD) surgical planning and post-surgical assessment are limited to static radiographic alignment and patient-reported questionnaires. Little is known about the compensatory biomechanical strategies for stabilizing sagittal balance during functional movements in ASD patients. Assessing postural stability during dynamic tasks may pave the way for a better understanding of postural compensatory mechanisms and risk for post-surgical mechanical complications, including proximal junctional kyphosis (PJK) and failure.

Traditional motion capture methods during routine clinical assessment of sagittal balance are impractical given the set-up time, space requirements, and high technology cost. Simple dynamic functional tasks, like a sit-to-stand (STS) maneuver, do not require the same amount of space as gait analysis and are diagnostically appropriate given these tasks are commonly arduous for ASD patients due to the necessary whole body balance and postural control.

Using 3D depth mapping sensor technology and biomechanical modeling, we have developed an efficient means for collecting in-clinic motion analysis data (Figure 1). We used this novel technology to longitudinally assess *dynamic sagittal balance* (DSB) from a cohort of 15 ASD patients undergoing multi-level spinal fusion, and to compare pre- and post-operative DSB data to 10 healthy controls. The purpose of this study was to define a set of objective biomechanical metrics that are representative of ASD post-surgical outcomes, and that may forecast post-surgical mechanical complications.

Methods: We collected in-clinic motion data from 15 ASD patients and 10 controls during an unassisted STS functional maneuver. Joint motions were measured using non-invasive 3D depth mapping sensor technology. Integrated mathematical methods for noise filtering and kinematic constraints provide high-fidelity joint-position tracking for biomechanical modeling, enabling reliable dynamic quantification of spine, hip, and knee biomechanics. Output variables include peak sagittal vertical axis (SVA) over the course of the STS, as well as forces and muscular moments at various joints. We compared changes in DSB metrics between pre and post-surgery, and then separately compared pre- and post-surgical data to controls.

Results: Standard radiographic and patient-reported outcomes significantly improved following realignment surgery. From the DSB biomechanical metrics, peak SVA and biomechanical loads and muscular forces on the lower lumbar spine significantly reduced following surgery (-19 to -30%, all $p < 0.05$). Also, as SVA improved, hip moments decreased (-28 to -65%, all $p < 0.05$) and knee moments increased (+7 to +28%, $p < 0.05$), indicating changes in lower limb compensatory strategies. After surgery, DSB data approached values from the controls, with some post-surgical metrics becoming statistically equivalent to controls.

Discussion: Our data highlight new biomechanical measurements of DSB and lower limb compensatory strategies that change with spinal realignment surgery in ASD patients. Peak SVA, biomechanical loads, and muscular forces on the lower lumbar spine significantly reduced following surgery. Relative biomechanical contributions from the hip and knee changed following surgery indicating reduced compensatory behavior from the hip. Inadequate improvement in DSB may indicate an increased risk for post-surgical PJK. Surgical planning should consider how pre and post-surgical rehabilitation could improve sagittal balance and improve outcomes.

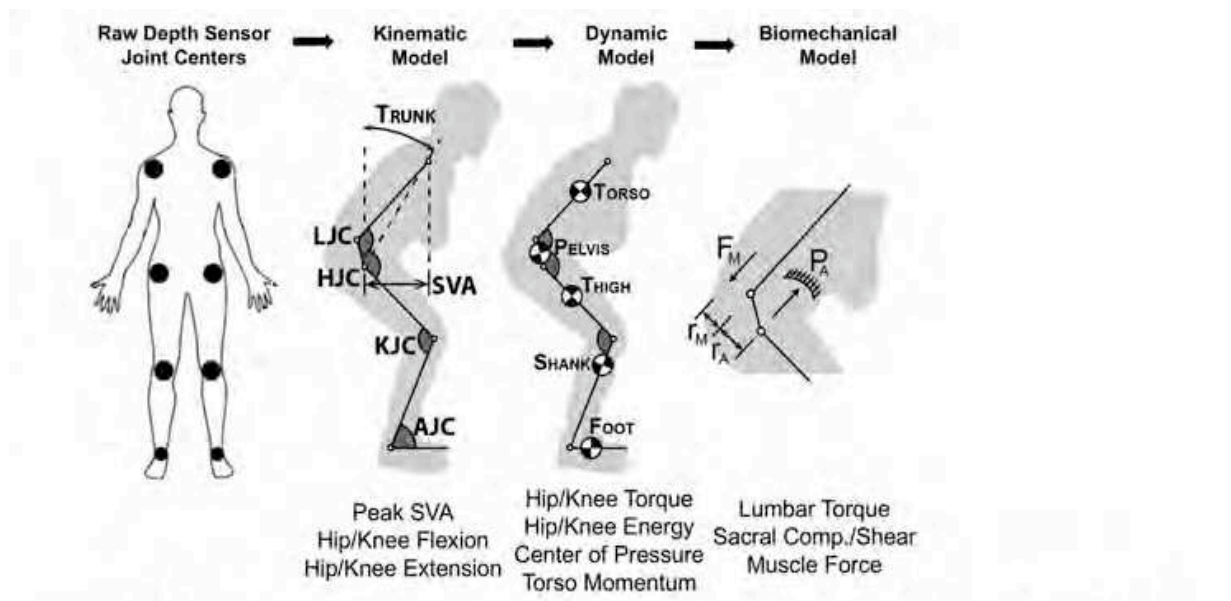


Figure 1. Data processing pipeline for recovering biomechanical variables from the 3D depth mapping motion data

Ultrasound measurement of the skin as a potential marker of bone quality: A prospective pilot study of patients undergoing lumbar spinal fusion

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Introduction: Bone consists of mineral and organic matrix (type I collagen). Clinically, bone strength is determined using bone mineral density (BMD). Studies using Fourier-transform infrared spectroscopy (FTIR) have shown that BMD is not the sole predictor of fracture development and “qualitative” markers such as bone collagen maturity play a role. However, the clinical use of FTIR is limited since a bone biopsy is required. Biochemically, there is a relationship between bone and other type I collagen containing connective tissues such as the skin’s dermis. Previous studies suggest that bone and skin degenerate in a parallel fashion. Ultrasound (US) is a non-invasive method to investigate the dermis at the microscopic level. Besides a decrease in dermal thickness, an increase in echogenicity in the reticular layer has been observed with aging, which is thought to be due to an accumulation of degenerated collagen. We hypothesized that US dermal thickness and echogenicity (proxies for collagen content and quality) correlate with bone collagen maturity.

Methods: Under appropriate IRB-approved protocols, 60 patients undergoing instrumented, posterior lumbar fusion were prospectively enrolled. Quantitative computed tomography (QCT) of the spine and skin US measurements at standardized locations on the lower back were performed. US dermal layer thickness and echogenicity of the lower third of the dermis (reticular dermis) were calculated (Figure 1). During surgery, bone biopsies (iliac crest and pedicle) were obtained. Collagen cross-links (ratio of mature to immature collagen cross-links) was assessed with FTIR. Considering the effects of race and anti-osteoporotic drug therapy, only data of Caucasian patients without anti-osteoporotic medications was extracted. Pearson’s correlation and linear regression tests were performed.

Results: 43 patients (20 male, 23 female, mean age (\pm SD) 62.0 \pm 11.4) met inclusion criteria. Among men, there was no correlation between US measurements and collagen cross-links. Among women, US dermal layer thickness correlated negatively with collagen cross-links in trabecular bone of the iliac crest ($r=-0.51$, $p=0.01$) and vertebra ($r=-0.59$, $p=0.01$) as well as in cortical bone of the iliac crest ($r=-0.50$, $p=0.02$) and vertebra ($r=-0.50$, $p=0.04$). In addition, echogenicity correlated positively with collagen-cross-links in trabecular vertebral bone ($r=0.59$, $p=0.01$). After age adjustment, US measurements and collagen cross-links in the cortical bone of the iliac crest only showed a trend, while remaining significant at the other anatomical locations. In both genders, US measurements showed no correlation with QCT BMD measurements.

Discussion: This study is the first to elucidate the relationship of collagen quality in skin and bone. Previous studies showed that skin thickness is only a poor predictor of BMD but demonstrated the ability to discriminate fracture patients from controls. This discrepancy could possibly be explained by our results, which suggest a significant correlation of skin US measurements with bone quality (collagen cross-links) rather than bone quantity (BMD). In addition, our study suggests obvious gender differences since significant results were only observed in female patients. US involves no radiation exposure, measurements are quick, simple and inexpensive. In summary, similar factors may determine both dermal layer and bone quality because of its comparable tissue composition.

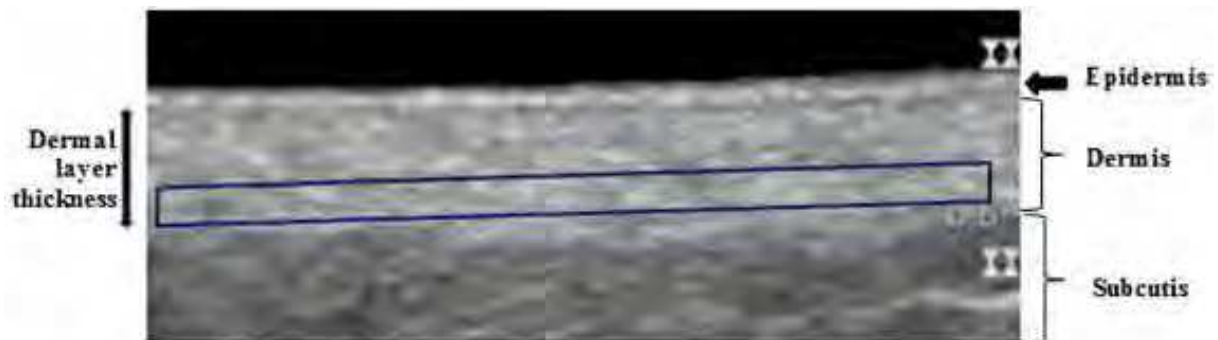


Figure 1. Ultrasound image of the skin showing the different skin layers: The dermal layer thickness was defined as the distance between the epidermal entrance echo and the subcutaneous fat. The echogenicity (extent to which a tissue structure reflects ultrasonic waves) of the lower third of the dermal layer (blue box) was measured.

Enhance long-term stability of alginate-based polyelectrolyte complex BMP-2 carrier by freeze-drying in spinal fusionLing Liu^{1,2}, **Wing Moon Raymond Lam**¹, Ming Wang¹, Jun Li³, Cho Hong, James Goh⁴, Hee Kit Wong¹

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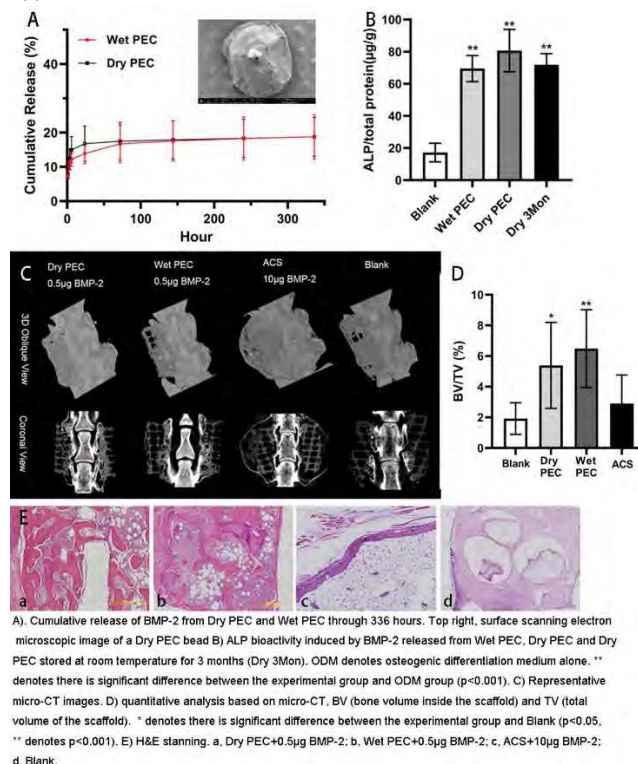
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Introduction: Bone morphogenetic protein-2 (BMP-2) has been widely studied in orthopedic researches and applied in spinal fusion surgery. Supraphysiological amount of BMP-2 and poor modulation capacity of absorbable collagen sponge leads to various complication such as heterotrophic bone formation, seroma formation [1]. The use of heparin incorporated polyelectrolyte complex (PEC) to control the release and protect bioactivity of BMP-2 reduces the required dose and minimises the severity of BMP-2 associated complications. However, preparation of PEC including coating alginate microbeads with multiple layers of polycations and heparin, and poor long-term stability in an aqueous medium form the barrier against its translation from bench to bedside. We hypothesise that removal of water from PEC via freeze-drying can prolong the shelf life by suppressing hydrolysis of alginate core. This study employed a freeze-drying technique with a cryoprotectant, trehalose, to prolong the shelf-life of PEC.

Method: Alginate beads were fabricated by dripping alginate solution into strontium chloride through a nozzle with a diameter of 0.35mm according to our previous reported method [2]. Beads were coated with protamine, and subsequently heparin to form functional PEC. PEC was lyophilized with 10% trehalose solution to preserve the beads. The surface morphology of freeze dried PEC were characterised by SEM. The release profile of BMP-2 (5µg) from freeze-dried PEC (Dry PEC) was compared with that from normally prepared PEC (Wet PEC). BMP-2 released from Wet PEC, Dry PEC and Dry PEC that had been stored at room temperature for three months (Dry 3Mon) were examined by ALP assay. The carrier performances of Dry PEC and Wet PEC were assessed in a rat posterolateral spinal fusion model. Twenty rats were designated to four groups: Dry PEC+0.5µg BMP-2 (N=6), Wet PEC+0.5µg BMP-2 (N=6), ACS+10µg BMP-2 (positive control, N=4), and blank control (N=4). Rats were euthanized after 8 weeks. Spines were harvested, underwent decalcified tissue processing and stained with hematoxylin and eosin.

Results: Release profile showed that both Dry PEC and Wet PEC released BMP-2 in a similarly controlled manner. On 336 hours, 18.76±6.48% and 18.75±5.66% of BMP-2 was released from Wet PEC and Dry PEC, respectively (Figure. 1A). Either freeze-drying or storing at room temperature for 3 months did not compromise the carrier performance, as indicated by the comparable ALP expression to Wet PEC (Figure. 1B). Lastly, micro-CT showed that Dry PEC+0.5µg BMP-2 induced solid spinal fusion between two transverse processes (Figure. 1C). Wet PEC+0.5µg BMP-2 achieved fusion which matched our previous findings [2]. The bone volume fraction of Dry PEC (5.39±2.81%) was comparable to that of Wet PEC (6.49±2.94%) (Figure. 1D). Although ACS induced successful fusion, new bone was formed ectopically, and limited amount of bone was observed inside the scaffold, as shown by significantly lower bone volume fraction (2.91±1.86%).

Discussion: This study proves that fusion efficacy of freeze-dried PEC is maintained in delivering a low dose of BMP-2. Freeze-dried PEC can be stored at room temperature for long-term, which can be a promising candidate to be used for orthopaedic applications.



A). Cumulative release of BMP-2 from Dry PEC and Wet PEC through 336 hours. Top right, surface scanning electron microscopic image of a Dry PEC bead B) ALP bioactivity induced by BMP-2 released from Wet PEC, Dry PEC and Dry PEC stored at room temperature for 3 months (Dry 3Mon). ODM denotes osteogenic differentiation medium alone. ** denotes there is significant difference between the experimental group and ODM group ($p < 0.001$). C) Representative micro-CT images. D) quantitative analysis based on micro-CT. BV (bone volume inside the scaffold) and TV (total volume of the scaffold). * denotes there is significant difference between the experimental group and Blank ($p < 0.05$). ** denotes $p < 0.001$). E) H&E staining. a. Dry PEC+0.5µg BMP-2; b. Wet PEC+0.5µg BMP-2; c. ACS+10µg BMP-2; d. Blank.

1. Mroz TE et al, Complications related to osteobiologics use in spine surgery: a systematic review. Spine (Phila Pa 1976) 2010; 35: S86-104 2. Hu T et al, Novel Protamine-Based Polyelectrolyte Carrier Enhances Low-Dose rhBMP-2 in Posterolateral Spinal Fusion. Spine (Phila Pa 1976). 2015 May 1;40(9):613-21.

The impact of obesity, diabetes, and epidural steroid injections on regional Bone Mineral Density (BMD) measured by Quantitative Computed Tomography (QCT) in the lumbosacral spine

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Introduction: Bone mineral density (BMD) is affected by various local and systemic conditions. It has been reported that high body mass index (BMI) is positively correlated with BMD in healthy adults; however, the effect of BMI on regional BMD in the axial skeleton is unclear. In addition, obese patients with spinal disease often have glucose intolerance and patients with lumbar spine pathology often have a history of epidural steroid injections (ESI). These factors can affect BMD. Compared to dual X-ray absorptiometry (DXA), quantitative computed tomography (QCT) is affected less by body habitus and allows for more accurate BMD measurements in obese patients. The aim of this study is to evaluate the effect of BMI, diabetes, and ESI on regional differences in BMD measured by QCT in a large lumbar fusion patient cohort.

Materials and Methods: 296 patients with preoperative CT scans who underwent posterior lumbar spinal fusion were included. We excluded patients who were underweight (BMI <18.5 kg/m²), on anti-osteoporosis treatment, had continuous use of systemic steroids for other medical conditions, or had missing data. The QCT-vBMDs of L1 to L5, S1 body, and the average of the bilateral sacral alae (SA) were obtained. Multivariate linear regression models were used to evaluate the association between vBMDs in different regions and BMI, diabetes, and history of epidural steroid injections) along with other demographic factors (gender, ethnicity, smoking status, and age). The statistical significance level was set at p<0.05.

Results: Mean age (± SD (range)) was 63.0 ± 13.4 (21-89). 53.1% of the patients were female. Mean L1/2 vBMD (± SD) was 122.4 ± 39.3 mg/cm³. Multivariate analyses demonstrated that obese and morbidly obese patients had significantly higher vBMD (obese; β=19.5, p = 0.001, morbidly obese; β=31.4, p < 0.001) in the SA (Figure 1). Diabetes showed independent positive associations with vBMDs in L1, L2, and the SA (L1; β=18.0, p = 0.024, L2; β=17.6, p=0.039, SA; β= 20.5, p=0.011). Additionally, patients with an ESI history demonstrated significantly lower vBMD in the SA (β=-12.0, p=0.028) (Figure 2).

Discussion: Our results demonstrate that obesity, diabetes, and epidural steroids affected vBMD differently by lumbosacral spine region. In our cohort, vBMD was affected by BMI in the sacral region only, whereas diabetes influenced vBMDs in the upper lumbar vertebrae (L1, L2) as well as the SA. ESIs showed a significant negative effect on vBMD in the SA and had a nonsignificant impact on other regions. The vBMD of the SA appeared to be more sensitive to various patient factors than other lumbar regions. While vBMD increases were associated with obesity and diabetes, previous studies of these patient populations demonstrated higher fracture risk and incidences of osteoporosis-related fixation failure. In addition to BMD, other markers of bone quality should be addressed in future longitudinal studies to elucidate the effect of these factors in the context of clinical outcomes.

Figure.1 Regression coefficients of categorized BMI in each level. (*statistical significance)

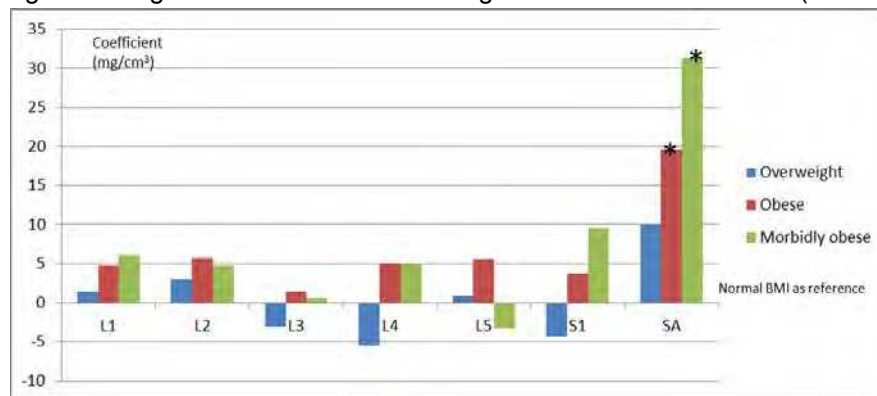
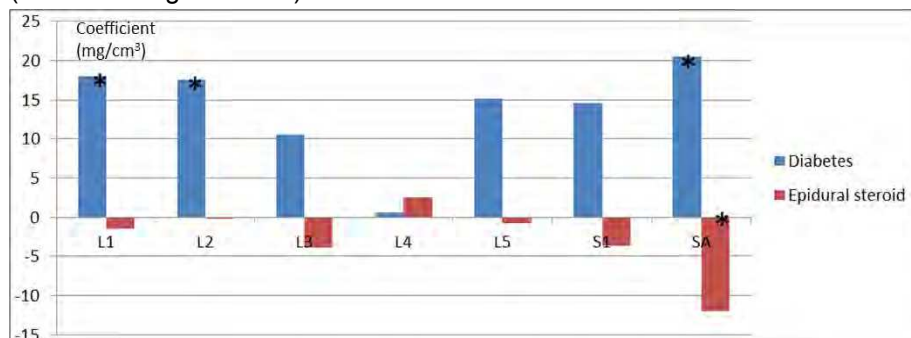


Figure 2. Regression coefficients of histories of diabetes and epidural steroid injection in each level. (*statistical significance.)



The importance of lumbar level stratification for quantitative MR studies of lumbar intervertebral discs: a cross-sectional analysis of 101 healthy adults

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Introduction: Quantitative imaging techniques, such as T2-mapping, are emerging within the spinal field. By allowing quantification of tissue characteristics, such MRI techniques show promise to reflect both structural and functional intervertebral disc (IVD) characteristics non-invasively. This information is useful for the search of biomarkers of pain and in the evaluation of early interventions. Numerous studies regarding quantitative MRI and IVD data exist, however, the majority are based on small cohorts using divergent methodology, limiting comparison between studies. No study has, in a standardized way in a large cohort, elucidated if and how quantitative MRI data vary depending on lumbar IVD level, which is important to establish as a base for future quantitative IVD studies. Therefore, the purpose of this study was to investigate if quantitative IVD T2-values depend on lumbar IVD level.

Methods: The lumbar spine (Th12/L1-L5/S1) of 101 volunteers (54 women, 47 men, mean[SD] age, height and weight: 30.0[3.6]years, 173.5[9.6]cm and 69.9[13.4]kg), without any history of back pain, were examined on a 3T Phillips scanner. Sagittal T2-mapping was performed using 8 echo times (15.8...162.8ms), 3mm slice thickness, 1.5mm interslice distance, 12 slices and repetition time 2000ms. All IVDs were stratified according to Pfirrmann grade (PF) and lumbar level. For each IVD the mean T2-time was determined for the entire IVD volume as well as in five regions of interests (ROI), from ROI1 anteriorly to ROI5 posteriorly.

Results: The IVD distribution within each PF at each lumbar level are displayed in Table 1. For the entire IVD volume, most apparent level-dependent differences were registered within PF2 IVDs, with significantly higher T2 in Th12/L1 compared to all other lumbar levels and 6-12% higher T2 in L1/L2 –L2/L3 compared to most of the IVDs in the lower lumbar spine. Additionally, L5/S1 IVDs with PF2 had 5% higher mean T2 compared to L4/L5 with PF2. For PF1 IVDs, Th12/L1 displayed 36-41% higher T2 compared to L3/L4-L4/5. In PF3 IVDs no significant level dependent T2 differences were discovered but for PF4 mean T2 of L5/S1 was approximately 18% higher compared to L3/L4.

The level-dependent T2-differences were even more obvious when comparing IVD subregions, with significant differences between multiple ROIs within each PF grade. Opposed to when analyzing the entire IVD, level-dependent T2-differences were also found within PF3 for several ROIs. For example, mean T2 in L3/L4 and L4/L5 was 13% respectively 10% lower compared to L5/S1 regarding ROI5 and Th12/L1 displayed 30% higher T2 compared to L3/L4 for ROI4.

Discussion: Significant level-dependent T2-differences within all PF grades, both for the entire IVD volume as well as for multiple subregions, shows that the level-dependent influence on T2-time cannot be neglected. The T2-differences between levels were most apparent within non-degenerated IVDs but also existed within degenerated IVDs. Quantitative imaging techniques are emerging in order to improve non-invasive diagnostics within low back pain. This work therefore is an important base for future research within the field, proving that it is necessary to stratify for lumbar level when performing quantitative MRI studies of the lumbar spine.

Figure1.

Example of PF2 L1/L2 (left; average of 91 IVDs) in comparison to PF2 L4/L5 (right; 63 IVDs)

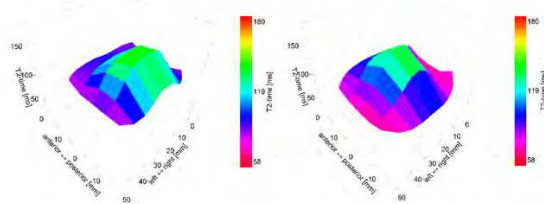


Table1.

Disc region/N	Intervertebral level					
	T12/L1	L1/L2	L2/L3	L3/L4	L4/L5	L5/S1
	<i>Pfirrmann grade 1</i>					
N	5	3	9	16	6	8
Entire IVD	139.2(27.9)cd	117.0(12.7)	110.5(15.4)	102.0(10.7)f	98.7(5.4)f	107.8(12.7)
	<i>Pfirrmann grade 2</i>					
N	92	91	84	74	63	53
Entire IVD	110.7(22.8)abcde	104.7(15.6)cddef	101.4(11.6)cdf	96.1(9.6)abf	93.8(9.4)abef	98.4(12.9)adf
	<i>Pfirrmann grade 3</i>					
N	3	4	7	9	16	21
Entire IVD	102.3(15.0)	84.2(8.4)	86.1(9.3)	87.3(9.2)	85.5(7.1)	85.1(5.4)
	<i>Pfirrmann grade 4</i>					
N	1	3	1	2	16	19
Entire IVD	167.6(-)	94.7(18.0)	90.8(-)	68.7(3.7)e	78.7(7.7)	80.8(11.3)c

Values are mean (SD) T2-time in ms averaged across the entire intervertebral disc volume. a, b, c, d, e, f refer, respectively to a p<0.05 for the difference to the L1/2, L2/3, L3/4, L4/5, L5/S1 or T12/L1 intervertebral levels.

Feasibility of lumbar disc lamellar measurement with in-vivo ultrasonography

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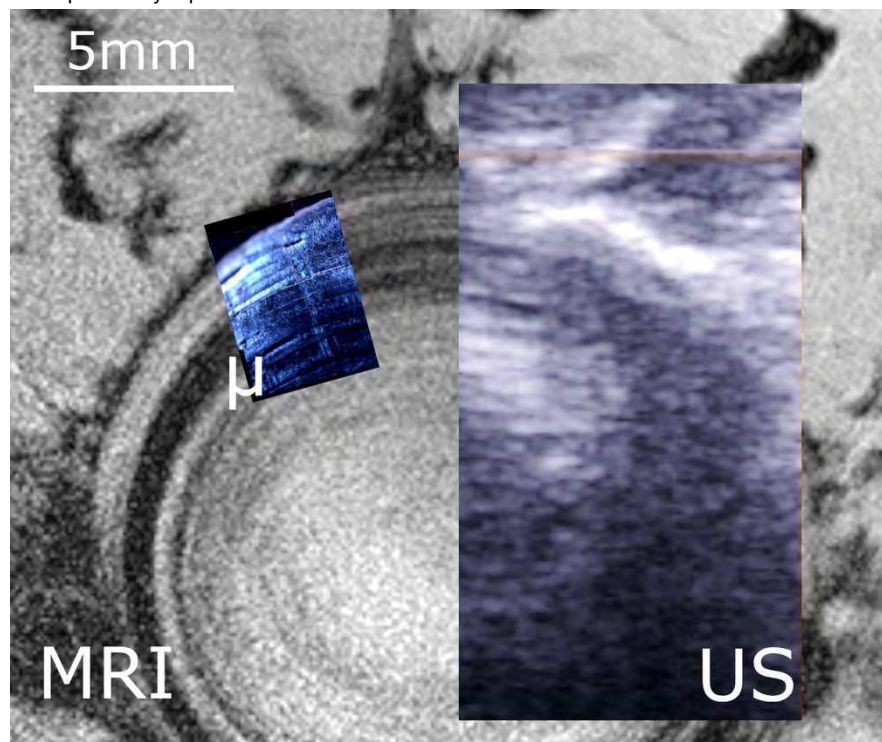
Introduction: Scoliotic spines tend to be stiffer than healthy ones. The origin of this increased stiffness is not yet completely understood, but recent ultrasound elastography measurements of lumbar discs showed that annulus fibrosus of adolescent idiopathic scoliotic (AIS) patients is stiffer than healthy ones [1]. This corroborates microstructural alterations of scoliotic discs that were previously observed in-vitro. Conventional ultrasonography allows for high-resolution and non-invasive imaging in vivo; this wide-spread technique could be used to characterize the lamellar structure of the annulus, potentially giving an insight on the mechanisms related to scoliosis progression. The aim of this work was to test the feasibility of healthy annulus ultrasonography by measuring lamellar thickness in vivo and comparing it with data from the literature. Further validation was obtained in vitro, by comparing ultrasonography with magnetic resonance imaging (MRI) and optical microscopy of animal samples.

Methods: Healthy adolescents were included prospectively after ethical committee approval. Ultrasonographic images of L3-L4 disc were acquired with abdominal approach for each patient with an Aixplorer and a SL-10 ultrasound probe. Annulus fibrosus was manually segmented in the images and lamellar thickness was measured automatically in the outer annulus through image analysis.

For in-vitro multi-modality image comparison, the first caudal disc of two intact cow tails were imaged by ultrasound in the ventral region. The same discs were then imaged with MR (Philips 1.5 T whole-body imager and a 47 mm microscopy coil). Finally, the discs were excised and frozen in a microtome; slices of 30 µm thickness were cut in the transverse plane, and the lamellar structure was imaged with a Nikon Eclipse E200 microscope, a 4x/0.10 Nikon objective with two polarizer filters and a QImaging Retiga 2000R camera. Microscope images (3x2 mm) were stitched together to form a larger view. The images from the three modalities were then resampled to the same pixel size of the ultrasonography (79 µm), and manually superimposed to qualitatively assess their consistency.

Results: Twenty-nine healthy adolescents were included (13 ± 2 years old, ranging from 10 to 16). Average lamellar thickness was 229.7 ± 91.5 µm, ranging between 156 and 323 µm. Figure 1 shows a mosaic of MRI, ultrasonography (US) and microscopy (µ), showing good qualitative agreement between the three modalities.

Discussion: A previous in vitro study reported a lamellar thickness of 280 ± 90 µm for old subjects (53-76 years) and 140 ± 20 µm for younger subjects (18-29 years) [2], i.e. the same order of magnitude observed in this study. Now that the feasibility of the technique has been established, further work will aim at comparing healthy and scoliotic discs to determine if the mechanical and microstructural alterations of the latter are reflected in the lamellar structure. Such finding could give an insight on the role of the disc in the insurgence and progression of scoliotic deformity and, given the accessibility of ultrasound in clinical routine, it could potentially represent a novel tool for scoliosis assessment and treatment decision.



1. Langlais T. et al (2018). Shear-wave elastography can evaluate annulus fibrosus alteration in adolescent scoliosis. *Europ Radiol*, 28(7), 2830-2837
2. F.Marchand and A. Ahmed (1990). Investigation of the laminate structure of lumbar disc anulus fibrosus. *Spine* 15(5):402-410.

Symptomatic implant/construct failure after metastatic spine tumour surgery

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Introduction: There is paucity of literature on the incidence and risk factors of symptomatic construct failures (SCF) after metastatic spine tumour surgery (MSTS). It is also unknown whether all SCF result in revision surgery. Hence, we aimed to evaluate the incidence and presentation of SCF following MSTS and to identify associated risk factors. We also intended to categorise SCF based on the management of these patients.

Methods: A total of 246 who underwent spinal fixations with or without decompression for Metastatic Spine Disease (MSD) at a single tertiary institute between 2005 and 2015, were evaluated retrospectively. We included patients with spinal metastasis undergoing surgery due to neurological deficits, spinal instability, intractable pain, or any combination of the above. Patients: <18 years of age; those who had prior spinal surgery for non-metastatic cause; those with any evidence of deep surgical site infections; or patients with actual or predicted survival of < 30 days were excluded. Demographic data, perioperative and postoperative clinical and radiological features were included. Radiological criteria for failures were defined. Early SCF included patients presenting within 3 months from index surgery while late SCF included patients presenting after 3 months. Univariate and multivariate model of competing risk regression analysis were done to find out the risk factors for the SCF with death as the competing event. A cumulative frequency curve was generated in order to compare the incidence of symptomatic construct failure with that of death.

Results: A total of 288 patients underwent MSTS between 2005 and 2015. Of these, 42 patients were excluded due to death within a period of <30 days after surgery or their surgeries did not include any instrumentation, leaving 246 patients for final analysis. Of these, a total of 14 failures (5.7%) were recorded and 10 patients underwent revision (4.1%). The median survival of the whole cohort was 13.4 months (range: 1-127 months). The mean age was 58.8 years (range: 21-87 years) and 48.4% were female. The median time to failure was 5 months (range: 1-60 months). Three groups of SCF were: a) Where primary implant was revised-five (35.7%) patients, b) peri-construct progression of disease requiring extension-five (35.7%) patients, c) ones that did not have revision-four (28.5%) patients. Four patients (28.5%) presented as early failures while 10 (71.5%) patients presented late. SCF commonly occurred at implant-bone interface (9/14) and these patients had Spinal Instability Neoplastic Score (SINS) >7. Thirteen (92.8%) patients developing failure had fixation spanning junctional regions. Multivariate competing risk regression showed preoperative ECOG (Eastern Cooperative Oncology Group) score as significant risk factor for implant failure (adjusted sub[HR] 7.0, 95% CI 1.63-30.07, p <0.0009).

Discussion:

The incidence of SCF (5.7%) was low in patients undergoing MSTS. Preoperative ambulatory status had 7 times higher risk of failure than non-ambulators. Lower pre-operative ECOG, pre-operative SINS >7 and fixations spanning junctional regions were associated with SCF. Majority of construct failures occurred at implant-bone interface.

Intraspinal diffusion tensor imaging parameters in quantitative assessment of patients with lumbar spinal canal stenosis

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Introduction: In Japan's rapidly aging population, lumbar spinal canal stenosis (LSS) continues to increase, causing compromised QOL in patients and becoming a major social issue. LSS has traditionally been evaluated by morphology, with little literature available on any form of quantitative assessment.

The objective of this study was to investigate whether intraspinal diffusion tensor imaging parameters such as apparent diffusion coefficient (ADC) and fractional anisotropy (FA) could prove useful in assessing lumbar spinal canal stenosis.

Methods: Participants comprised 5 healthy volunteers (mean age 27.2 years) and 27 patients with LSS (mean age 58.4 years) who were imaged on a 3.0 Tesla MRI. Intraspinal ADC and FA values were measured in a total of 10 intervertebral discs from healthy volunteers and 52 intervertebral discs from LSS patients. Intraspinal canal area, Schizas classification (A normal, B: mild stenosis, C: severe stenosis) and correlations with symptoms were investigated. Clinical symptoms were checked for the presence of lumbar pain, intermittent claudication (IMC), and bladder and bowel dysfunction (BBD).

Results: Compared to healthy individuals, patients with LSS had a significantly lower ADC ($p < 0.05$) and significantly higher FA value ($p < 0.01$). In Schizas classification, stenosis worsens from A to C. ADC values decreased significantly and FA values increased significantly in that order ($p < 0.05$). A positive correlation was found between intraspinal canal area and ADC values ($r = 0.63$, $p < 0.01$) and a negative correlation between intraspinal canal area and FA values ($p = -0.61$, $p < 0.01$). No correlations were noted between lumbar pain and ADC or FA values. In patients with intermittent claudication (IMC) or bladder rectal disorder (BBD), ADC values were significantly lower ($p < 0.05$) and FA values were significantly higher ($p < 0.05$), while no significant correlation was noted between lumbar pain and ADC values.

Discussion: Correlations between DTI parameters (ADC values and FA values), morphological evaluation of the spinal column, and clinical symptoms were determined in LSS patients. Thus far, most assessment of LSS has depended on morphology, and little literature is available on quantitative evaluation methods. Results from our study show that LSS patients have significantly lower ADC values and significantly higher FA values compared to healthy persons. When ADC and FA values were evaluated in association with Schizas class and the effects on intraspinal canal area were compared, ADC values showed a positive correlation, while FA values showed a negative correlation to the area. No correlation to clinical symptoms of lower back pain was apparent, while patients with intermittent claudication or bladder rectal disorder had significantly lower ADC and significantly higher FA values. Associations were identified between intraspinal ADC and FA values and Schizas classification, intraspinal canal area, and clinical symptoms, indicating these parameters may be used in the quantitative assessment of LSS.

1. Schizas C, Theumann N, Burn A, Tansey R, Wardlaw D, Smith FW, Kulik G. Qualitative grading of severity of lumbar spinal stenosis based on the morphology of the dural sac on magnetic resonance images. *Spine (Phila Pa 1976)*. 2010;35(21):1919-24.

How does lumbosacral multi-level spondylolytic spondylolisthesis differ from mono-level spondylolytic spondylolisthesis in spino-pelvic sagittal alignment?

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Introduction: Spondylolytic spondylolisthesis (SS) usually occurs at the most caudal lumbar vertebra, but much less infrequently at consecutive double or even more levels. Spino-pelvic sagittal alignment has been well illustrated in mono-level SS, yet remains unclear in consecutive multi-level SS. The aim of this study is to investigate the spino-pelvic sagittal alignment in multi-level SS patients (multi_SS) in comparison with mono-level SS patients (mono_SS) and healthy controls.

Methods: We retrospectively reviewed the standing lateral X films of 453 adult patients with symptomatic spondylolisthesis (Meyerding grade I or II) secondary to SS who had undergone surgical intervention at our single center between January 2007 and January 2018, and 158 asymptomatic volunteers who were recruited as healthy controls. In the patient group, IS was confirmed via 3-D CT reconstruction. Radiographic parameters were measured, including slip parameters, pelvic parameters and sagittal alignment parameters. Pelvic incidence-lumbar lordosis (PI-LL) mismatch and the ratios of L4-S1 segmental lordosis to LL (L4-S1/LL), L5-S1 segmental lordosis to LL (L5-S1/LL) and pelvic tilt to PI (PT/PI) were also calculated to evaluate the relationship between spinopelvic parameters and a morphologic parameter characteristic of each individual.

Results: In the SS patients, multi-level spondylolysis was detected in 51 (11.6%) patients and mono-level spondylolysis in 402 (88.4%) patients, respectively. Age and BMI were similar among the multi_SS subgroup, and the mono_SS subgroup and the control group. In comparison to the control group, SS patients had larger PI, PT, SS, PT/PI, LL, PI-LL mismatch, L4-S1 lordosis, C7 tilt and SVA ($P<0.05$) and lower L4-S1/LL and L5-S1/LL ratios. In SS patients, there was no significant difference in PI and SS between multi_SS and mono_SS ($P>0.05$), but multi_SS subgroup had higher PT and PT/PI than mono_SS subgroup ($P<0.05$). In contrast to mono_SS subgroup, multi_SS subgroup was observed with lower L5-S1 lordosis and L4-S1/LL and L5-S1/LL ratios, as well as greater PI-LL mismatch and larger C7 tilt. At the same time, multi_SS subgroup had larger L5 incidence, iliac crest height and lower sacral table angle. Accordingly, multi_SS subgroup reported worse ODI (55.7 ± 10.1 vs 44.1 ± 11.4 , $P<0.001$) and VAS back scores (5.4 ± 2.0 vs 4.8 ± 1.6 , $P<0.001$) than mono_SS.

Discussion: A high-PI pattern of spino-pelvic sagittal alignment pattern might be involved in the development of spondylolytic spondylolisthesis, regardless of mono-level or multi-level. Differently from mono_SS, multi_SS is characterized with more anterior trunk tilt, more insufficiency of lumbosacral lordosis and higher pelvic retroversion. These findings emphasize the need for an adapted surgical correction in these patients with distinct sagittal malalignment. Also, lumbo-pelvic parameters including high PI, L5 incidence, and iliac crest height and low sacral table angle might be associated with the occurrence of consecutive multi-level spondylolysis.

Facet Joint Capsular Laxity in Degenerative Lumbar Spondylolisthesis Associated with the Increased Expression of Fractalkine CX3CL1/CX3CR1 Chemokine

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Introduction: Involvement of CX3CL1 and its receptor CX3CR1 in leukocyte recruitment and adhesion in chronic inflammatory disease and their activity have been established in ligament flavum, synovial membrane, and intervertebral discs. The purpose of this study was to investigate the role of fractalkine CX3CL1/CX3CR1 chemokine on facet joint capsular laxity in degenerative lumbar spondylolisthesis (DLS) and the correlation between CX3CL1/CX3CR1 chemokine and degree of slippage in DLS

Methods: The mRNA concentrations of CX3CL1/CX3CR1 chemokine were analyzed in facet joint capsule surgically obtained from grade 1 (n =12), grade 2 (n =12) and more than grade 3 (n =11) DLS by real-time PCR. Grade 1 to 3 was decided upon degree of slippage which is, < 5mm, 5 - 10mm, and > 10mm. The localization of CX3CL1/CX3CR1 chemokine within the facet capsule was determined using immunohistochemical study. Plasma level of soluble fractalkine (sFKN) was measured by enzyme-linked immunosorbent assay (ELISA).

Results: CX3CL1/CX3CR1 Expression by Immunohistochemical Analysis The ratio of CX3CL1/CX3CR1 positive cell in the facet joint capsule obtained in high grade DLS patients was significantly higher than in low grade DLS patients. Both of CX3CL1 and CX3CR1 were expressed on infiltrated mononuclear cells in the facet joint capsule.

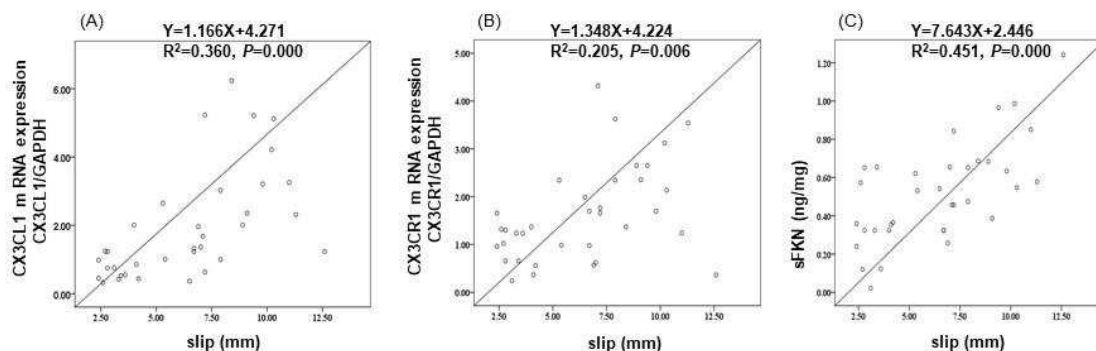
CX3CL1/CX3CR1 mRNA Expression by real time-PCR In the quantitative RT-PCR, CX3CL1/CX3CR1 expression in the high grade DLS patients was higher compared to that in the low grade DLS patients. An amount of CX3CL1/CX3CR1 mRNA expression in the high grade DLS patients was relatively greater than in the low grade DLS patients ($P = 0.000, 0.003$).

Serum levels of soluble CX3CL1 Serum CX3CL1 in high grade DLS patients was prominently elevated compared to that in low grade DLS patients. ($P = 0.002$).

Correlation between serum CX3CL1 level, mRNA Expression of CX3CL1/CX3CR1 and the degree of slippage We assessed the correlation between serum CX3CL1 level, mRNA expression of CX3CL1/CX3CR1 and degree of slippage. Degree of slippage in DLS patients was significantly correlated with both serum CX3CL1 level ($R^2 = 0.451, P = 0.000$) and mRNA expression of CX3CL1/CX3CR1 ($R^2 = 0.360, P = 0.000$) ($R^2 = 0.205, P = 0.006$) (Figure).

Discussion: It was assumed that CX3CL1/CX3CR1 would be very important in migration of inflammatory cells into diseased facet joint capsule. First, overexpressed sFKN promotes the recruitment of CX3CR1-expressed mononuclear cells into the diseased capsule. And then inflammation, vascular injury and angiogenesis occur. CX3CL1, expressed on the cell membrane of endothelium by stimulation of pro-inflammatory cytokines, mediates activation and adhesion of leukocytes to express CX3CR1. The recruitment of mononuclear cells induces the proliferation of fibroblast and inflammatory cell in the facet joint capsule of DLS. Second, the enhanced CX3CL1/CX3CR1 activity induces the degradation of the capsular matrix leading to facet joint capsular laxity. This study identified for the first time that increases in CX3CL1 and CX3CR1-expressing cells are significantly related to facet joint capsular laxity, which may provide new conceptual and therapeutic approaches for treating DLS.

Figure. Correlation of the degree of slippage with mRNA expression of CX3CL1(A), mRNA expression of CX3CR1(B), and serum level of CX3CL1(C).



Association of hypertrophy of the ligamentum flavum with an increase in myofibroblasts in the dorsal layer of the ligament in lumbar spinal canal stenosis

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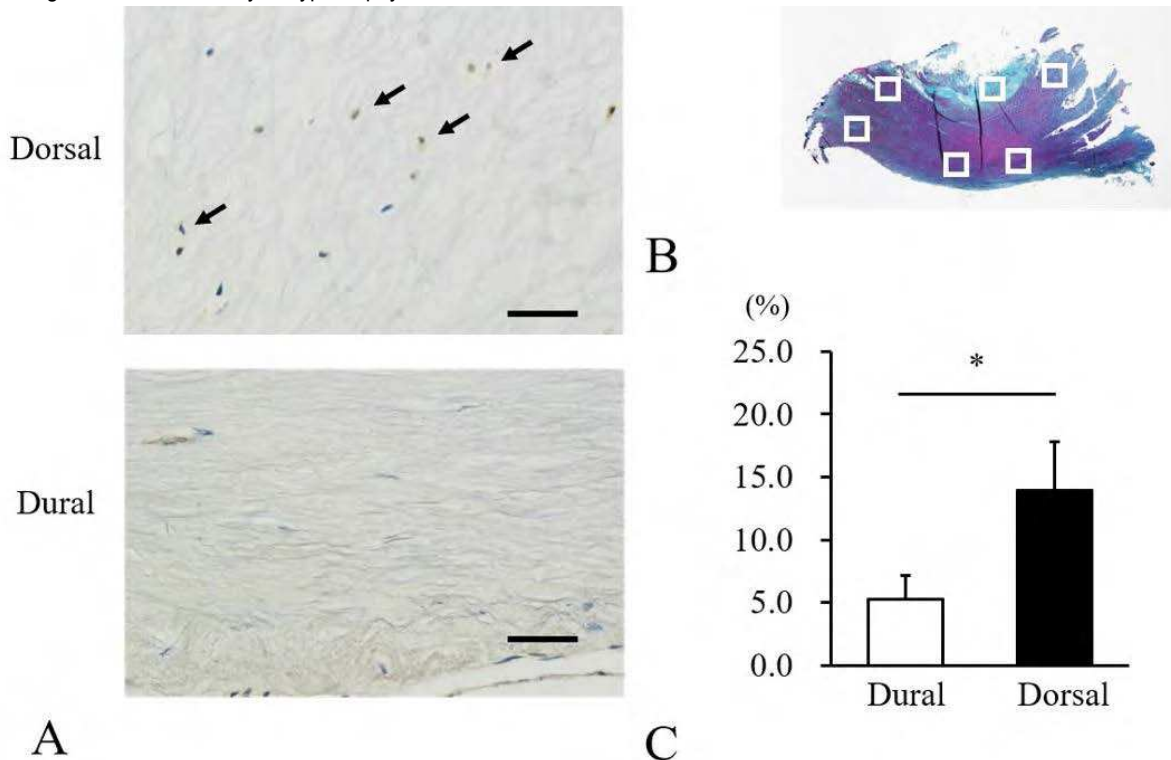
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Introduction: Hypertrophy of the LF is a major contributor to the development of lumbar spinal canal stenosis (LSS). Although previous studies have identified some factors related to hypertrophy of the LF, the etiology remains unclear. However, it is well known that myofibroblasts have a key role in the pathology of fibrosis in other tissues, including the skin, liver, kidney, and lung. We hypothesized that myofibroblasts were also important players in the pathology of fibrosis in the LF. The aim of this study was to determine whether myofibroblasts can be detected in hypertrophic ligaments and whether more myofibroblasts are present on the dorsal layer, and if so, to identify the signal pathway involved.

Methods: Fifty-one LF tissue samples were collected intraoperatively from patients with LSS aged 51–81 years. Twenty-one samples were used for histological assessment of the degree of fibrosis, 12 were used to compare expression levels of collagen mRNA between the dural and dorsal layers, and 7 were used for immunohistochemical analysis of the distribution of myofibroblasts using alpha-smooth muscle actin (α -SMA). We also investigated the correlation between α -SMA and collagen mRNA expression levels in 14 LF cells to determine whether there was a relationship between the number of myofibroblasts and production of collagen. We then divided a further 4 LF samples from 4 patients into 8 samples and investigated the signaling pathways related to expression of myofibroblasts by gene set enrichment analysis.

Results: In the histological study, the tissue in the dorsal layer stained blue with Masson's trichrome. The fibrosis score was significantly higher in the dorsal layer than in the dural layer (3.52 ± 0.15 vs 0.90 ± 0.15 , $p < 0.05$). Gene expression of COL1A1, COL3A1, and COL5A1 was significantly higher in the dorsal layer than in the dural layer (2.32 ± 0.48 vs 1.00 ± 0.34 , $p < 0.05$; 1.84 ± 0.37 vs 1.00 ± 0.33 , $p < 0.05$; and 1.90 ± 0.22 vs 1.00 ± 0.17 , $p < 0.01$, respectively). Immunohistochemistry revealed a significantly greater number of α -SMA-stained cells in the dorsal layer than in the dural layer ($14.4\% \pm 2.7\%$ vs $5.9\% \pm 1.4\%$, $p < 0.05$) (Figure). There was a strong correlation of α -SMA mRNA expression with COL1A-1 mRNA expression in LF cells ($r = 0.665$, $p = 0.009$). Gene set enrichment analysis showed that the set of fibrosis-related gene signals, including those for epithelial-mesenchymal transition, hypoxia, and inflammation, were upregulated to a greater extent in the dorsal layer than in the dural layer.

Conclusion. This study is the first to demonstrate higher myofibroblast expression levels in the dorsal layer of the LF than in the dural layer. We confirmed that hypertrophy of the LF in LSS is associated with increased expression of myofibroblasts in the dorsal layer. Inflammation, hypoxia, and epithelial-mesenchymal transition could be causes of expression of myofibroblasts leading to fibrosis and finally to hypertrophy of the LF.



Automation of MRI gradings to aid longitudinal studies of lumbar spinal stenosis in the Wakayama Spine Study

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Introduction: MRI scanning has revolutionized the clinical diagnosis of lumbar spinal stenosis (LSS). Up to now the interpretation of MRI has been qualitative. Quantitative grading of the images is time-consuming and difficult, and may be subject to bias. The labor involved in interpreting images hinders the analysis of large epidemiological studies of spinal stenosis. The lack of a universally accepted grading system complicates comparisons between studies. In order to analyze a large longitudinal dataset of spinal images, collected by the Wakayama Study Group, we aim to develop a rapid automated image analysis system for spinal stenosis grading. Here we show that a system (SpineNet), previously demonstrated to provide objective, unbiased and reproducible readings which are comparable to those of an expert radiologist¹, can be retrained to the different grading system used by the Wakayama study group. We compared gradings obtained by SpineNet with the gradings obtained manually.

Methods: 1011 participants in the Wakayama prefecture of Japan were recruited to the Wakayama Spine Study (men 335, women 676 mean age 66.3 years). All subjects underwent lumbar spine MRI performed to a standardized protocol in a mobile unit (Excelart 1.5 T; Toshiba; Tokyo, Japan). Lumbar spinal stenosis was assessed centrally from the bony margins of MRI axial sequences by one experienced orthopaedic surgeon (YI). The severity of LSS was qualitatively graded on the axial images as: none; mild - a maximum of 1/3 narrowing; moderate—narrowing between 1/3 to 2/3, and; severe as more than 2/3 narrowing. Using a classifier set of 870 scans assessed by YI, SpineNet was trained to read 5 axial T2 images from L1/2-L5/S1 and classifying LSS in 4 grades.

Results: Complete axial views were available for 4855 lumbar intervertebral levels from 971 participants. The machine used 4365 axial views to learn (training set) and graded the remaining 490 axial views (testing set). The agreement rate (YI/SpineNet) was 65.7% (322/490) and the reliability (Lin's correlation coefficient) was 0.73. In 2.2% of scans (11/490) there was a difference in classification of 2 and in only 0.2% (1/490) was there a difference of 3. When classified into 2 groups as 'severe' vs 'no/mild/moderate'. The agreement rate was 94.1% (461/490) with a kappa of 0.75.

Conclusion: This study showed that SpineNet can rapidly "learn" to grade central LSS with excellent reliability after a period of "training" on the readings of the surgeon. These data suggest that quantitative readings using SpineNet are quick and reliable when compared with reading by a trained, experienced surgeon. Thus SpineNet can be used reliably for rapid grading of LSS in the MRIs of the large longitudinal cohorts such as those collected by the Wakayama Spine Study.

The influence of developmental spinal stenosis on reoperation risk at the adjacent segment after decompression surgery for lumbar spinal stenosis

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Introduction: Developmental spinal stenosis (DSS) is manifested as pre-existing narrowing of the bony spinal canal. With a narrowed spinal canal, neural tissues may be more prone to compression and development of symptoms. Multilevel involvement is commonly observed and there is a possible risk of reoperation due to the predilection for symptomatic stenosis. Reoperation at the adjacent level may be attributed to adjacent level degeneration but the influence of DSS on reoperation rate is unknown. The aim of study is to determine the risk of reoperation at the adjacent level after decompression surgery for lumbar spinal stenosis with particular emphasis on the influence of DSS.

Methods: This was a retrospective study of consecutive patients with decompression-only surgery for lumbar spinal stenosis and minimum 5-years follow-up. Adult deformities, previous spinal surgery, and spondylolisthesis were excluded. Presenting symptoms, levels operated on initially and at reoperation were studied. MRI measurements included the anteroposterior bony spinal canal diameter, degree of disc degeneration (Pfirrmann grading, Schenidermann classification, anterior or posterior disc bulging and herniation, disc height) and ligamentum flavum thickness. DSS was defined by respective bony spinal canal diameter measurements. Risk factors for reoperation at the adjacent level were determined and included into a multivariate stepwise logistic regression for prediction modeling. Odds ratios (ORs) with 95% confidence intervals were calculated.

Results: A total of 235 subjects were analyzed and 21.7% required reoperation at adjacent segments. The mean duration of follow-up was 10.1 (\pm SD of 4.8) years since the index surgery. No associations were found between reoperation and gender, nor with disc height and disc degeneration at adjacent segment. Reoperation at the adjacent segment was associated with DSS ($p=0.026$), the number of operated levels ($p=0.008$) and age at surgery ($p=0.013$). Multivariate regression model ($p<0.001$) controlled for other confounders showed that DSS was a significant predictor of reoperation at an adjacent segment, with an adjusted OR of 3.93 (95% CI: 1.10, 14.01, $p=0.035$).

Discussion: This is a novel outlook on the effects of DSS on the risk of reoperation at the adjacent segment after lumbar spinal stenosis decompression surgery. Adjacent nonoperated DSS levels are 3.9 times more likely of undergoing future surgery. This is a poor prognostic marker that can be identified during the index decompression surgery. Nonoperated DSS levels are high risk for surgery after lumbar spinal stenosis decompression surgery. Adjacent levels should be screened for DSS prior to the index operation for risk assessment. There are significant implications on the approach to designing patient specific management strategies.

Hypoalbuminemia and Elevated CRP as Predictors for Superficial, Deep, and Urinary Tract Infections

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Introduction: The utility of pre-operative laboratory measurements has previously been studied in orthopaedic trauma patients¹ but has not been studied extensively for elective lumbar surgeries. Previous studies have showed low pre-operative levels of albumin can predict post-operative complications after lumbar surgery²⁻⁵, since low levels of albumin are seen to be a marker of malnutrition⁶. In addition, C-reactive protein (CRP) has been identified as a marker for survival in patients with chordoma⁷ since CRP is a recognized marker for inflammation⁸. This retrospective database study aimed to look at low, normal, and high ranges for albumin and low and normal ranges for CRP as risk factors for post-operative infections and revision surgeries in three types of lumbar surgery.

Methods: Within the Humana portion of the PearlDiver Record Database, patients who underwent anterior lumbar interbody fusion (ALIF), posterior lumbar interbody fusion (PLIF), and lumbar discectomy from January 1, 2007 to September 30, 2015, were identified. Patients were stratified based on albumin and CRP lab measurements. The normal albumin range was defined as 3.5-5.4 g/dL, with the low albumin group being < 3.5 g/dL^{9,10}. The high albumin range was removed from the study due to insufficient numbers. The normal CRP range was defined as < 1.0 mg/dL, and the high CRP group was ≥ 1.0 mg/dL¹¹.

Data was collected from three months prior to the operation to one year post-operation. Pre-operative lab values were collected within three months prior to surgery. The post-operative complications included superficial, deep, and urinary tract infections, which were followed for three months. Revision surgeries were followed up to a year. The no complications group had no infections within three months, and no revisions within one year. Chi-squared analyses were used to calculate *P*-values for all odds ratios, and statistically significant *P*-values were defined as *P* < 0.05.

Results: A total of 81,351 patients were included in this study. Complication rates are listed in Table 1. For all included procedures, a pre-operative albumin level above normal range was a statistically significant independent risk factor for deep infection and UTI when compared to patients with pre-operative normal range albumin (*p* < 0.001). In patients undergoing PLIF, having an above normal range CRP level was a statistically significant independent risk factor for UTI and a trending but statistically insignificant risk factor for deep infection (*p*=0.004).

Discussion: For ALIF, PLIF, and lumbar discectomy, low pre-operative albumin levels were statistically significant risk factors for deep infection and UTI within three months after surgery, which is consistent with what is currently found in the literature. With exception to UTI in patients undergoing PLIF, elevated CRP levels were a less reliable metric for predicting post-operative deep infection and UTI after all three types of surgery.

Table 1. Complication rates for all procedures and complications.

Procedure	Complication	Rates			
		Normal Albumin	Low Albumin	Normal CRP	High CRP
ALIF	No complications	18.33%	21.30%	18.58%	17.90%
	Superficial Infection	X	X	X	X
	Deep Infection	1.77%	3.42%	X	5.25%
	UTI	14.21%	28.16%	15.81%	18.85%
PLIF	No complications	6.41%	48.76%	39.65%	49.14%
	Superficial Infection	0.64%	X	X	X
	Deep Infection	4.93%	15.28%	7.31%	11.00%
	UTI	20.9%	33.48%	19.01%	29.55%
Discectomy	No complications	42.19%	29.47%	36.27%	40.37%
	Superficial Infection	0.50%	X	X	X
	Deep Infection	4.61%	15.79%	X	14.29%
	UTI	19.86%	32.63%	23.46%	22.36%

ALIF: anterior lumbar interbody fusion, PLIF: posterior lumbar interbody fusion, X: If there are fewer than 11 patients in any category, PearlDiver does not release the exact number of patients due to privacy limitations.

1. Lakomkin N, Sathiyakumar V, Dodd AC, et al. Pre-operative labs: Wasted dollars or predictors of post-operative cardiac and septic events in orthopaedic trauma patients? *Injury*. 2016;47(6):1217-1221. doi:10.1016/j.injury.2016.03.004

2. Adogwa O, Martin JR, Huang K, et al. Preoperative serum albumin level as a predictor of postoperative complication after spine fusion. *Spine*. 2014;39(18):1513-1519. doi:10.1097/BRS.0000000000000450
3. Bohl DD, Shen MR, Mayo BC, et al. Malnutrition Predicts Infectious and Wound Complications Following Posterior Lumbar Spinal Fusion. *Spine*. 2016;41(21):1693-1699. doi:10.1097/BRS.0000000000001591
4. Zhang Z, Guo Z, Qi Q, et al. [Analysis of risk factors for deep surgical site infection after posterior thoracic and lumbar surgery]. *Zhonghua Wai Ke Za Zhi*. 2015;53(5):345-348.
5. Phan K, Kim JS, Xu J, et al. Nutritional Insufficiency as a Predictor for Adverse Outcomes in Adult Spinal Deformity Surgery. *Global Spine J*. 2018;8(2):164-171. doi:10.1177/2192568217708777
6. Fanali G, di Masi A, Trezza V, Marino M, Fasano M, Ascenzi P. Human serum albumin: From bench to bedside. *Molecular Aspects of Medicine*. 2012;33(3):209-290. doi:10.1016/j.mam.2011.12.002
7. Hobusch GM, Bodner F, Walzer S, et al. C-reactive protein as a prognostic factor in patients with chordoma of lumbar spine and sacrum—a single center pilot study. *World J Surg Oncol*. 2016;14. doi:10.1186/s12957-016-0875-8
8. Neumaier M, Braun KF, Sandmann G, Siebenlist S. C-Reactive Protein in Orthopaedic Surgery. *Acta Chir Orthop Traumatol Cech*. 2015;82(5):327-331.
9. Lenke LG, Bridwell KH, Blanke K, Baldus C. Prospective analysis of nutritional status normalization after spinal reconstructive surgery. *Spine*. 1995;20(12):1359-1367.
10. Boosalis MG, Ott L, Levine AS, et al. Relationship of visceral proteins to nutritional status in chronic and acute stress. *Crit Care Med*. 1989;17(8):741-747.
11. Funovics PT, Edelhauser G, Funovics MA, et al. Pre-operative serum C-reactive protein as independent prognostic factor for survival but not infection in patients with high-grade osteosarcoma. *Int Orthop*. 2011;35(10):1529-1536. doi:10.1007/s00264-011-1208-8

Clinical Features and Treatments of Pyogenic Spondylodiscitis with Severe Paralysis

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Introduction: Pyogenic spondylodiscitis (PSD) is the most common spinal infectious disease, which affects adjacent intervertebral bodies with subsequent involvement of the intervertebral disc. It may progress to complications including epidural abscess, collapse of the infected vertebra, and severe paralysis, but the exact pathophysiology is still unknown. This study was designed to identify the optimal treatment for PSD with severe paralysis by examining patients' conditions and outcomes.

Methods: We retrospectively analyzed 75 consecutive cases of PSD treatments from 2007 to 2017. Patients were divided into two groups based on the Frankel classification, severe paralysis (unable to walk) and mild/no paralysis (able to walk), and were followed until normalization of C-reactive protein (CRP) levels. The patients' medical records were reviewed for the number of systemic inflammatory reaction syndrome (SIRS) criteria met, the score of Eastern Cooperative Oncology Group Performance Status (PS), type of onset (Kulowski's classification), type of causative microorganism, the serum levels of CRP/WBC/albumin, presence of the spinal epidural abscess, types of treatments, and prognosis.

Results: Of the 75 patients reviewed, 46 were male and the age range was from 45 to 95 (average 70). Majority (63%) of the patients had lumbar lesion, and 10% had multi-level localization of PSD. The causative microorganism was identified in 68% of the cases with staphylococcus aureus being the most common (38%). Thirty-six patients had conservative treatments, 14 patients underwent posterior decompression surgery, and 25 patients underwent spinal stabilization surgery. Compared to the mild/no paralysis group (54 patients), the severe paralysis group (21 patients) had a significantly higher number of SIRS criteria met, PS grade, and WBC counts at the first visit to our hospital. Moreover, the percentage of patients who had bacteremia, acute onset, cervical lesion, or transfer to different hospitals were significantly higher among the severe paralysis group. There were 29 cases of epidural abscess complications, but there was no significant difference between the two groups. Eighteen of the 21 patients in the severe paralysis group underwent a surgical procedure, of which 12 had improvement in their paralysis. Patients without improvement in their paralysis had significantly lower albumin levels compared to those with improvement. Only the spinal stabilization surgery showed significant relationship with recovery from severe paralysis.

Discussion: Indications for surgical intervention among patients with PSD are compression of neurological structures, mechanical instability, and failure of conservative treatments. However, it is still controversial whether decompression of the spinal cord or surgical stabilization with instruments is the optimal strategy for treating PSD with paralysis.

The present study has shown that unlike decompression of the spinal canal, spinal stabilization surgery is associated with better recovery of neural function among patients with PSD and severe paralysis. PSD with acute onset, bacteremia, low level of serum albumin, and cervical PSD is associated with a greater risk of severe neurological deficit. Therefore, if conservative treatments fail, spinal stabilization surgery may be suggested. Prior to the surgery, restoring a patient's serum albumin level may be important as lower level was associated with less improvement in paralysis.

Avoiding infection and screw loosening due to biofilm at bone-screw interface: Periop measures

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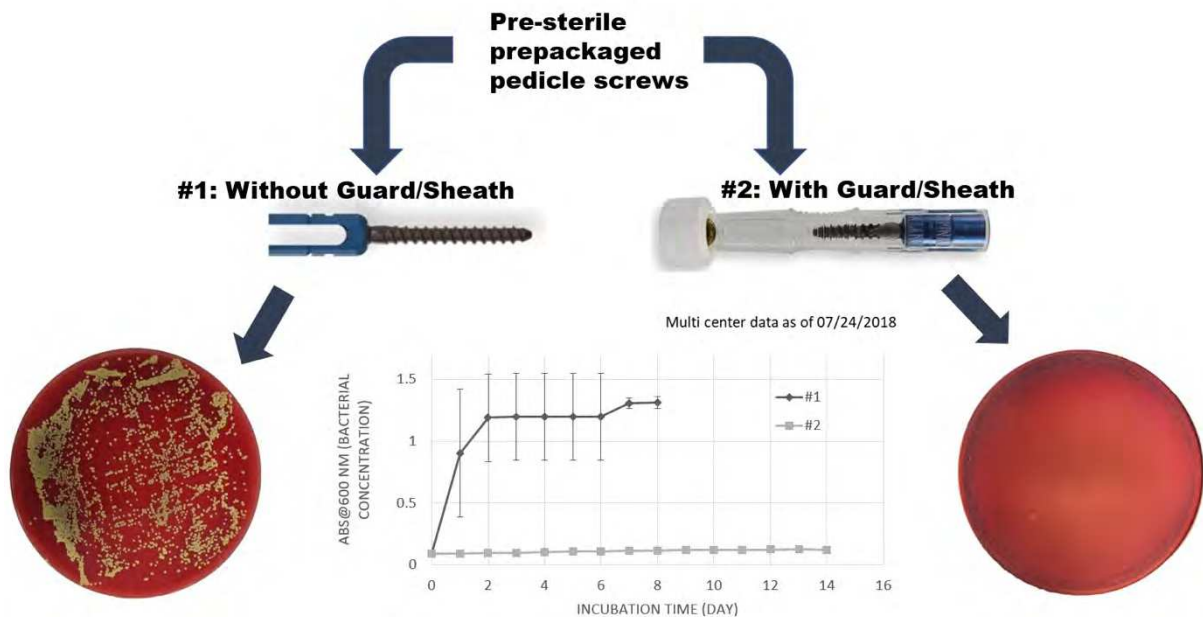
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Introduction: Post-operative infections occur at the higher end of 2-13%, as cited in the literature, and are underestimated due to various reasons in such publications. Furthermore, the widespread and indiscriminate use of local vancomycin powder has raised concerns of near-term antibiotic resistance. Recent evidences also show that local vancomycin powder was associated with a higher prevalence of gram negative and polymicrobial organisms in patients, who ultimately developed post-operative infection. Despite concerns associated with vancomycin application immediately before closure, it is theoretically impossible to irrigate the screw-bone interface post-implantation. Consequently, any contamination of pedicle screw before implantation is permanent, and has the potential to cause deep-bone infection, or hardware loosening due to encapsulation of biofilm between the bone and the screw. Therefore, continued vigilance and effective preventive measures should be undertaken if available. The objective of the current study is to provide well-quantified and effective results for one such measure.

Methods: Two groups of sterile prepackaged pedicle screws, one with an intraoperative guard (group 1: an upcoming practice) and the other without such a guard (group 2: current practice), each consisting of 26 samples distributed over 23 independent timepoints (spinal fusion surgeries) and 4 independent hospitals, were loaded onto the insertion device by the scrub tech and left on the sterile table. 20 minutes later, the lead surgeon who had just finished preparing the surgical site, touches the pedicle screw. Then instead of implantation it was transferred to a sterile container using fresh clean gloves for bacterial analysis.

Results: Spectrophotometry results detected saturated levels of turbidity within 24-48 hours in samples from group 2. The samples from group 1 showed no turbidity for the entire duration of the incubation period (14 days). Every plate, from each sample of group 2 had visible CFU growth within 24 hours past streaking. The total CFUs ranged from 105-107 per sample. The colonies continued to grow until confluency was reached. No CFU growth occurred in plates extracted from group 1 for the duration of the incubation period (7 days). Please note that the incubation period for spectrophotometry was 14 days (or until saturation) and for streaking it was 7 days (or until confluency).

Discussion: The standard unguarded pedicle screws presented bioburden in the range of 105-107 CFUs per screw, whereas the guarded pedicle screws showed no bioburden. The results showed high size of effect despite variability (multiple surgeons, staff, hospitals and practices), and was binary in nature. The study proves that it is necessary to shield sterile implants intraoperative, otherwise they become unsterile. The result of this study provides multicenter clinical evidence that standard pedicle screw handling techniques leads to contamination of pedicle screws and thereby the screw-bone interface. This can be avoided by using a sterile intraoperative guard, which can come preinstalled inside the individually packaged sterile screws, thereby shielding the pedicle screws intraoperatively until implantation. This adaptation of an implant guard is achieved without affecting the standard surgical flow or increasing the responsibilities upon the surgical staff.



Immuno-stimulatory capacity of decorin in the intervertebral disc and the mechanical consequence of resultant inflammation

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Introduction: Herniation and degeneration result in mechanical degradation of the intervertebral disc (IVD). Given that inflammation is associated with such disorders, it is possible that inflammation contributes to this mechanical degradation. When tissues are damaged, structural proteins within the IVD become compromised and it is hypothesized that annulus fibrosus (AF) cells sense these resident proteins and trigger inflammation, thereby contributing to a decline in mechanical integrity. One possible family of inflammation-triggering resident proteins are small leucine-rich proteoglycans (SLRPs). The purpose of this study was two-fold: to determine if decorin, a resident IVD SLRP, is immuno-stimulatory to IVD cells and to characterize the mechanical consequence of decorin-induced inflammation at the whole IVD level.

Methods: Cellular response to decorin: AF cells were isolated from rat tail IVDs and cultured for 24 hours under one of the following conditions: 1) control (standard culture media); 2) decorin (standard media plus 5 µg/mL bovine decorin); 3) decorin plus TAK-242 (decorin condition plus TAK-242; a TLR4 inhibitor; decorin binds to TLR4 on the cell surface). Dimethyl sulfoxide (DMSO) was used as the carrier for TAK-242, therefore DMSO only and TAK-242 only controls were also examined. Resultant expression of cytokines and chemokines including TNF-α, MIP-2, RANTES, IL-6, and MCP-1 were quantified over 24 hours (in the case of TAK-242 only MIP-2 was quantified given its rapid and sustained secretion following exposure to decorin) and statistically compared between each condition. Whole IVD response to decorin: 50 rat tail functional spine units (FSU; vertebra-IVD-vertebra) were dissected. A 33 gauge needle was used to inject a total volume of 20 µL stimulant into the nucleus of each IVD. The stimulants included: decorin (two concentration levels: 0.5 µg/mL or 5 µg/mL) and decorin plus TAK-242 (5 µg/mL decorin + 0.2µM TAK-242). PBS only, TAK-242 only, DMSO only were included as controls. All FSUs were then cultured for six days while unloaded. Following culture, each FSU was mechanically tested in cyclic compression-tension to obtain the neutral zone size and stiffness, and tensile and compressive stiffness. Mechanical properties were statistically compared between each condition.

Results: Cellular response to decorin: AF cells exposed to decorin showed significant increases in pro-inflammatory cytokine and chemokine production. The presence of TAK-242 with decorin fully blunted production of MIP-2 (Figure 1). Whole IVD response to decorin: Whole IVDs injected with decorin showed a dose-dependent decrease in neutral zone and tensile stiffness and an increase in neutral zone size. When both TAK-242 and decorin were injected into the IVD, mechanical stiffness was preserved and not different from PBS injected sham controls (Figure 2)

Discussion: This study revealed a novel mechanism of inflammation initiation in the IVD and the mechanical consequence of such inflammation. Specifically, IVDs injected with the resident SLRP decorin demonstrated a dose-dependent increase in compliance, which was significantly blunted by treatment of TAK-242, a TLR4 inhibitor. Future research should consider the dose-dependent effect of decorin and whether TAK-242 is effective in a therapeutic treatment scenario, reducing inflammation after the onset of damage.

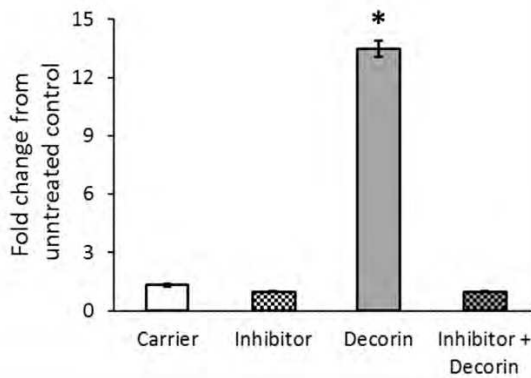


Figure 1. Mean ± SEM concentration of MIP-2 following 6 hours culture with 1) DMSO only (Carrier); 2) TAK-242 only (Inhibitor); 3) 5 µg/mL Decorin; 4) TAK-242 + 5 µg/mL decorin (Inhibitor + Decorin).

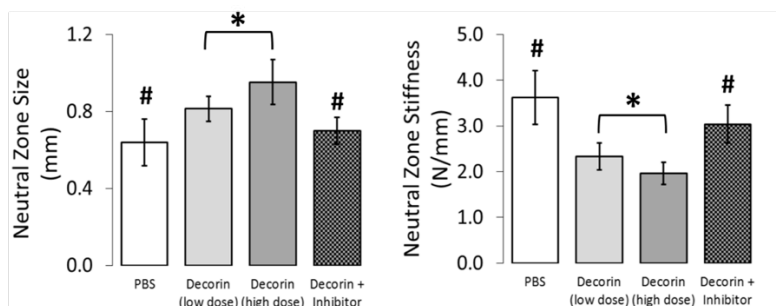


Figure 2. Mean ± SEM for each outcome measure for IVD mechanical testing. A significant dose-dependent response of decorin was observed in neutral zone stiffness, neutral zone size, and maximum tensile stiffness (not shown). IVDs treated with decorin in the presence of TAK-242 (Decorin + Inhibitor) did not statistically differ from sham controls (PBS injected) for any mechanical variable.

810nm low level laser therapy regulating polarization of M1/M2 macrophages and its mechanism

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Introduction: Macrophages play a key role in the secondary injury stage of spinal cord injury. M1 macrophages dominate the injury zone and secrete a large number of cytotoxic factors, which hinders the repair of spinal cord injury. Recent studies have found that M2 macrophages can secrete anti-inflammatory factors and promote axonal regeneration, which can promote the recovery of spinal cord injury. Therefore, regulation of the polarization phenotype and secretion state of macrophages after spinal cord injury is of great significance for injury repair. Low level laser therapy (LLLT), as a non-invasive treatment that has been widely used, has been shown to have a positive effect on functional rehabilitation in rats with spinal cord injury. However, whether LLLT can directly regulate the polarization and secretion status of M1 macrophages is unclear. This study was to investigate the regulation of LLLT on the polarization and secretion of M1 macrophages and its related mechanisms.

Methods: Mouse primary bone marrow-derived macrophages were obtained and cultured in vitro, and M1-type macrophages were obtained by inducing bone marrow-derived macrophages using LPS+INF- γ . M1 macrophages were randomly divided into a weak laser irradiation group (M1+LLLT) group and a control group (M1 group). The in vitro standardized LLLT-macrophage irradiation model was constructed, and the LLLT parameters (wavelength: 810 nm; power density: 2 mW/cm²; spot area: 4.5 cm²; irradiation time: 440 s; energy: 4 J) were selected for LLLT. The M1+LLLT group was irradiated. RT-qPCR and ELISA were used to detect the expression of IL-1RA and IL-10 in M1 macrophages. The expression of iNOS, Arg-1, CD206, AKT, p-AKT, CREB and p-CREB in the two groups was analyzed using Western Blot. Dorsal root ganglion neurons (DRG) were cultured in two groups of macrophage conditioned medium to measure the length of axon growth and to evaluate the effect of LLLT on neuronal axon growth.

Results: LLLT can down-regulate the expression of M1 macrophage marker iNOS and up-regulate the expression of M2 macrophage markers Arg-1 and CD206. After LLLT irradiation, the expression of IL-1RA and IL-10 was increased in M1 macrophages. LLLT can significantly promote the expression of polarized pathway proteins AKT, P-AKT and P-CREB. Cultured dorsal root ganglia (DRG) using macrophage conditioned medium found that conditioned medium after LLLT irradiation significantly promoted DRG axon growth.

Discussion: LLLT can regulate the macrophage polarization phenotype through AKT/CREB pathway, induce M1 macrophage to transform into M2 type, increase the expression of anti-inflammatory factors, and promote the growth of neuron axons. LLLT has a good application prospect in the treatment of nerve repair such as clinical spinal cord injury.

Mechanical characterization of lumbar annulus fibrosus in adolescent idiopathic scoliosis before and after surgical intervention

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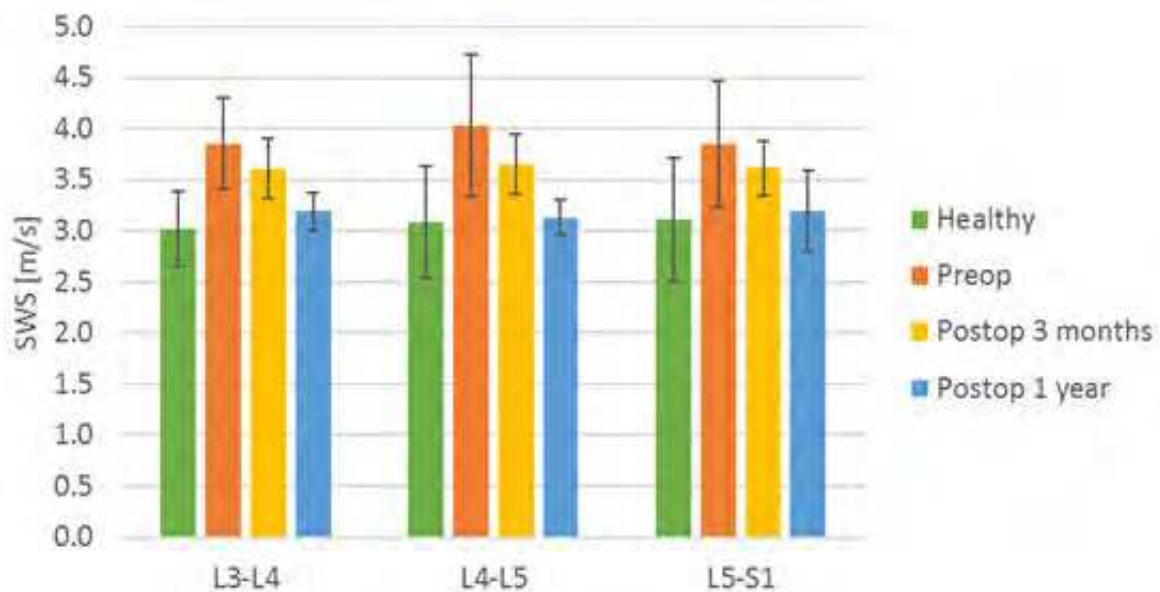
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Introduction: Scoliotic spines are usually stiffer than healthy ones; this was often observed through clinical examinations and radiological bending tests. Recently, shearwave speed (SWS) measurements in adolescent idiopathic scoliotic (AIS) patients showed that the origin of this increased stiffness could be the intervertebral disc annulus fibrosus [1], especially in lumbar discs: a higher SWS corresponds to a stiffer tissue. Further investigation on this finding could elucidate the origin of postoperative complications, such as adjacent disc disease. The aim of this study was to determine if surgical intervention to correct severe AIS would affect the mechanical properties of the annulus fibrosus.

Methods: Fifty-nine healthy subjects (13 ± 2 years old) and 23 AIS patients (15 ± 2 years old, $57^\circ \pm 14^\circ$ Cobb angle) were included after ethical committee approval. Two patients had lumbar curves (apex in L2), while the rest were thoracic (apex above T11). SWS was measured with an Aixplorer and a SL10-2 linear probe in the three discs from L3-L4 to L5-S1, with a previously described protocol [1]: the subject was supine, and measurement were performed with abdominal anterior approach. Disc levels were determined relative to the aortic bifurcation, which usually corresponds to the L4 vertebra. A total of 30 images were acquired per disc, and the SWS in the annulus fibrosus was averaged to obtain a single value per disc. For AIS patients, measurements were performed before surgery and three months and one year after it. Kruskal-Wallis tests were performed to compare healthy, AIS preop and postop SWS, as well as disc levels. Results are reported as mean \pm standard deviation.

Results: SWS differences between disc levels were not significant (Figure 1, $p > 0.05$), so they were pooled for the following results. Average SWS in healthy subjects, all disc levels pooled, was 3.1 ± 0.6 m/s, which was significantly lower than AIS preop AIS (3.9 ± 0.6 m/s, $p < 0.001$, Figure 1). Three months postop SWS was still higher than healthy (3.6 ± 0.3 m/s, $p < 0.001$), but it approached normal values at one year (3.2 ± 0.3 m/s, $p > 0.05$ relative to healthy).

Discussion: In this study, mechanical properties of scoliotic lumbar intervertebral discs were evaluated, for the first time, before and after surgical intervention using direct noninvasive *in vivo* measurements. The results confirm the common assumption that scoliotic spines are stiffer than healthy ones, consistently with the previous literature [1]. Results also show that lumbar discs tend to normalize one year after surgery. Moreover, this process of disc recovery seems to be underway as early as three months after surgery. Data collection on a larger cohort is under way, aiming at determining if curve topology influences AIS disc alterations, or disc normalization after surgery. A longer longitudinal follow-up will also help clarify the impact of disc properties on the clinical outcome.



1. [1] Langlais T. et al (2018). Shear-wave elastography can evaluate annulus fibrosus alteration in adolescent scoliosis. *Europ Radiol*, 28(7), 2830-2837.

Cortical trajectory pedicle screws versus traditional trajectory: differences in fatigue loading conditions

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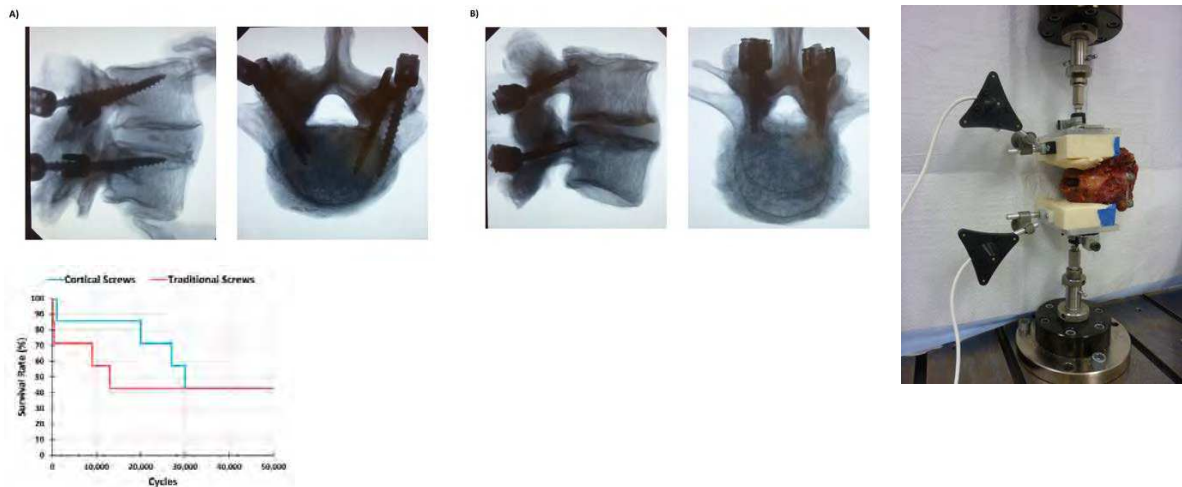
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Introduction: Cortical trajectory (CT) pedicle screws are an alternative instrumentation method to traditional trajectory (TT) pedicle screws. Santoni and colleagues provided the first description of biomechanical properties of CT pedicle screws identifying a 30% increase in uniaxial pullout strength relative to TT pedicle screws.¹ Subsequent biomechanical studies of CT screws demonstrated superior insertional torque²⁻³, increased pullout strength⁴⁻⁶, and decreased bending after fatigue⁷. Clinical studies, primarily retrospective in nature, have touted less estimated blood loss, lower rates of screw loosening, and overall safety of the technique^{2, 8-10}. This project was designed to compare the biomechanical properties of CT versus TT lumbar pedicle screws under compressive and flexion fatigue loading conditions as these rather than instantaneous measures likely predict clinical applicability.

Methods: L2-3 and L4-5 motion segments from seven lumbar spines were randomly assigned to TT screw or CT screw fixation. BMD was measured with DEXA scans. Pedicle screws were inserted under fluoroscopic guidance by the senior author (Figs. A and B). Motion segments were then subjected to a 750 N compression load and corresponding 7.5 Nm flexion moment without rod construct to represent the intact state. The motion segments were subsequently surgically destabilized and rods were affixed. They were then exposed to 200 - 750 N loads with 2.0 – 7.5 Nm flexion moments at 2 Hz for 50,000 cycles. Motion was monitored using infrared optical motion tracking and load cell data (Fig. C).

Results: Stiffness and range of motion were found to correlate significantly with BMD in the destabilized instrumented state ($p=0.014$ and $p=0.005$, respectively). CT and TT pedicle screws did not differ in stiffness or flexion in the intact or destabilized states. When normalizing for BMD, the cortical trajectory screws demonstrated reduced flexion range of motion than traditional screws in the destabilized instrumented state ($p=0.026$). The destabilized and instrumented states of both screw trajectories were significantly less stiff than the intact states ($p=0.016$ and $p=0.016$). Three of seven samples in each group survived 50,000 cycles without failure. TT screw failures tended to fail earlier than CT screws though this was not statistically significant. All traditional group failures happened by 13,000 cycles whereas only one cortical trajectory model failed within that timeframe (Fig. D).

Discussion: Cortical trajectory and traditional trajectory lumbar pedicle screws demonstrate similar biomechanics in a randomized single motion segment model. CT screws provided more resistance to flexion in the destabilized instrumented state when normalized to bone mineral density. CT and TT screws demonstrated similar overall survival properties but with failures occurring earlier in the traditional trajectory group. One possible explanation for the earlier failure of TT screws is the presence of lower quality cancellous bone at the bone-thread interface compared with the cortical bone engaged in CT screws. Both cortical and traditional pedicle screw insertion techniques may be considered for pedicle fixation.



1. Santoni BG, Hynes RA, McGilvray KC, Rodriguez-Canessa G, Lyons AS, Henson MAW, Womack WJ, Puttlitz CM. Cortical bone trajectory for lumbar pedicle screw. *Spine*. 2009 366-373.
2. Phan K, Hogan J, Maharaj M, Mobbs RJ. Cortical bone trajectory for lumbar pedicle screw placement: a review of published reports. *Orthop Surg*. 2015 Aug;7(3):213-21.
3. Matsukawa K, Yato Y, Kato T, Imabayashi H, Asazuma T, Nemoto K. In vivo analysis of insertional torque during pedicle screwing using cortical bone trajectory technique. *Spine*, 2014, 39: E240–E245.
4. Sakura H, Miwa T, Yamashita T, Kuroda Y, Ohwada T. Posterior lumbar interbody fusion with cortical bone trajectory screw fixation versus posterior lumbar interbody fusion using traditional pedicle screw fixation for degenerative lumbar spondylolisthesis: a comparative study. *J Neurosurg Spine*. 2016; 25(5):591-59.
5. Calvert GC, Lawrence BD, Abtahi AM, Bachus KN, Brodke DS. Cortical screws used to rescue failed lumbar pedicle screw construct: a biomechanical analysis. *J Neurosurg Spine*, 2015, 22: 166–172.
6. Matsukawa K, Yato Y, Kato T, Imabayashi H, Asazuma T, Nemoto K. Cortical bone trajectory for lumbosacral fixation: penetrating S-1 endplate screw technique: technical note. *J Neurosurg Spine*, 2014, 21: 203–209.
7. Radcliff K, Klocke N, Harris J, et al. Simulating the long-term biomechanical performance of cortical screws: can a more MIS screw option provide equivalent stability as traditional pedicle screws? *Proceeding of SMISS Global Forum*, 2014.
8. Gonchar I, Kotani Y, Matsumoto Y. Cortical bone trajectory versus percutaneous pedicle screw in minimally invasive posterior lumbar fusion. *Spine J*, 2014, 14: S114–S115
9. Malcolm JG, Moore MK, Choksh FH, Ahmad FU, Refai D. Comparing cortical trajectory transforaminal lumbar interbody fusions against pedicle trajectory transforaminal lumbar interbody fusions and posterolateral fusions: a retrospective cohort study of 90-day outcomes. *Neurosurgery*, 2018; 83(6): 1234-40.
10. Steel TR, Rust TM, Fairhall JM, Mobbs RJ. Monosegmental pedicle screw fixation for thoraco-lumbar burst fracture. *J Bone Joint Surg Br*, 2004, 86 (Suppl. IV): 458.

Dysregulated bone marrow stromal cells in Modic type 1 changes

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Introduction: Modic type 1 changes (MC1) are fibrotic-inflammatory vertebral bone marrow changes adjacent to degenerating discs and are specific for axial low back pain [1]. In MC1, extra-cellular collagen is deposited, myelopoiesis is dysregulated, and bone is rapidly remodeled. These are signs of chronic inflammation. The cellular mechanism is unknown, yet bone marrow stromal cells (BMSC) are key regulators of myelopoiesis, can differentiate into collagen-producing cells, and modulate inflammation [2]. We hypothesized that BMSC in MC1 show functional changes that explain molecular changes in MC1.

Methods: From patients undergoing lumbar spondylodesis, bone marrow aspirates (n=5 MC1 + 5 control, adjacent level healthy bone marrow) or biopsies (n=2+2) were taken through pedicle screw trajectory before screw insertion.

Aspirates: BMSC were isolated by plastic adherence and characterized (passage 2): CD14/16/19/34/45/73/90/105/284 expression (FACS), RNA-sequencing (Illumina Novaseq), proliferation rate (CellTrace™), differentiation capacity (histology).

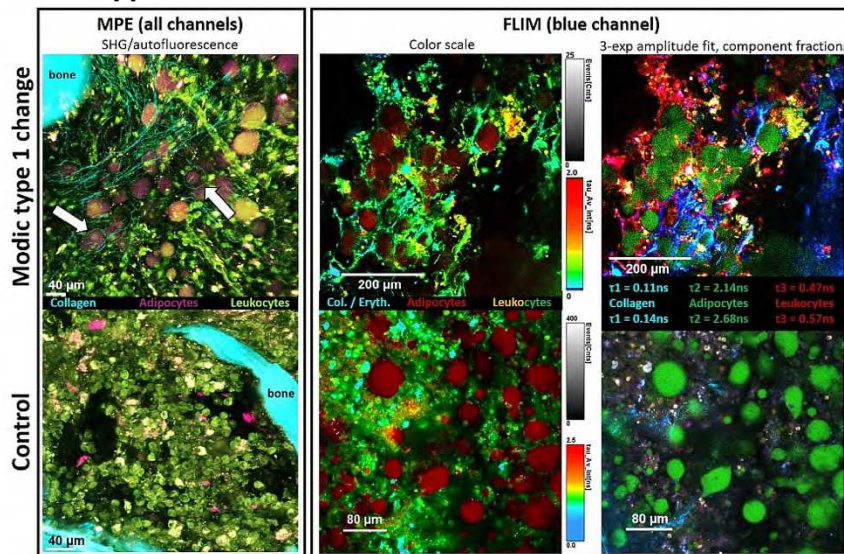
Biopsies: fixed, dehydrated, trimmed for imaging using multiphoton fluorescence microscopy (MPE) (excitation: 880 nm, emission: 460/50 (blue), 525/50 (yellow), 585/40 (green), 650/50 (red)). Second-harmonics-generation of collagen (SHG) and tissue auto-fluorescence were recorded of entire biopsies with up to 200 µm penetration depth. Spectrally selective fluorescence-life-time-imaging-microscopy (FLIM) of the auto-fluorescence signal was performed in key areas of the biopsies. Time-correlated-single-photon-counting histograms were fitted using reconvolution of the instrument response function and triple-exponential decay function.

Results: MC1 vs Ctrl BMSC: reduced proliferation rate (29.3±1.0 vs. 26.2±1.0 hours, p=0.07). No difference in expression of surface markers. Top most differentially expressed genes: aggrecan (ACAN, fc=3.94, fdr<0.001, p<1e-7), osteopontin (OPN, fc=0.19, fdr<0.05, p<1e-5), IL-13Rα2 (IL13RA2, fc=3.61, fdr<0.05, p<1e-5), neurofilament medium (NEFM, fc=3.00, fdr=0.14, p<1e-4), Unc-5 netrin receptor C (UNC5C, fc=0.38, fdr=0.14, p<1e-4). Differentiation assays corroborated distorted BMSC differentiation capacity indicated by OPN/ACAN: osteogenic differentiation (-26±17%), adipogenic differentiation (+89±119%). Chondrogenic differentiation is currently investigated. Neurotrophic activity of BMSC in MC1 are suggested by dysregulation of NEFM and the neuronal damage marker UNC5C.

Fibrotic changes indicated by upregulated IL13RA2 corroborated MPE/MPE-FLIM findings, where abundant collagen fibers were found in MC1 (Figure), particularly in areas of adipocyte clusters and around adipocytes (arrows). MC1 bone marrow also had a generally lower cellularity. MPE-FLIM revealed different intrinsic fluorescent life-times for adipocytes (τ=2.1-2.7ns), leukocytes (τ=0.4-0.8ns), erythrocytes (τ=0.2-0.4ns), and for the SHG of collagen fibers (τ<0.15ns) and allowed to distinguish bone marrow cell populations with minimal tissue processing and without immunofluorescent staining.

Discussion: High resolution MPE imaging of full-mount biopsies in combination with FLIM revealed unprecedented insight into MC1 pathomechanism. It is a prime technology to investigate fibrotic pathologies of larger and delicate tissues like bone marrow and allows to morphologically study the important interaction of mesenchymal cells with leukocytes.

Together, these data suggest a dysregulation of bone marrow mesenchymal cell populations in MC1 (BMSC, adipocytes, osteoblasts), that helps explaining the molecular changes in MC1. The BMSC/adipocyte axis seem to play a pivotal role in the fibrotic pathomechanism. Adipocytes have not been regarded as pathomechanistically relevant yet and hence open novel targets for therapeutics. Furthermore, neurotrophic changes in MC1 BMSC may relate to sensory nerve fiber ingrowth and pain mechanism [3].



- [1] Dudli S, Sing DC, Hu SS, et al. ISSLS PRIZE IN BASIC SCIENCE 2017: Intervertebral disc/bone marrow cross-talk with Modic changes. *Eur Spine J.* 2017;26(5):1362-1373. [2] García-García A, de Castillejo CLF, Méndez-Ferrer S. BMSCs and hematopoiesis. *Immunol Lett.* 2015;168(2):129-135. [3] Fields AJ, Liebenberg EC, Lotz JC. Innervation of pathologies in the lumbar vertebral end plate and intervertebral disc. *Spine J.* 2014;14(3):513-521.

High Fat Diet and Leptin Receptor Deficiency have Sex-Dependent Effects on Spinal Structures in a Type 2 Diabetes Mouse Model

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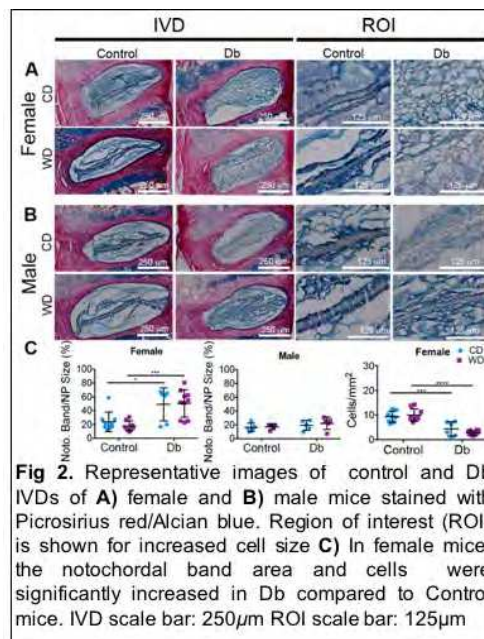
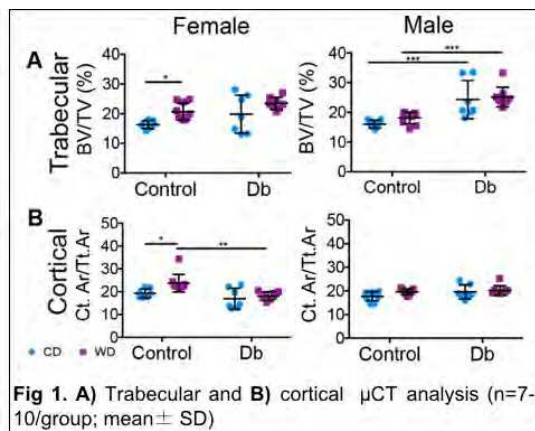
Introduction: Type 2 diabetes (DM) and obesity are associated with back pain, increased risk for spinal surgery complications, and intervertebral disc (IVD) herniation^{1,2}. Yet this relationship is complex and difficult to identify in epidemiological studies. Obesity and Western diets are the driving factors for the rising global prevalence of DM. Western diets result in leptin resistance, increased serum leptin levels, and higher risk for diabetic complications, especially for women³. Mice given Western style diets had increased serum leptin levels and diminished IVD and vertebral health, and these effects were also sex-dependent^{4,5}. Together, the literature points to a need to better identify the specific relationships between DM, obesity, and spinal pathologies. This study assessed if DM and Western diets result in IVD degeneration and vertebral pathology in a sex-specific manner using diabetic and dietary mouse models.

Methods: Homozygous B6.BKS(D)-Lepr db/J (Db) mice and their heterozygous littermates (Control; n=7-10/group/sex) were lifelong fed Western Diets (WD; 40% kcal from fat) or Control Diets (CD; 10% kcal from fat). At 3 months of age, mice were sacrificed, spines were analyzed by mCT for trabecular bone volume and cortical bone fraction. IVD morphology was assessed by Picrosirius red/Alcian blue and Hematoxylin/Eosin stain. Diet and genotype differences were analyzed via Two-Way ANOVA and Bonferroni testing. $p < 0.05$ determined significance.

Results: Dietary effects on trabecular and cortical bone were largest in female mice: female Control mice had increased trabecular bone volume and cortical bone fraction on WD compared to CD. Further, female WD mice had decreased cortical bone fraction for Db compared to CD mice, highlighting a genotype effect. In male mice, Db genotype only increased trabecular bone volume; no other mCt parameters were affected by diet or genotype. Effects on IVD morphology were prominent and mainly observed in female mice. Female Db mice had significantly larger notochordal bands, decreased NP cellularity, and a smaller GAG rich NP region that appeared less dense when compared to control mice (Fig. 2). Male mice showed no differences between groups.

Discussion: Db genotype and Western diet resulted in diminished bone quality and IVD morphology in female mice, while genotype was the driving factor for vertebral changes in male mice. These results emphasize that diabetic females on WD are of greater risk for spinal pathology. This findings are in line with previous studies, which showed a significantly altered NP in a Type 1 DM mouse model with a larger, unorganized notochordal band, decreased GAG content, and upregulation of the catabolic marker ADAMTS-5⁶. Additionally, leptin has been shown to upregulate ADAMTS-5 in IVD cells⁷ and the enlarged cells and disrupted matrix in the NP observed with the Db mice may suggest that leptin is increasing catabolism in the disc of female Db mice. Future studies will determine leptin levels in IVDs and assess if increased leptin and catabolism are driving the changes in spinal structures observed in this study.

Acknowledgements: Funded by NIH/NIAMS (R01 AR069315)



1. Sakellariadis, N. 2006. The influence of diabetes mellitus on lumbar intervertebral disk herniation. *Surgical Neurology* 66(2), pp. 152–154.
2. Anekstein+ 2010. Diabetes mellitus as a risk factor for the development of lumbar spinal stenosis. *The Israel Medical Association Journal* 12(1), pp. 16–20.
3. Macedo+ 2012. Cafeteria diet-induced obesity plus chronic stress alter serum leptin levels. *Peptides* 38(1), pp. 189–196.
4. Illien-Jünger+ 2015. Chronic ingestion of advanced glycation end products induces degenerative spinal changes and hypertrophy in aging pre-diabetic mice. *Plos One* 10(2), p. e0116625.
5. Illien-Jünger+ 2018. Dietary Advanced Glycation End Products Have Sex- and Age-Dependent Effects on Vertebral Bone Microstructure and Mechanical Function in Mice. *Journal of Bone and Mineral Research* 33(3), pp. 437–448.
6. Illien-Junger+ 2013. Combined anti-inflammatory and anti-AGE drug treatments have a protective effect on intervertebral discs in mice with diabetes. *Plos One* 8(5), p. e64302.
7. Li+ 2014. Leptin downregulates aggrecan through the p38-ADAMTS pathway in human nucleus pulposus cells. *Plos One* 9(10), p. e109595.

Effect of spinal surgery on prognosis in patients with symptomatic spinal metastasis: a prospective cohort study

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Background: Symptomatic spinal metastasis (SSM) is characterized by severe back pain and neurological deficits and generally has a poor prognosis. However, the effect of spine surgery on the prognosis of SSM is unclear.

Methods: In total, 122 patients with SSM were enrolled in this prospective cohort study. Both groups of patients received adjuvant therapy including radiation therapy and chemotherapy, if indicated. Evaluation was performed at the study start and once a month after the onset of SSM using the Eastern Cooperative Oncology Group performance status (PS), Barthel index (BI) for activities of daily living (ADL), and neurological status. The prognosis was evaluated by the Kaplan–Meier method, and significant prognostic factors were assessed by multivariate analysis using a Cox proportional hazard model.

Results: Eighty-six patients underwent spine surgery and 36 did not. The median survival time (MST) was 5.17 months (95% confidence interval (95%CI), 4.16–6.18 months). The MST of patients who did and did not undergo surgery was 7.87 months (95%CI, 2.92–12.58 months) and 2.57 months (95%CI, 1.69–3.44 months), respectively ($p < 0.01$). The multivariate analysis revealed that the primary tumor type, visceral and cerebral metastasis, postoperative PS, and chemotherapy were independent prognostic factors. Unexpectedly, the combination of spine surgery and postoperative chemotherapy was associated with a 15.4-month extension of MST (95%CI, 11.09–19.71 months) compared with spine surgery alone (MST, 4.37 months; 95%CI, 2.77–5.96 months). One month after SSM, the PS, BI, and ambulation rate were significantly higher in patients who did than did not undergo surgery. As a result, 64% of patients who underwent surgery received postoperative chemotherapy, whereas only 25% of patients who did not undergo surgery received chemotherapy.

Conclusions: Spine surgery for SSM improved the PS, ADL, and ambulation status and allowed more patients to receive chemotherapy. The role of spine surgery in the management of SSM should be considered not only as a palliative option but also as a strategy to prolong survival.

Prognostic factors for drop foot due to lumbar degenerative diseases: The impact of surgical timing on postoperative recovery.

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Introduction: Drop foot may be caused by lumbar spinal diseases and may affect daily life. There are limited data regarding predictors of drop foot, especially surgical timing. To investigate the prognostic factors for improvement of drop foot, especially the appropriate timing of surgery.

Methods: We retrospectively reviewed data from 88 patients with drop foot. We defined drop foot as a tibialis anterior muscle strength score on manual muscle test (MMT) ≤ 3 . Prognostic factors for drop foot were examined by multivariate logistic regression analysis. We set cutoff variables for short duration of drop foot before surgery at one, two, and three months, in order to determine the most favorable timing of surgery.

Results: The mean tibialis anterior muscle strength improved from 1.7 (range 0–3) preoperatively to 3.3 (range 0–5) postoperatively. Forty patients (45.5%) recovered from drop foot after surgery. When comparing age ($P < 0.001$), hernia ($P = 0.006$), number of involved levels ($P < 0.001$), and preoperative tibialis anterior muscle strength ($P = 0.007$), we found significant differences. Considering duration of drop foot before surgery, two months was more appropriate than the other durations. Multivariate logistic regression analysis was performed with these five factors (age, hernia, preoperative anterior tibialis muscle strength, number of involved levels, and duration of drop foot before surgery < two months), that were shown to be significant by univariate analysis. Age (OR = 0.93; 95% CI = 0.93–0.98; $P = 0.01$), preoperative tibialis anterior muscle strength (OR = 12.2; 95% CI = 2.45–60.4; $P = 0.002$), and duration of drop foot before surgery (OR = 3.60; 95% CI = 1.10–11.8; $P = 0.03$) were significant prognostic factors.

Discussion: Previous studies showed that various factors were related to the improvement of drop foot. As expected, our multivariate analyses found that age, preoperative tibialis anterior muscle strength, and duration of drop foot before surgery had significant effects on the recovery from drop foot. Almost all these studies showed that short duration of drop foot prior to surgery improved postoperative outcome. Nevertheless, the definition of short duration was inconsistent. Our study suggests that surgery within two months after the onset of drop foot may improve postoperative outcome.

Predictive factors related with recovery of bowel and bladder function and ambulatory capacity in surgically treated traumatic conus medullaris syndrome with thoracolumbar fracture

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Introduction: Traumatic conus medullaris syndrome (T-CMS) is a neurological condition caused by compression of the conus medullaris and is often combined with thoracolumbar fracture. There have been a paucity of literatures regarding prognosis and predictors related with recovery of bowel and bladder function and ambulatory capacity in T-CMS. This study was performed to evaluate the prognosis of T-CMS and find possible predictive factors of these functions.

Methods: Thirty-two consecutive patients, who diagnosed with T-CMS combined with acute thoracolumbar and surgically treated, were retrospectively analyzed. T-CMS was defined with both clinical (lower leg weakness or bowel urinary dysfunction) and radiological features (compression on conus medullaris with or without the signal change on T2-weight magnetic resonance image). If the location of compression was unclear between conus medullaris and pure cauda equina, it is classified into indeterminate CMS (n=7). Baseline demographic factors including age, gender, cause of injury, time to surgery, ASIA grade (A; 7 patients, B; 1 patient, C; 13 patients, D; 6 patients, E; 5 patients at baseline) and impaired anal sphincter function (26 patients, 81.3% at baseline) were collected from medical records. The thoracolumbar fracture type (AO type A fractures; 25 cases, AO type B fracture; 1, and AO type C fractures; 6) and the high signal intensity of conus medullaris (0=none, 1=definite, and 2=indeterminate) at injury were evaluated using magnetic resonance image. At final follow-up (mean 40.0±28.7months), ASIA grade, gait grade (G1, wheel chair ambulation; G2, gait with aid such as walker, crutch, or cane; G3, independent gait) and bowel or urinary function grade (U1, complete dysfunction; U2, partial recovery without catheterization and enema; U3, complete recovery) were evaluated. Baseline parameters were compared between final ASIA grade groups gait grade groups, and bowel-urinary grade groups.

Results: Among ASIA-A patients, 2 patients were improved to ASIA-C at final follow-up. One patients in ASIA-B improved to ASIA-D. Among ASIA-C patient, nine patients changed to ASIA-D and one patient to ASIA-E. One patient became ASIA-A. There were no changes in all ASIA-D and E patients. At final follow-up, 7, 11, and 14 patients (21.9%, 34.4%, and 43.8%) were G1, G2, and G3 and 13 patients (34.4%, 25%, and 40.6%) were U1, U2, and U3.

The thoracolumbar fracture type, the presence of high signal intensity, and ASIA grade at baseline were significantly different among final ASIA grade groups, gait groups and bowel and urinary function groups. Impaired anal sphincter function at baseline and number of indeterminate CMS were significantly different among bowel and urinary function groups. (All P<0.05)

Discussion: The recovery rates of ambulatory capacity and the bowel and urinary function T-CMS are relatively high comparing with the prognosis of traumatic cord injury in other studies. The fracture-dislocation type fracture, the definite high signal intensity on conus medullaris, and poor ASIA grade at baseline may be the predictive factors related with poor recovery of function. Impaired anal sphincter function at baseline may also predict poor bowel and urinary function.

No long-time benefit from fusion in decompressive surgery for lumbar spinal stenosis. 5 year-clinical results and 2-year MRI follow-up from the Swedish Spinal Stenosis Study, a multicenter RCT of 233 patients.

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Introduction: The role of fusion in surgery for lumbar spinal stenosis (LSS) is a controverser in spine surgery. The aim of this study was to examine if additional fusion improves the outcome after decompression for LSS with or without preoperative degenerative spondylolisthesis (DS). The clinical results after 2 years from this study showed no benefit from fusion.

Methods: From 2006 to 2012, 233 patients aged 50-80 years with spinal stenosis on 1 or 2 adjacent lumbar levels on MRI were included and operated in the study. Randomization was made between decompression with concomitant fusion and decompression only. The material was stratified for the existence of preop DS ≥ 3 mm on plain X-ray. 135 (58%) of the patients had preop DS (mean 7.4 mm). Outcome measures were collected from the Swedish register for spine surgery (Swespine) with the primary outcome measure ODI. Follow-up with MRI was done 2 years post-op. Of the eligible patients, the follow up rate after 5 years was 95%.

Results: At the 5-year follow-up, there were significant improvements in all outcome measures compared to preoperative regardless of treatment group. For all patients, regardless of DS, ODI was 25 in the decompression group and 28 in the decompression + fusion group ($p=0.23$), back pain (VAS) 35 vs. 38 ($p=0.37$), and leg pain 32 vs. 34 ($p=0.67$). In the group with preop DS ODI was 23 in the decompression group and 28 in the decompression + fusion group ($p=0.15$), back pain 33 vs. 38 ($p=0.30$) and leg pain 34 vs. 32 ($p=0.77$). Satisfaction with surgery was reported for all patients by 69% in the decompression group and 65% after fusion, OR 1.1 (95%CI 0.7-1.2). In the DS group the corresponding fractions were 68% vs. 67%, OR 1.0 (95%CI 0.7-1.4). The proportion of patients who had subsequent lumbar surgery within 5 years was 22% in the decompression group and 23% in the decompression + fusion group regardless of the presence of DS. Reasons for a second operation was predominantly restenosis or foraminal stenosis at index level after decompression alone, and stenosis in the upper adjacent segment after decompression + fusion. MRI two years post-op revealed new stenosis in the adjacent segment proximal to the operated level in 15% after decompression alone and 40% after decompression + fusion ($p<0.005$). In the decompression alone group 8% had restenosis at operated level.

Discussion: In this multicenter RCT we found no long-time benefit from fusion in decompressive surgery for LSS, regardless of if DS was present preop or not. These results confirm the 2-year results published 2016. In this elderly population with one- or two-level LSS, surgery should be limited to the less invasive procedure of decompression alone to decrease the number of complications and costs for the society. Due to the progressive degenerative nature of LSS, as many as up to 23% of operated patients had repeated lumbar surgery within five years. This predominantly due to either development of stenosis in a new lumbar segment or restenosis in a decompressed segment.

A Comparison of Functional and Quality of Life Improvement in Six Different Types of Lumbar Surgery in a Pan Canadian Database.

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Introduction: Patient centered outcomes can be used to rank surgical indications by rate of success for improving patient quality of life (QOL) and function. The objective of this study is to compare the outcomes of common lumbar spinal surgical procedures to each other.

Methods: To determine the efficacy of different types of surgical indications across Canada, we examined patient EQ5D and Oswestry Disability Index (ODI) improvements of 6 common lumbar surgical indications in the CSORN database. The surgeries included 1) discectomy for radiculopathy, 2) artificial disc for degenerative disc disease, 3) spinal fusion for degenerative disc disease, 4) decompression and fusion for degenerative spondylolisthesis, 5) simple decompression for spinal stenosis, and 6) spinal fusion for degenerative scoliosis. Improvements from baseline were assessed at 3, 12 and 24 months. T-tests were used to determine patient improvement. EQ5D outcomes were compared to published data for total hip and knee replacement.

Results: Table 1: Improvement in QOL (EQ5D) and Function (ODI) with 6 Surgical Indications

Surgical Indication	Improvement in EQ5D	N (12m)	Improvement in ODI	N (12m)	Improvement in ODI			
					3 mo	12 mo	24 mo	
1) Discectomy for radiculopathy *	0.289	0.312	0.3258	199	25.5	29.6	31.8	228
2) Artificial disc for degenerative disc disease	0.203	0.231	0.242	70	16.7	19.6	21.5	73
3) Fusion for degenerative disc disease	0.181	0.217	0.234	66	14.5	19.7	20.7	76
4) Decompression and fusion for degenerative spondylolisthesis	0.255	0.251	0.226	118	17.6	21.3	20.2	124
5) Simple decompression for spinal stenosis	0.197	0.18	0.183	156	17	18.4	16.8	176
6) Spinal fusion for degenerative scoliosis	0.1687	0.236	0.149	23	-2.2	16.3	9.7	24

*p<=0.05

Sample size varied depending on time point and were as low as 12 for group 6 at 24m.

Discussion: While surgical outcomes vary widely, within this study, discectomy was found to be the statistically superior surgery for restoring quality of life and function. Simple decompression for spinal stenosis, and spinal fusion for degenerative scoliosis consistently demonstrated the poorest outcomes. Total hip and total knee typically demonstrate QOL improvements of 0.31 and 0.22 on the EQ5D. The majority of spine surgeries in our list produce results similar to hip and knee arthroplasty. Careful patient selection is required for decompression and adult scoliosis surgery.

Association between the definition of unfavorable surgical outcomes and their risk factors after spine surgery for lumbar spinal stenosis

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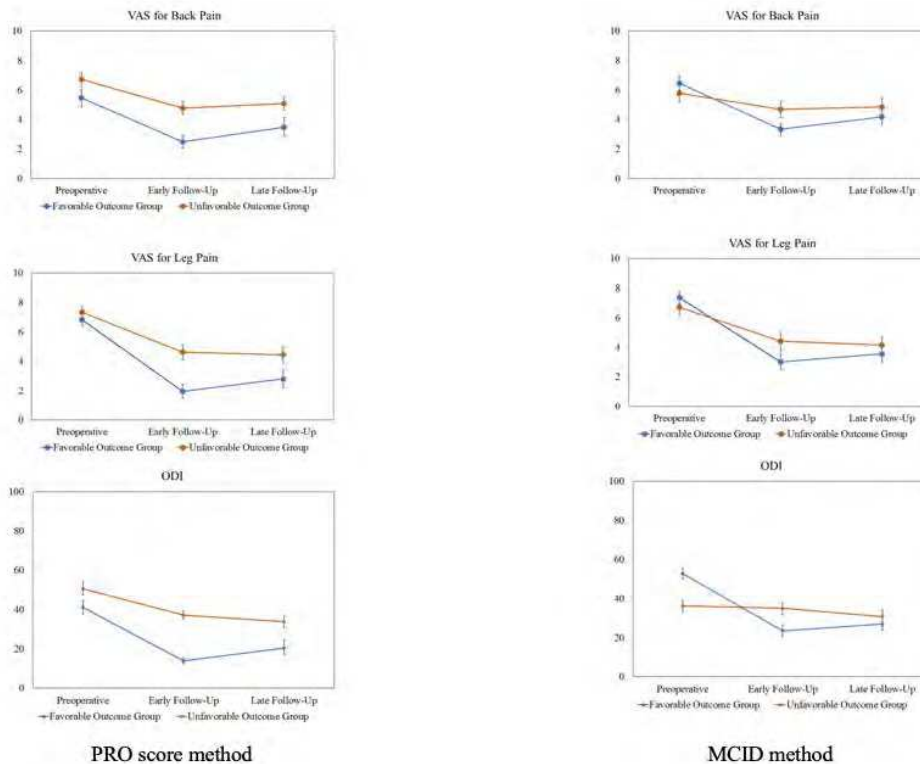
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Introduction. A risk factor or predictor of surgical outcomes might be associated with the definition of successful surgical outcome. In general, two methods have been used to evaluate surgical outcome. One is the absolute level achieved, for which patient-reported outcomes (PROs) scores *per se* can be used after surgery. The other is the relative change after surgery, for which the minimum clinically important difference (MCID) of the PRO scores can be used after surgery. The purpose of this study was, first, to compare risk factors for each unfavorable surgical outcome according to two different definitions of 'unfavorable' surgical outcomes by using either the MCID or PRO score *per se* and, second, to compare the clinical courses from preoperative to 2–3 years after surgery between the favorable and unfavorable outcomes according to two different definitions after surgery for LSS.

Methods. As an observational study, the enrolled 295 patients who underwent spine surgery for LSS and followed up at 3 years after surgery were divided in a favorable and an unfavorable group, based on two different definitions for favorable surgical outcomes at 6 – 12 months after surgery: patient reported outcome (PRO) and minimally clinical importance difference (MCID) methods. In the "PRO score" method, the patients were dichotomized into favorable (ODI ≤ 22) and unfavorable (ODI > 22) outcome groups at 6 – 12 months after surgery. In the MCID method, the patients were dichotomized according to the MCID value for the ODI scores at 6 – 12 months after surgery. A decrease of 12.8 points from the preoperative value was set as the criterion for categorizing the "favorable" and "unfavorable" outcome groups. As a primary outcome, the risk factors for unfavorable surgical outcomes according to each definition were investigated at 6 – 12 months after surgery. The secondary outcome was a comparison of the clinical courses from preoperative to 3 years after surgery between the favorable and unfavorable groups according to above two different definitions of surgical outcome.

Results. In the PRO score method, low educational level (elementary or middle school attainment; P = 0.006; OR, 2.278) and preoperative ODI score (P = 0.008; OR, 1.025) were associated with a higher odds for unfavorable surgical outcome. In the MCID method, preoperative ODI score was associated with a higher odds (P < 0.001; OR, 0.920) for favorable surgical outcome. No significant differences in VAS scores for back and leg pains, and ODI scores in the late follow-up were found between the favorable and unfavorable groups by the MCID method, while there were significant differences in VAS scores for back and leg pains, and ODI scores in the late follow-up between the favorable and unfavorable groups by the PRO score method (**Figures**).

Discussion. The risk factor for unfavorable outcome after surgery depends on the definition of unfavorable outcome. Increased preoperative ODI score would be a risk factor for postoperative ODI of >22 after surgery for LSS, whereas it would be associated with a high odds for improvement in ODI score of >12.8.



Signaling peptides from human mesenchymal stem cells including connective tissue growth factor enhance chondrogenesis in disc cells.

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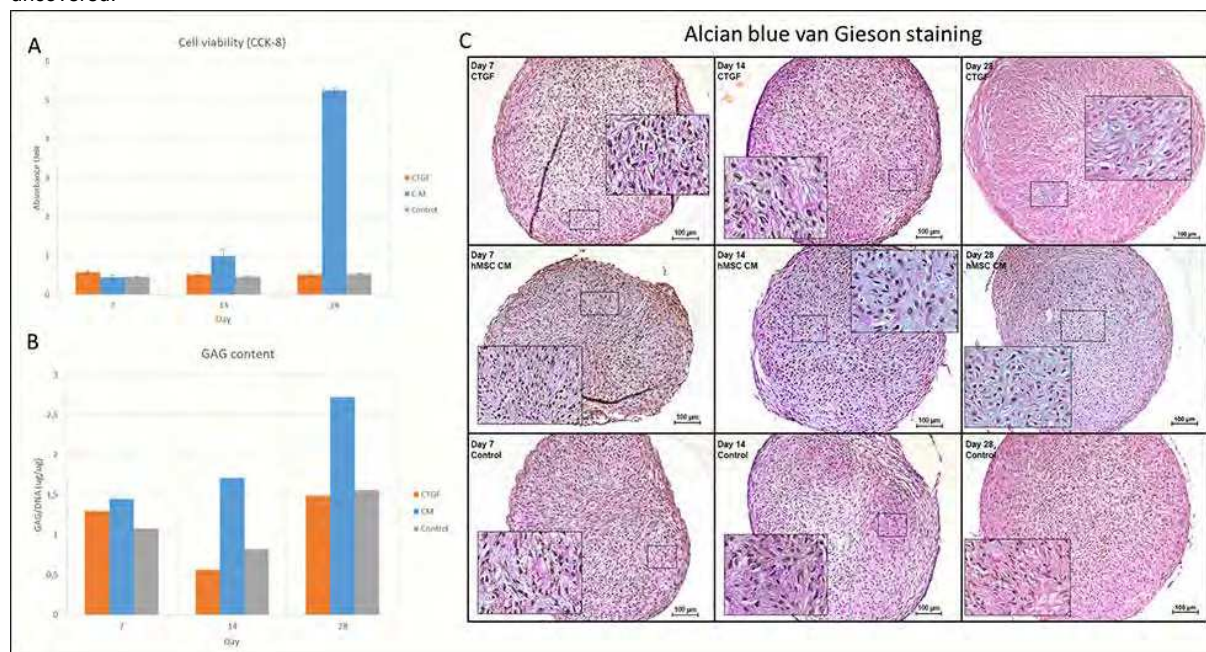
Background: Intervertebral disc (IVD) degeneration is one of the main causes of low back pain (LBP) involving loss of proteoglycan and extracellular matrix (ECM) affecting the disc cells (DCs) [1]. Current treatments are symptomatic and can be highly invasive, thus less invasive strategies that promote biological repair of IVD are invaluable. Innovatively, transplantation of human mesenchymal stem cells (hMSCs) or injection of growth factors locally is employed as a therapeutic intervention to counteract IVD degeneration [2]. However, identification of substances responsible for the regenerative effect remains elusive. One possible candidate, connective tissue growth factor (CTGF) has been identified in the secretome of notochordal cells and reported to regulate cartilage and bone development as well as promote ECM production in degenerated IVD and proliferation of chondrocytes [3]. The aim was to investigate the presence of CTGF in secretome of hMSCs and further compare and evaluate the effects of CTGF and hMSC conditioned media (CM) on DCs isolated from patients with LBP in terms of cell proliferation, viability, proteoglycan accumulation and chondrogenesis.

Method: Firstly, bone marrow derived hMSCs were cultured in MSC growth media and CM was collected every 48 hours. The CM were pooled and centrifuged (1195 rpm at 4°C for 5 minutes). Supernatant was collected and analyzed with tandem mass spectrometry and the rest was stored at -80 °C for pellet stimulation.

Next, DC pellets were performed (200,000 cells/pellet) and were stimulated with 10ng/mL CTGF in chondrogenic media and CM supplemented with chondrogenic media at 1:1 ratio for 28 days. The pellets were harvested at day 7, 14, and 28. Cell viability, histological staining with Alcian blue van Gieson, glycosaminoglycan (GAG) and DNA assays were performed.

Results: Firstly, tandem mass spectrometry analysis of hMSC conditioned media identified the CTGF as one of the five peptides of interest at high relative abundance. Secondly, enhanced cell viability was observed in DC pellets stimulated with CM but not with CTGF compared to control at day 28 (Fig A). A higher DNA content was seen both for pellets stimulated with CM and CTGF at day 28 compared to control. GAG assay revealed CM stimulated group possessed highest GAG content at all time points compared to CTGF stimulated group and control (Fig B). Histological staining showed proteoglycan accumulation in CM stimulated pellets as early as in day 7 and throughout the experimental time points whereas in CTGF stimulated pellets, it appeared later, mainly at day 28 (Fig C).

Conclusion: These findings suggest that CM enhances cellular viability as well as promote ECM production in DCs, which were previously exposed to inflammatory and degenerative environment in the IVDs. Similarly, CTGF which was demonstrated to be present in hMSC conditioned media, imposed chondrogenic effect on DCs, but not as strong as that of CM. This implies the participation of CTGF in the process where MSCs influence IVD regeneration, but other factors alone or in combination have a greater impact. Thus, CM possesses regenerative potential but the constituents responsible for these effects are yet to be uncovered.



1. Airaksinen, O., et al., Chapter 4. European guidelines for the management of chronic nonspecific low back pain. *Eur Spine J*, 2006. 15 Suppl 2: p. S192-300.
2. Peroglio, M., et al., Thermoreversible hyaluronan-based hydrogel supports in vitro and ex vivo disc-like differentiation of human mesenchymal stem cells. *Spine J*, 2013.
3. Matta, A., et al., Molecular Therapy for Degenerative Disc Disease: Clues from Secretome Analysis of the Notochordal Cell-Rich Nucleus Pulposus. *Sci Rep*, 2017. 7: p. 45623.

Nutrient supply and nucleus pulposus cell function: effects of the transport properties of the cartilage endplate and potential implications for intradiscal biologic therapy

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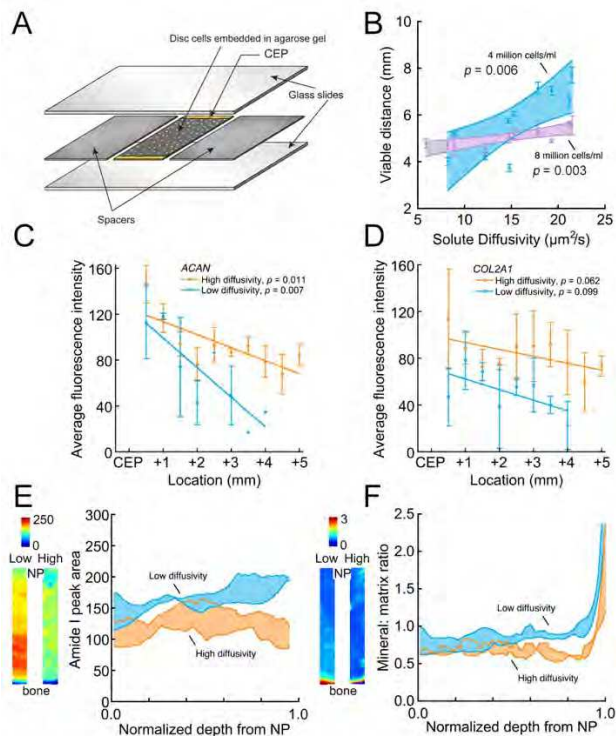
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Introduction: Intradiscal biologic therapy (stem cell, gene, or growth factor) is a promising strategy for disc regeneration. However, these therapies require a rich nutrient supply, which may be limited by the transport properties of the cartilage endplate (CEP). This study investigated how physiologic fluctuations in CEP transport properties impact nutrient diffusion and disc cell survival and function.

Methods: Human CEP tissues harvested from six fresh cadaveric lumbar spines (38-66 years old; Pfirrmann grades II-IV) were placed at the open sides of diffusion chambers. Bovine nucleus pulposus (NP) cells cultured inside the chambers were nourished by nutrients diffusing through the CEP tissues (**Fig. A**). After 72 hours in culture, depth-dependent NP cell viability and gene expression were measured using a live/dead assay and *in situ* hybridization. These cell viability and function outcomes were related to CEP transport properties and CEP biochemical composition, determined using fluorescence recovery after photobleaching (solute: 376 Da fluorescein) and Fourier transform infrared spectroscopy imaging.

Results: Solute diffusivity varied nearly 4-fold amongst the CEPs ($14.8 \pm 5.1 \mu\text{m}^2/\text{s}$; range: 5.9–21.5 $\mu\text{m}^2/\text{s}$), and chambers with the least permeable CEPs had up to 51% shorter viable distance from the CEP/nutrient interface (**Fig. B**). CEP transport properties also influenced anabolic and catabolic gene expression by the NP cells. Specifically, CEPs that permitted the least transport attenuated the expression of aggrecan (**Fig. C**), type II collagen (**Fig. D**), and matrix metalloproteinase-2. Doubling the chamber cell density shortened the viable distance; however, this effect depended on CEP transport properties. Namely, for the CEPs that provided high diffusive transport (diffusivity $>15 \mu\text{m}^2/\text{s}$), the average viable distance was 22.9% shorter in the chambers with the higher cell density, which is consistent with the increased nutrient demand. However, for CEPs with low diffusivity ($<15 \mu\text{m}^2/\text{s}$), there was overlap in the relationships between viable distance and solute diffusivity (**Fig. B**). This suggests that in those cases, the main limiting factor was poor nutrient supply owing to low diffusive transport, not the increased nutrient demand caused by the higher number of cells. Solute diffusivity in the CEP was associated with biochemical composition: low diffusivity CEPs had significantly higher amounts of collagen (Amide I peak: 208.4 ± 35.7 vs. 149.8 ± 25.9 , $p = 0.0006$; **Fig. E**) and aggrecan (carbohydrate peak: 154.1 ± 117.8 vs. 60.8 ± 36.3 , $p = 0.047$), more mineral (phosphate:Amide I peak ratio: 1.02 ± 0.37 vs. 0.64 ± 0.26 , $p = 0.011$; **Fig. F**), and lower collagen maturity (1660:1690 cm^{-1} peak ratio: 1.35 ± 0.14 vs. 1.97 ± 0.36 , $p = 0.0003$).

Discussion: These findings demonstrate that CEP transport properties have significant effects on nutrient supply and NP cell survival/function. CEPs associated with poor diffusion had compositional deficits that block nutrient passage. Moreover, these deficits had a detrimental effect on viability as cell density was increased. Taken together, these findings suggest that deficits in CEP matrix composition and transport properties may prevent adequate nutrient diffusion, and could thereby hinder the success of biologic therapies that require increased nutrient supply. Non-invasive screening tools which are sensitive to CEP composition, e.g. quantitative MRI, could help identify patients with adequate nutrient supply who might benefit from these therapies.



A. NP cells obtain nutrients from their culture medium outside the chambers via diffusion through human CEP sections. B. Viable distance correlated with diffusive transport in the CEPs (determined for fluorescein, 376 Da) at the open sides of the chambers. Bands show 95%CI. C-D. Average fluorescence intensity indicating mRNA expression. ACAN levels decreased with increasing distance from the CEP, and the slope was greater for CEPs with low diffusivity. COL2A1 levels tended to decrease with increasing distance, and levels were lower for the CEPs with low diffusivity. E-F. Representative peak integration maps and normalized distribution plots showing greater collagen (Amide I peak) and mineral:matrix ratios in CEPs with low diffusivity. Bands show mean \pm SD for 3 sections per CEP.

The role of integrin α 5 β 1 in the alteration of notochordal cell induced by dynamic loading

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The authors declare no conflicts of interest.

Introduction: In many cell types, transmembrane receptors are considered to transmit mechanical stress to cytoskeleton. We previously reported the role of α 5 β 1 integrin on intervertebral disc (IVD) degeneration using an ex-vivo culture system in which IVDs were exposed to dynamic mechanical loading. The aim of this study is to elucidate the relationship between integrin α 5 β 1 and the loss of notochordal cell (NC), which is the initial alteration in the early phase of IVD degeneration.

Methods: Sixty 12-week-old male Sprague–Dawley rats were used. IVD tissues between the 7th and 8th caudal vertebrae were subjected to dynamic compressive stimuli (1.3MPa, 1Hz) in a dynamic organ culture system for 2 or 6 days under the following conditions; unloaded condition (Group C, control group), axial mechanical loaded condition with 1.3MPa, 1Hz (Group L) and loaded with an inhibitor of integrin α 5 β 1 (Group TL). Regarding the assessment, (1) Histology was assessed with Safranin-O section by Masuda's grade. (2) Multi-color immunofluorescence staining for brachyury, sox9, and DAPI was performed. Furthermore, immunopositivity of brachyury and sox9 were calculated by the percentage of each positive cells/all DAPI-positive cells, respectively. Multi-way ANOVA with the Tukey-Kramer post-hoc test was used with significance of $P < 0.05$.

Results: (1) Histological grades of Group C had no significant histological change of NP and AF, at day2 and day6. The score of Group L and Group TL were 6.5 and 5.5, respectively. And they had the significant difference between them ($p < 0.05$). At day6, it of Group L (7.6) and Group TL (6.3) increased than day2. In addition, the discrepancy of them was expanded according to loading time and Group TL was significantly lower than Group L ($p < 0.05$). (2) The immunostaining revealed that brachyury and sox9 of Group C were widely observed approximately 80-90% at both day2 and day6. The immunopositivity of brachyury of Group L and Group TL were significantly decreased according to loading time (at day2: Group L; 32.2%, Group TL; 59%, at day6: Group L; 4.7%, Group TL; 21.8%). Interestingly, the value of immunopositivity of brachyury of Group TL was significantly higher than Group L at day2 and day6. Whereas, immunopositivity of sox9 were also decreased with loading time in Group L and Group TL (at day2: Group L; 80.4 %, Group TL; 86.0 %, at day6: Group L; 50.6 %, Group TL; 62.2 %). It of Group TL was significantly higher than Group L at both day2 and day6

Discussion: In the current study, the dynamic compressive loading led to the IVD degeneration according to loading time. In addition, the expression of brachyury and sox9 was reduced by the dynamic loading, especially the expression of brachyury remarkably reduced compared to the expression of sox9. The brachyury was considered to be more sensitive to dynamic load than sox9. Interestingly, these alterations due to mechanical stress was inhibited by the inhibitor of integrin α 5 β 1. Therefore, it is considered that integrin α 5 β 1 may play the role in the alterations of NC leading the early phase of IVD degeneration.

MSC homing into intervertebral discs enhances the Tie2 positive progenitor cell population, prevents cell death and induces a proliferative response

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Introduction: Homing of human mesenchymal stem cells (MSCs) has been described as potential alternative to MSC injection, aiming to enhance the regenerative capacity of the intervertebral disc (IVD).¹ IVD cells expressing Tie2 (Angiopoietin-1 receptor) represent a progenitor cell population which decreases with aging and degree of IVD degeneration.² This results in a potential loss of the IVD's regenerative capacity.

Objectives: The aims of this study were to assess whether MSC homing into an IVD

- enhances the Tie2 positive progenitor cell population,
- affects the IVD cell survival, and
- induces a proliferative response in the IVD

A bovine whole organ culture model and human IVD tissues from three patient groups (non-degenerative, trauma, degenerative) were used.

Methods: Human MSCs (n=9 donors) isolated from bone marrow aspirates obtained with written consent from patients undergoing spine surgery were labeled with fluorescent dye (PKH26+PKH67).

Bovine organ culture: IVDs were isolated from bovine tails (n=27, 6-10 months) and cultured under free-swelling conditions. MSCs (1×10^6) were placed on the endplates of bovine IVDs. Untreated IVDs from same tail were used as controls (ctrl).

Human organ culture: Traumatic and degenerative human IVD tissue was obtained with written consent from patients undergoing spine surgery. Non-degenerative IVDs were harvested from organ donors after donor and familial consent. IVD tissue from each donor was separated in two equal portions and placed in a 15ml tube respectively. MSCs (1×10^5) were added onto one tissue portion. The other portion was used as untreated control. After 5 days of co-culture and MSC migration, IVD cells were isolated by tissue digestion (collagenase 2, 12h). Percentages of Tie2 positive, dead (DAPI positive) and proliferative (Ki-67 positive) IVD cells were evaluated by flow cytometry. Gates were defined with unstained samples. A portion of bovine IVD cells was collected for gene expression analysis. IHC staining (Ki-67) was performed on healthy human disc tissue.

Results: MSC homing significantly

- increased the proportion of Tie2 positive progenitor IVD cells in bovine IVDs (2.4 ± 1.3 -fold; $p=0.04$) and 7/10 human IVDs (Fig. 1a/e);
- decreased the fraction of dead IVD cells in bovine IVDs (0.8 ± 0.4 -fold; $p=0.02$) and 7/10 human IVDs (Fig. 1b/f); and
- induced a proliferative response in bovine IVDs (2.5 ± 1.9 -fold; $p=0.013$) and 5/6 human IVDs (Fig. 1c/g/h)

A positive correlation between the upregulation of Tie2 and anti-apoptotic Bcl2 was observed following MSC homing into bovine IVDs ($R^2=0.96$, Fig. 1d).

Discussion: Stimulation of bovine and human IVD cells by homed MSCs resulted in an enhanced population of Tie2 positive IVD progenitor cells, induced a proliferative response and reduced IVD cell death. In this respect, we observed a positive correlation between the upregulation of Tie2 and Bcl2 transcripts. Bcl2 represents an antagonist of the apoptosis cascade, where it counteracts the apoptosis-promoting factor Bax; hence, increased Bcl2 expression may contribute to the improved survival phenotype of IVD cells upon MSC homing.

Our findings suggest a prominent role for paracrine stimulation, indicating that homed MSCs may represent "biological factories" secreting growth- and survival factors to help resident cells to reverse or slow down a potential ongoing degenerative process.

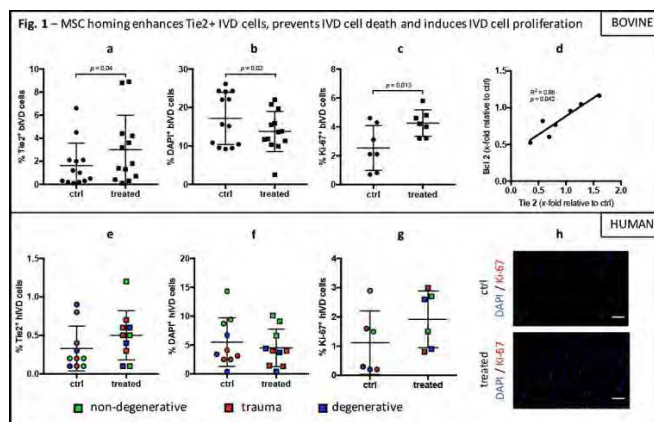


Fig. 1. Bovine: MSC homing significantly a) enhanced the Tie2⁺ progenitor cell population at day 5 (ctrl: 1.6 ± 1.9 %, treated: 3.0 ± 3.0 %); b) reduced the fraction of dead bovine IVD cells at day 5 (ctrl: 17.2 ± 7.3 %, treated: 13.8 ± 6.0 %); c) induced a proliferative response at day 5 (ctrl: 2.5 ± 1.6 %, treated: 4.3 ± 0.9 %, $p=0.013$). d) The gene expression of Tie2 was positively correlated with the expression of Bcl2 ($p=0.042$, $R^2=0.96$). **Human:** Three tissue groups were investigated (non-degenerative, trauma, degenerative). Graphs show summary of all groups. MSC homing e) enhanced the Tie2⁺ disc progenitor cell population in 7 of 10 analyzed human IVDs; f) reduced the fraction of dead IVD cells in 7 of 10 analyzed human IVDs; g) induced a proliferative response in five of six human IVDs. h) IHC staining for Ki-67 confirmed flow cytometry results (n=3: 1.2 ± 0.6 fold; scale bar = 50 μ m)

1. Illien-Jünger S. et al., Spine 2010
2. Sakai D. et al., Nat. Commun. 2012

Potential involvement of oxidative stress/inflammatory cytokines cascade in ligamentum flavum hypertrophy

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Introduction: Lumbar spinal canal stenosis (LSS) is a common spinal degenerative disease, and increasing with aging of society. Hypertrophy of the ligamentum flavum (LF) of the lumbar spine could be one of the main causes of the stenosis, however, the pathological mechanism of LF hypertrophy has not fully understood. Here, we hypothesized that inflammatory cytokines and oxidative stress could play crucial roles in LF hypertrophy. The first objective of this study was to clarify the involvement of inflammatory cytokines in human LF hypertrophy. The second objective was to elucidate whether oxidative stress contributes to overexpression of inflammatory cytokines in human LF cells.

Methods: Human IVD samples: Normal LF samples were collected from three patients (1 male, 2 female, with a mean age of 43.6 years). Hypertrophied LF were taken from 15 patients (13 male, 2 female, with a mean age of 72.5 years). Immunohistochemistry: The human samples were stained with hematoxylin-eosin (H&E), Elastic van Gieson (EVG) and Masson Trichrome (MT). Antibodies to TNF- α and IL-6 were used to analyze the involvement of inflammatory cytokines in hypertrophied LF. Human LF cells culture: Human LF cells were isolated and cultured as reported previously. We treated cultured LF cells with buthionine sulfoximine (BSO) (1mM), TNF- α (50nM), and IL-6 (100nM) for 24 h. Real-time RT-PCR: We measured the relative mRNA expression of Elastin, TNF- α , IL-6 and MMP-3 normalized by the expression of β -actin. Statistical analysis: Differences between the groups were analyzed by the Student t test (* $p < 0.05$).

Results: Immunohistochemical analysis clearly showed a high frequency of both TNF- α and IL-6 positive cells, indicating that inflammatory cytokines were accumulated in hypertrophied LF. Real-time RT-PCR analysis showed that mRNA expression of elastin was significantly reduced with TNF- α ($p < 0.05$). Treatment of IL-6 also reduced the mRNA expression of elastin, but not significantly ($P = 0.10$). The mRNA expression of MMP-3 was significantly induced by treatment of IL-6 as well as TNF- α ($P < 0.05$). Expectedly, real-time RT-PCR showed that mRNA expression of both TNF- α and IL-6 was significantly increased with the treatment of BSO in a dose-dependent manner ($p < 0.05$).

Discussion: The experiments described in this investigation demonstrate that inflammatory cytokines were associated with human LF hypertrophy. Furthermore, we found that oxidative stress contributed to overexpression of inflammatory cytokines in human LF cells. These findings lend support to the hypothesis that oxidative stress/inflammatory cytokines cascade is a critical mediator in the pathogenesis of LF hypertrophy. Despite some limitations, the present study sheds a novel light on the pathology of LF hypertrophy and suggests that pharmacological inhibition of oxidative stress may be a potential therapeutic option for treating patients with LSS.

Genome-wide DNA methylation analysis identifies a differentially methylated profile associated with human intervertebral disc degeneration

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Introduction: Intervertebral disc (IVD) degeneration, biochemically characterized by degradation of the extracellular matrix, is significantly associated with low back pain. The pathophysiology of IVD degeneration is not entirely understood; however, environmental and endogenous factors under genetic predisposition are considered to initiate the degenerative changes of human IVDs. DNA methylation, one of the epigenetic mechanisms that regulate gene expression, is an essential mechanism to ensure cell-specific gene expression for normal development and tissue stability. Aberrant epigenetic alterations play a pivotal role in several diseases, including cancer, neurodegenerative diseases and osteoarthritis. However, epigenetic alterations, including DNA methylation, in IVD degeneration have not been evaluated. The purpose of this study was to comprehensively compare the genome-wide DNA methylation profiles of human IVD tissues with early and advanced stages of disc degeneration.

Method: Human samples: Human IVD tissues obtained from spine surgeries were used in this study (average age: 55.6 [25-83] years-old). Human IVD tissues were divided into two groups: early stage degeneration (n=8, Pfirrmann's grade: I-III) and advanced stage degeneration (n=8, Pfirrmann's grade: IV). Genome-wide DNA methylation profiling: Genomic DNA isolated from frozen human IVD tissues were processed for genome-wide DNA methylation profiling using the Infinium HumanMethylation450 BeadChip array. Data processing: 1. Extraction of raw methylation data, clustering and scatter plot of each group values of each sample were performed using methylation module in Genomestudio software. 2. Identification of differentially methylated regions (DMRs) was performed using R software with ChAMP package. Gene ontology (GO) analysis: GO analysis was performed using human GO term associations. The enrichment of GO terms was statistically evaluated using the DAVID bioinformatics database functional tool.

Results: 1. Unsupervised hierarchical clustering revealed that early and advanced stage degenerated samples segregated into two main clusters by their DNA methylome. Scatter plots of methylated ratios by both groups identified differentially methylated loci associated with IVD degeneration (Fig. 1). 2. A total of 220 differentially methylated loci (DMLs) were identified between early and advanced stages of degeneration (Table 1). Among these, 4 loci were hypomethylated, and 216 loci were hypermethylated in advanced stage degenerated IVDs. 3. GO enrichment analysis of genes containing DMLs identified 2 significant GO terms for biological processes, such as hemophilic cell adhesion (P=5.86E-06) and cell-cell adhesion (P=9.86E-05).

Discussion: We conducted a genome-wide DNA methylation profile comparative study and observed significant differences in DNA methylation profiles between early and advanced stage of human IVD degeneration. 225 differentially methylated loci were significantly enriched for biological functions, such as cell adhesion, suggesting the implication of DNA methylation in the process of human IVD degeneration.

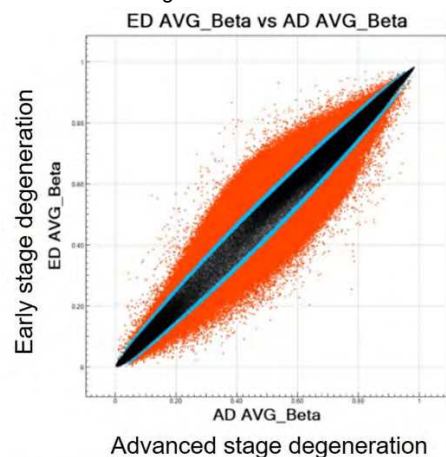


Fig. 1. Scatter plot of DNA methylation

Illumina probe ID	Associated gene	mean Beta		Δmean Beta	adj.P.Val	P.Value	Region
		GroupF	GroupAD				
Hypomethylation							
cg10846936	CARD14	0.58834	0.4774588	-0.110885116	0.0077819	2.27E-07	Body
cg09422970	CRHR1	0.63649	0.5862672	-0.050218804	0.0242955	2.26E-06	5'UTR
cg26175287	C14orf139	0.34208	0.2979304	-0.044147002	0.0319538	3.5E-06	TSS1500
cg04634182	ZBTB47	0.56717	0.4838178	-0.083351824	0.0484236	1.38E-05	5'UTR
Hypermethylation							
cg00106685	GNL3	0.55961	0.6649718	0.105383371	0.0002914	3.93E-10	1stExon
cg22777949	SNORA52	0.18843	0.2721094	0.083679742	0.0005680	1.56E-09	TSS1500
cg24668990	XKR5	0.2109	0.2880199	0.07712002	0.0005680	2.30E-09	Body
cg11871820	MED23	0.17805	0.285811	0.107756592	0.0017788	9.59E-09	TSS200
cg24947371	GPR133	0.6032	0.7683756	0.165178116	0.0027495	1.85E-08	Body

Table. 1. Genes associated with significantly differentially methylated loci

Diurnal variation of vertebral T2-time investigated with T2 mapping

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Introduction: The intervertebral disc (IVD) display a dynamic behavior over the day and MRI performed after/during loading of the spine has been shown to induce IVD T2-time changes. However, how the surrounding tissue, as endplates and vertebrae, respond to loading regarding MRI signal is sparsely investigated. The increasing interest of endplate changes and Modic changes as potential pain generators in low back pain (LBP), along with advancement of functional quantitative MRI techniques, makes it important to establish if a diurnal as well as loading variation in the vertebral body (VB) tissue exists. Therefore, the aim of this study was to investigate the diurnal T2-time variation of the VB and how such is affected by applied load.

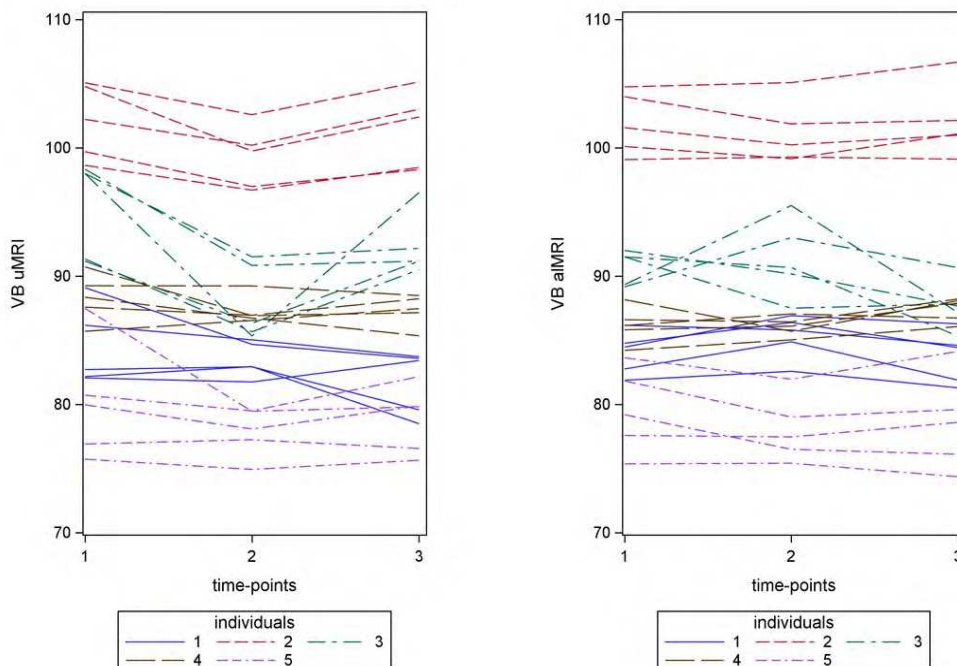
Methods: T2-mapping (1.5T Siemens scanner) of L1-S1 of five healthy volunteers (mean age 40 years, range 27-63) was performed with conventional supine MRI (unloaded MRI=uMRI) and axial loading during MRI (aLMRI), approximately 20 minutes apart, at three time-points during a day (7am, 12am, 5pm). For T2-time determination of the VB (n=25), volumetric regions of interest were segmented. The VB T2-times were compared between the three time-points both at uMRI and aLMRI.

Results: uMRI did not reveal any diurnal T2 variation of the VB, with mean T2 (SD) at the three time-points 86.8 (8.4), 86.6 (8.7) and 87.9 (8.3) ms. aLMRI revealed a significant VB T2 change between all time-points (+1.2ms to -2.9ms, SD range 3.4-3.8), $0.0001 > p < 0.02$.

Contrary to analysis at a group level, in some individuals a very wide range of VB T2 variation was discovered over the day. In addition, there was a wide inter-individual variation in absolute VB T2-values with a range 72.2-108.3ms at uMRI respectively 71.6-107.5ms at aLMRI. The highest range of T2-times were noted in an individual with quite extensive endplate lesions and Modic changes respectively in one individual with multiple Schmorls nodules.

Discussion: This pilot study in healthy individuals show lack of significant diurnal VB T2 variation at uMRI, and minor but significant diurnal T2 variation at aLMRI. However, the wide intra-individual T2 variation in some subjects calls for further investigation to elucidate if, and how, the diurnal T2 pattern of the VB is affected by certain specific tissue characteristics like Modic changes/Schmorls nodules and degeneration grade of adjacent IVDs. It is important to elucidate if T2 mapping of the spine can be performed regardless of time-point and the potential impact of various VB characteristics on the T2-time, in order to adequately interpret T2 mapping data.

Figure 1.



Vertebral body (VB) T2-time (ms) at three time-points (7am, 12am, 5pm) during a day, at both unloaded MRI (left) and at aLMRI (right).

Disc Degeneration – More Than an Aging Process

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Introduction: Disc degeneration is frequently associated with back pain however many people with disc degeneration are asymptomatic. Most systems for disc grading typically rely only on visual features of the disc and do not take age into account. However, disc degeneration is known to increase with age with degenerate discs more prevalent in older individuals. Here, we investigated the prevalence of disc degeneration, in the form of Pfirrmann grading, in different age groups in both a symptomatic clinical sample and in a population sample having back pain information.

Methods: Two study samples were included: (1) a population sample from TwinsUK which consisted of 968 volunteers (mean age 56.1 ± 9.4) with follow-up scans 1384 scans in total, 8292 discs, and (2) a symptomatic clinical sample from Oxford Secondary Care Lumbar MRI Cohorts (OSCLMRIC) which consisted of 660 patients (mean age 51.8 ± 15.4) having a total of 905 scans, 5411 discs. Since TwinsUK consist mainly of female volunteers, only scans from female patients in OSCLMRIC were used in this study. Scans are T2-weighted sagittal; scans in OSCLMRIC vary in terms of acquisition and protocol unlike scans in TwinsUK. For each scan, we look at the Pfirrmann grading (grading 1 to 5) of the lower two lumbar discs, L4-L5 and L5-S1, where the mean grading of the two discs provided one grading per scan. Gradings were obtained automatically using SpineNet and are consistent across the study samples. SpineNet provides rapid automatic reading comparable with those of a radiologist, and is able to compare info from large cohorts even if read on different machines without tremendous time and labour effort. We examined four age groups: 30-39, 40-49, 50-59, and 60-69 years.

Results: Figure 1 shows the frequency of the Pfirrmann grading by age group. Disc degeneration follows aging as the average grading of the discs tend to get higher as the subjects get older. This progression can be seen both in the population and clinical samples. Interestingly, we observed differences in distributions between the two samples in younger age groups, 30-39 and 40-49, but not in older age groups. These differences are even clearer when we look at the average Pfirrmann grading of the two samples, again in different age groups, shown in Table 1 and Figure 2.

Discussion: The results obtained by comparing two different cohorts, both analysed by automated image analysis on the same grading system, show a clear difference in the Pfirrmann grading of disc degeneration between the clinical and population samples at the younger age groups, but this difference disappears in the 50-69 years age groups. The results indicate that when considering the clinical significance of degeneration scores, age needs to be taken into account.

Table 1. Means, standard deviations, differences of the means, and the null hypothesis results of the Pfirrmann grading by age groups.

Age Groups	Population (TwinsUK)	Clinical (OSCLMRIC)	Difference	H ₀ at 5% Significance Level (Mann-Whitney U test)
30 - 39	2.44 ± 1.14	3.12 ± 1.14	0.68	Reject (p ≤ 0.05)
40 - 49	3.13 ± 1.08	3.40 ± 0.91	0.27	Reject (p ≤ 0.05)
50 - 59	3.55 ± 0.94	3.62 ± 0.83	0.07	Does not reject (p > 0.05)
60 - 69	3.93 ± 0.75	4.02 ± 0.73	0.09	Does not reject (p > 0.05)

Figure 1. Frequency of Pfirrmann grading in different age groups in population (TwinsUK) and clinical (OSCLMRIC) samples.

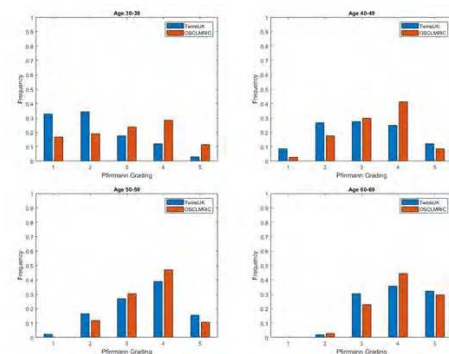
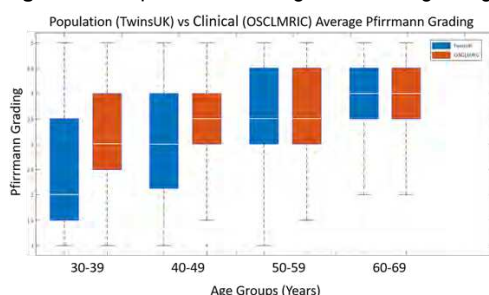


Figure 2. Box plot of the average Pfirrmann grading of clinical and population samples.



Is the Lumbar Spinous Process a Reliable Sagittal Plane Reference Landmark?

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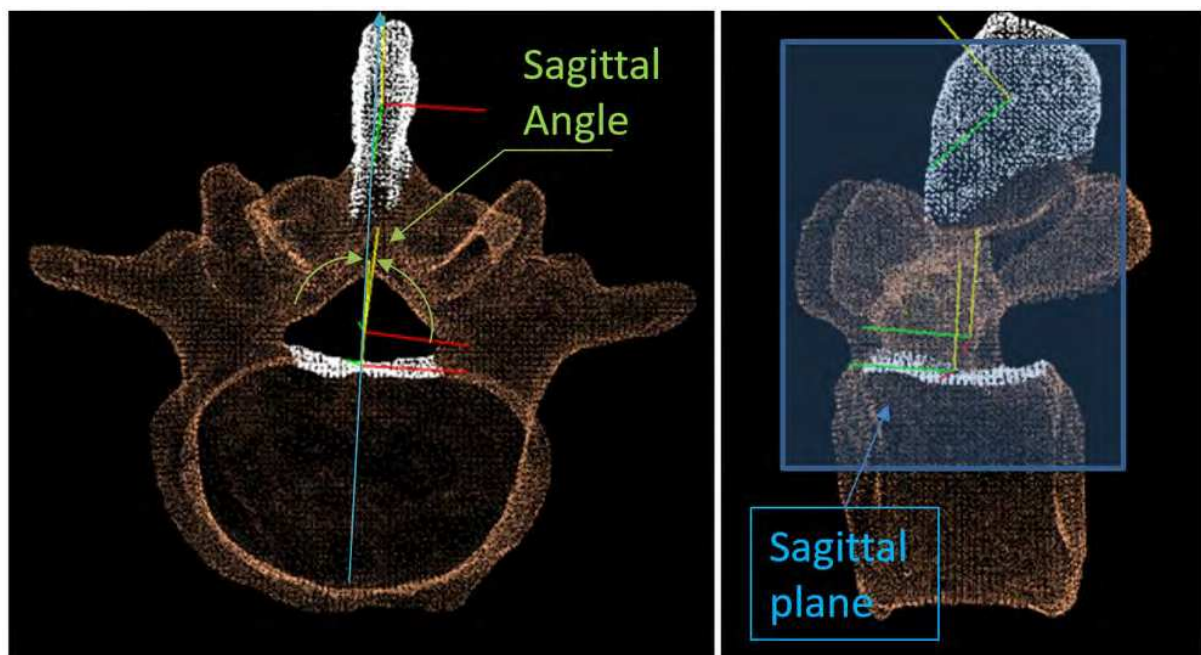
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Introduction: The spinous process is a structural component of the vertebral spine that is commonly employed as anchoring for spinal hardware in surgical cases and also as a reference landmark to define the sagittal plane assuming a 90° angle between it and the posterior wall to analyze tropism in the lumbar spine. To date, there is scarce data in the literature about its morphology and symmetry on the transverse plane usually seen on axial cuts in MR or CT clinical scans. Therefore, the objective of this work was to contribute to the field with an *in vivo* three-dimensional determination of the orientation of the spinous process on CT scans of asymptomatic and low-back pain subjects with respect to the sagittal plane.

Methods: A total of n=77 subjects (38M, 39F; age range 22-59 y.o.) were enrolled in this IRB-approved study. Thirty were symptomatic for low back pain with the remaining 47 recruited as controls. Lumbar CT scans were used to segment individual vertebrae using commercially available software. Custom-written Visual C++ routines aided in modeling the spinous process as a solid structure [1, 2] and its principal axis was determined via eigenvectors. This principal axis was effectively the tube axis and its orientation was referenced to a local Cartesian coordinate system set on each vertebral posterior wall centroid [1,3] (Fig. 1). The angle between the spinous process principal axis and the sagittal plane on the transverse plane was reported as the Sagittal Angle. A positive value was associated with the left side, the opposite side being negative. Results are presented as mean±SEM and significance was set at $p < 0.05$.

Results: Overall, spinous processes in females were tilted to the left compared to those in males ($0.84^\circ \pm 0.33^\circ$ vs. $0.22^\circ \pm 0.31^\circ$, $p = 0.019$), with a range of $+11.5^\circ$ to -22.3° . When considering lumbar levels, while the mean values were smaller in the upper levels, there were no statistically significant differences between levels. The values for sagittal angles and [range] were $0.09^\circ \pm 0.45^\circ$ [-10.3° , $+9.3^\circ$] at L1; $-0.22^\circ \pm 0.47^\circ$ [-13.8° , 8°] at L2; $0.06^\circ \pm 0.47^\circ$ [-12.2° , $+9.3^\circ$] at L3; $-0.77^\circ \pm 0.41^\circ$ [-8.7° , $+6.1^\circ$] at L4, and $-0.78^\circ \pm 0.69^\circ$ [-22.3° , $+11.5^\circ$] at L5, respectively. Importantly, there was no difference in orientation between asymptomatic and symptomatic subjects.

Discussion: This study showed that the spinous process, which is usually thought to be the physical representation of the sagittal plane when the spine is upright, is not necessarily co-planar with said anatomical plane. However, as with many features in the human body, it can be subject to asymmetry. This imbalance in orientation has biomechanical implications as the spinous processes are muscle attachment sites. The resulting mechanical imbalance may influence the spinal loading, function and possible spinal degeneration pathways. However, more importantly, these results question the reliability of the spinous process as a dependable landmark to establish the sagittal plane, particularly in cases of characterization of tropism. Further studies are warranted that can define new suitable measurements/parameters and analysis techniques.



1. Sugisaki K, An HS, Espinoza Orías AA, Rhim R, Andersson GB, Inoue N. Spine (Phila Pa 1976). 2009 Nov 15;34(24):2599-604.
2. Aliaga Crespo BA, Espinoza Orías AA, Andersson GBJ, An HS, Inoue N. GP112 Proc. 45th ISSLS Annual Meeting Banff, Canada, May 14-18, 2018
3. Udayakumar R, An HS, Espinoza Orías AA, Sugisaki K, Andersson GBJ, Inoue N. Proc. ISLSS 36th Annual Meeting, Loews Hotel, South Beach, Miami, FL. May 4-8, 2009

Is the anatomy of failure in lumbar disc herniation clinically relevant?: a prospective study

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Introduction: Lumbar disc herniation (LDH) is one of the most common spine pathologies. Recently end plate junctional failure (EPJF)(Type I failure) has been proposed as the predominant mode of LDH challenging the old dogma of annulus fibrosus (AF)(Type II failure) being the most common site of rupture. Since the clinical relevance of this finding is yet to be established, we conducted this study to substantiate the evidence and determine whether there are differences in incidence, presentation, progression as well as outcomes (particularly need for surgery) between the two types of disc failure.

Methods: A prospective study was carried out including patients 15 to 65 years of age presenting with symptoms typical of single level LDH with radiculopathy and in whom a conservative treatment was proposed at the initial presentation. MRI and CT scan of the lumbosacral spine was performed for all the patients to confirm the diagnosis, the level and type of disc herniation. The patients were divided in two groups based on CT scans, EPJF group (Type I herniation) and AF group (Type II herniation). Visual Analog scale (VAS) score, modified Oswestry Disability Index (mODI) score, Sciatica Frequency Index (SFI) and Sciatica Bothersome Index (SBI) were taken for each patient at presentation and then at 3 months, 6 months and 12 months follow-up.

Results: Out of a total of 111 patients (Male: Female = 77:34), 44 were classified as EPJF group and 67 as AF group. Both the groups were similar with respect to the descriptive variables and MRI features like level, stage and location of disc herniation. There was no significant difference ($p>0.05$) in the mean VAS score, mODI score, SFI and SBI at the initial presentation in both the groups. After excluding losses to follow-up (17 patients), both the groups had similar outcomes at 3 months, 6 months and finally at 1 year. 5 patients (13.2%) of EPJF group (n=38) and 4 (7.1 %) of AF group (n=56) needed surgery. The clinical indices in the patients managed conservatively or surgically in both the groups were similar at the initial presentation, during course of follow-up and at the end of 12 months. Using repeated measures ANOVA all the outcome variables were statistically insignificant between the groups.

Discussion: In some previous in-vitro studies as well as in the in-vivo study by Rajasekaran et al, it has been postulated that EPJF is the predominant mode of structural failure of the disc and that the group of patients requiring surgery have a higher incidence of EPJF. This study contradicts this claim by providing prospective evidence that the incidence of AF rupture (Type II failure) is higher in the overall cohort of LDH patients. Since the clinical presentation and prognosis is similar irrespective of the type of disc herniation, this study questions the relevance of determining the anatomy of disc failure in LDH patients. A larger multicenter study is required to draw a definite conclusion in this regard.

Lumbar spine slenderness in adolescent idiopathic scoliosis

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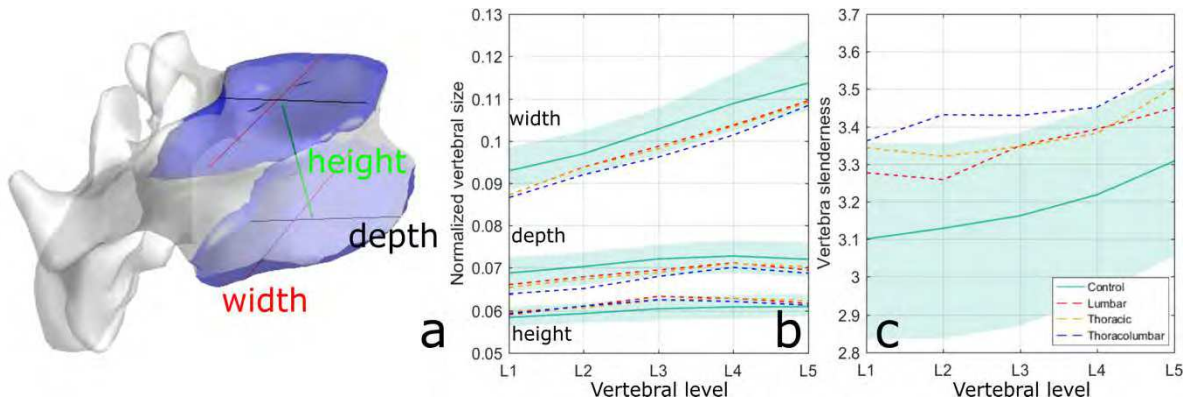
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Introduction: The deformity of the scoliotic spine (a lateral displacement of the apical vertebra, a torsion of the vertebral column and a flattening of the sagittal profile) is often compared to a buckling, which is a form of mechanical instability that may occur in slender structures under compressive loading. It is more likely for buckling to occur in a long and slender structure, such as the spine, rather than in a short and thick one. Spine slenderness is suspected to play a role in the progression of scoliosis; however, the impact that curve topologies has on slenderness is not yet known. Since lumbar region is the mechanical foundation of the spine, the hypotheses of this study were that slenderness of lumbar spine in adolescent idiopathic scoliosis (AIS) patients would be different than healthy subject, and that curve topology could affect slenderness.

Methods: Eighty-three control subjects (14 ± 3 years old) and 321 AIS patients (14 ± 2 years old, Cobb angle $35^\circ \pm 18^\circ$) were included in this study, after ethical committee approval. AIS patients were grouped by curve topology: thoracic (T), thoracolumbar (TL) and lumbar (L). They all underwent low-dose calibrated biplanar radiography in standing position, and their spine was reconstructed in 3D with previously validated methods. Height, width and depth of lumbar vertebrae were computed from the 3D reconstruction (Figure 1a), and they were normalized by vertical spinal length to account for differences in subject height. Slenderness ratio was then calculated as the ratio of vertebral body height and the minimal endplate radius of gyration, which is a means of calculating cross-sectional size while accounting for cross-sectional shape. Differences between AIS patients and healthy subjects were analyzed by curve topology at all vertebral levels with Mann-Whitney tests.

Results: Figure 1 reports normalized vertebral size and Figure 1b slenderness ratios of L1-L5 vertebrae; the shaded area represents the 1st and 3rd quartiles of values in healthy subjects. AIS patients had significantly taller but narrower and shallower vertebrae than healthy ones at L2 to L4 levels ($p < 0.05$), irrespective of curve topology. Consistently, vertebral slenderness ratio was significantly higher at all vertebral levels ($p < 0.05$). TL patients had the slenderest vertebrae, because they were narrower and shallower but with similar height than the other AIS patients (Figure 1b). Slenderness of the apical vertebra tended to decrease with Cobb angle ($p < 0.001$, $r = -0.25$) and increase with age ($r = 0.3$).

Discussion: In this study, lumbar spine morphology of AIS patients was evaluated with minimally invasive imaging methods, in standing position, and it was compared to that of controls. AIS patients had slenderer lumbar spines than controls; thus, the foundation of the spinal structure was mechanically less stable. This instability was common to all curve topologies but more pronounced in TL curves. Nevertheless, slenderness tended to decrease with scoliosis severity. These findings could potentially have an impact on the decision to treat, since lumbar instability might play a role on deformity progression or treatment efficacy.



Does Body Mass Index Affect Spinal Alignment and Low Back Pain in Patients with Primary Osteoporosis?

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Introduction: Obesity is associated with an increased risk of worsening the severity and dysfunction of chronic low back pain and cervical pain. Conversely, excessive weight loss decreases estrogen levels and promotes poor nutrition, enhancing the risk of osteoporosis. Few papers provide detailed information on patient characteristics such as the body types of osteoporosis patients in such studies. Based on the hypothesis that differences in body type influence vital patient characteristics such as bone mineral density, low back pain, and spinal alignment, we studied how Body Mass Index (BMI) might affect these findings in patients with osteoporosis.

Methods: A total of 144 women aged ≥ 60 years with primary osteoporosis were enrolled in this study. Bone mineral density was measured by the DEXA method (lumbar spine, femoral neck); total body lean muscle mass and limb muscle mass (corrected by squaring body height) were determined through bioelectrical impedance analysis; and pelvic tilt (PT), pelvic incidence minus lumbar lordosis (PI-LL) and sagittal vertical axis (SVA) were assessed from the whole spine standing x-rays to evaluate sagittal spine alignment. Nutritional status was determined from the Controlling Nutritional Status (CONUT) score, and the Oswestry disability index was the low back pain score. Patients were compared after stratification based on BMI into the low BMI group (BMI < 20), normal BMI group (≥ 20 BMI < 25) or high BMI group (BMI ≥ 25).

Results: Lumbar spine bone mineral density showed a tendency to be lower in the low BMI group, while femoral neck bone density was significantly lower in the low BMI group ($p < 0.05$). Corrected total body lean muscle mass and corrected limb muscle mass were both low in the low BMI group and high in the high BMI group. Patients in the low BMI group had low SVA levels, high CONUT scores, low ODI scores, and low VAS scores ($p < 0.05$), but in the high BMI group, there were no significant changes in these parameters. No significant differences were noted among the 3 groups in PT and PI-LL values.

Discussion: This study showed that despite low bone density, low muscle mass, and poor nutritional status, sagittal alignment had been maintained with little low back pain in patients with low BMIs. The bones and muscles of patients with low BMI do not bear as much weight, so despite low bone mineral density and low skeletal muscle mass, the spine is not as stressed, resulting in maintenance of a better spinal balance. However, since these patients do have lower bone mineral density, lower muscle mass, and poorer nutritional status, if they do happen to suffer a vertebral fracture, there is a possibility that misalignment of the spine may result. For this reason, active implementation of exercise therapy and nutritional counseling may prove to be quite effective in patients with low BMI.

Conclusions: Osteoporosis patients with low BMI had maintained their osagittal spinal alignment with little low back pain despite reduced bone mineral density, reduced muscle mass, and poor nutritional status.

A network meta-analysis of effectiveness of specific modes of exercise for chronic low back pain

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Introduction: Meta-analyses showed that passive therapies, such as ultrasound [1] and massage [2] are ineffective for treating CLBP. However, various modes of exercise have been shown by pair-wise meta-analysis [3], to be effective for reducing CLBP. It is unclear however whether some specific modes of exercise be more effective than others for non-specific CLBP. Our aim was to conduct a network meta-analysis to compare, and rank, different kinds of interventions to examine the effectiveness of specific exercise approaches for reducing pain and improving function in non-specific CLBP.

Methods: Five electronic databases and references of previous systematic reviews were searched (PROSPERO registration: CRD42017068668). Eligible studies were randomised controlled or clinical trials that examined the efficacy of exercise training compared to either non-exercise training treatments or a different exercise training on pain and physical function in adults with non-specific chronic low back pain. Exercise modalities examined were resistance training, stabilisation/motor control, Pilates, yoga, McKenzie, flexion based exercises, aerobic exercise, water-based exercises, stretching, multimodal and 'other'. Control interventions considered included no-treatment control group (reference), 'hands-off' control (e.g. general practitioner management, education or psychological interventions) and 'hands-on' control (e.g. manual therapy, chiropractic, passive physiotherapy, osteopathic, massage or acupuncture). Intervention effects were estimated using standardised mean differences (SMD). Random effects network meta-analyses were conducted to compare different exercises and non-exercise interventions.

Results: After title and abstract review of 6,217 records and subsequent full text screening by at least two reviewers, 71 studies were included in the qualitative synthesis with 103 exercise interventions, 42 control comparators, and a total of 4414 participants. For reducing pain, Pilates (pooled SMD [95% CI]: -1.76[-2.75,-0.78], $p < 0.0001$), aerobic exercise (-1.33[-2.51,-0.15], $p = 0.027$) and stabilisation/motor control (-1.44[-2.10,-0.78], $p < 0.0001$) were, respectively, 55%, 19% and 15% likely to be the best intervention. No-treatment control (reference) and hands-off control (-0.09[-1.14,0.96], $p = 0.87$) were 51% and 37% likely to be the most ineffective interventions. For improving function, 'other' (-0.85[-1.45,-0.26], $p = 0.005$), Pilates (-1.03[-1.71,-0.35], $p = 0.003$) and stabilisation/motor control (-1.09[-1.56,-0.62], $p < 0.0001$) were, respectively, 25%, 25% and 24% likely to be the best intervention. No-intervention control (reference) and 'hands-on' control (-0.28[-0.93,0.37], $p = 0.39$) were 71% and 12% respectively to be the least effective interventions. The test for network inconsistency was significant for both the pain ($p = 0.02$) and function ($p < 0.0001$) outcomes. 51 studies (72%) were at high risk of bias on at least one domain (excluding participant blinding) of the Cochrane Collaboration Risk of Bias Tool.

Discussion: Whilst it is known that exercise, in general, can improve CLBP, the current study is the first network meta-analysis to consider the effectiveness of specific kinds of exercise for improving pain and function in non-specific CLBP. Our findings suggest that active modes of exercise (such as aerobic exercise, Pilates, stabilisation exercise) may be more beneficial for non-specific CLBP than light forms (such as stretching). The findings provide additional evidence against passive therapies for CLBP. Heterogeneity between studies and few studies with low risk of bias are limitations.

[1] Ebadi et al. Cochrane Database of Systematic Reviews. 2011;3.

[2] Furlan et al. Spine. 2002;27(17):1896-910.

[3] Searle et al. Clin Rehab 29:1155-67

Optimising conservative management of chronic low back pain: a randomised trial of general strength and conditioning versus motor control manual therapy.

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Introduction: Exercise and spinal manipulative therapy are commonly used in practice for the treatment of chronic low back pain (CLBP). Pain intensity is the most studied outcome, however self-report pain has limited efficacy for differentiating interventions. Physical function (e.g. trunk endurance) and other self-reported measures (e.g. kinesiophobia) are important clinical outcomes that have received limited attention to date. We assessed two common conservative treatments, general strength and conditioning (GSC) and motor control exercise plus manual therapy (MCMT), for treating CLBP on physical function and self-reported outcomes.

Methods: Participants aged 25-45 years with CLBP (≥ 12 weeks) were randomised to a 6-month intervention of MCMT (n=20) or GSC (n=20). The primary outcome was trunk extension endurance, with trunk flexion endurance, leg strength and endurance, cardio-respiratory fitness and self-report measures of kinesiophobia, disability, quality of life and pain intensity as secondary outcomes. Data was collected at baseline, three and six months. Random effects linear mixed models with an intent-to-treat approach were used to analyse data to determine a group by time interaction between the interventions.

Results: At six months, GSC had greater improvements in trunk extension endurance (mean difference [95% confidence interval]: 81.8 [34.8, 128.8] seconds; $p=0.004$), trunk flexion endurance (51.5 [20.5, 82.6] seconds; $p=0.004$), leg muscle strength (24.7 [3.4, 46.0] kilograms; $p=0.001$) and leg muscle endurance (9.1 [1.7, 16.4] repetitions; $p=0.015$) compared to MCMT. GSC also had greater improvements in disability (-5.7 [-11.2, -0.2] %; $p=0.041$) and kinesiophobia (-6.6 [-9.9, -3.2] points; $p<0.001$) when compared to MCMT at six months. No between-group differences were seen for cardio-respiratory fitness or quality of life at the end of the intervention. Pain intensity had significant within-group reductions in MCMT and GSC (both, $p<0.001$), however no between-group differences were observed.

Discussion: GSC significantly improved trunk endurance, leg muscle strength and endurance, self-report disability and kinesiophobia compared to MCMT. Both interventions had similar reductions in pain intensity. These results provide important findings into the effectiveness of GSC and MCMT on outcomes beyond pain intensity. It is possible that additional benefits can be achieved through GSC compared to MCMT and should be considered when treating an individual with CLBP. Lastly, these results may allow patients and clinicians to make a well-informed treatment decision based on additional goals beyond reducing pain intensity.

Voluntary Physical Activity Reinforces the Efficacy of Acute Non-Steroidal Anti-inflammatory Drug Treatment for Osteoporosis-related Pain in a Mouse Model of Ovariectomy-induced Osteoporosis

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Introduction: Osteoporosis-related pain can result from local fractures but also occurs in the absence of observable bone trauma. We reported cutaneous hypersensitivity and deep musculoskeletal pain in a mouse model of ovariectomy (OVX)-induced osteoporosis and partial pain control with anti-osteoporosis drugs, so additional treatments are necessary for osteoporosis-related pain. Exercise therapy is effective for improving bone density and musculoskeletal pain, including low back pain and arthritis. Furthermore, non-steroidal anti-inflammatory drugs (NSAIDs) are widely prescribed drugs for musculoskeletal pain and inflammation. However, the individual or combined effect of increased physical activity with NSAIDs on osteoporosis-related pain is unknown. This study aimed to investigate the effect of exercise therapy on bone mineral density (BMD) and behavioral indexes of osteoporosis-related pain in OVX mice and when combined with acute ibuprofen treatment.

Methods: C57BL6 female mice (n=57) at age 6 weeks were randomly assigned to receive access to running (running group) or fixed wheel (sedentary group) in their home cages. After three months with wheel access, OVX and sham surgery were performed. After allowing 10 weeks for osteoporosis to develop, mice were randomly assigned to receive either ibuprofen or vehicle (sham/vehicle, OVX/vehicle, OVX/running, OVX/ibuprofen, or OVX/running+ibuprofen; n=8 per group). Vertebral and femoral BMD were evaluated before the behavioral testing and after ibuprofen treatment. The animals received ibuprofen (60 mg/kg, 20 mg/ml orally) or vehicle (3.0 mL/kg orally, sucralose syrup). Mice were then monitored at baseline, and 60, 120, and 180 min after treatment for cutaneous hind-paw hypersensitivity (von Frey, acetone-evoked behavior, and radiant heat), deep musculoskeletal discomfort (grip test assay), and physical function (rotarod assay).

Results: Vertebral and femoral BMD, cutaneous hind-paw hypersensitivity, and deep musculoskeletal pain were significantly altered in the OVX mice than in the sham-operated controls ($p < 0.05$). The OVX/running group showed significant improvement in vertebral BMD ($p < 0.05$) but cutaneous hind-paw hypersensitivity and deep musculoskeletal pain were not affected. Ibuprofen had partial efficacy on cold and heat hypersensitivity 120 min after treatment ($p < 0.05$). By contrast, ibuprofen+running in the OVX mice had significantly greater efficacy than ibuprofen alone ($p < 0.0001$). The OVX-induced impairment in grip force strength, used as a measure of deep musculoskeletal discomfort, was insensitive to both exercise and ibuprofen therapy. No changes were observed in the rotarod for overall motor function.

Discussion: We demonstrated efficacy of the combination of exercise and acute ibuprofen treatment in the OVX mouse model of osteoporosis-related pain. Although exercise did not directly affect pain in this study, exercise positively influenced physical function and consequently, may lead to increased NSAID efficacy. This study suggests that exercise therapy improves BMD and may enhance the effect of NSAIDs in patients with osteoporosis.

Statistical morphometric analysis of lumbar paraspinal muscles in patients with lumbar pathology

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Introduction: Recent evidence suggests an association between low back pain (LBP) and lumbar paraspinal muscle morphometric changes, such as atrophy. Quantitative measurements of muscle cross-sectional area (CSA) are commonly used to examine their relationship with different LBP conditions. However, measurements of this kind fail to describe detailed morphometric property alterations (e.g. variation) within each muscle group. Statistical shape analysis is a technique that can extract the morphometric variations (called a mode) from the population under study and rank their contributions to help intuitively uncover morphometric patterns associated with diseases. This method has been successfully used in cardiac and brain MR imaging¹, but not for lumbar paraspinal muscles so far. We employed statistical shape analysis to determine the global and local shape variations in lumbar paraspinal muscles, related to lumbar disc herniation and spinal stenosis for patients with LBP.

Methods: We selected lumbosacral MR images of 112 patients (male=59, age=30~59yo) participating in the Genodisc European research consortium project on commonly diagnosed lumbar pathologies. 66 of the participants had been diagnosed with disc herniation, 31 with spinal stenosis, and 13 with both conditions. Axial T2-weighted MRI scans of the L4-L5 and L5-S1 levels at mid-disc were used for analysis. The left and right multifidus, psoas, and erector spinae muscles were manually segmented. To establish the common coordinates needed for shape analysis, population-averaged MRI templates (**Fig.1**) were constructed by deforming and averaging all MR images using group-wise nonlinear registration for each level². To normalize the global individual size differences and reveal localized shape variations, the muscle segmentations were linearly registered to MRI templates that represented the averaged anatomy of the muscles of interest. With statistical shape analysis of the linearly deformed muscle segmentations, the dominant principal shape variations (or modes) explaining 95% of the morphometric variations among the cohort were extracted. Pearson correlation coefficients between each mode and one condition (disc herniation or spinal stenosis) were computed while controlling for age, sex and the other lumbar condition.

Results: The modes associated with significant correlations ($p < 0.05$) are visualized in **Fig.1**, with the contribution of each mode in descending order (i.e., Mode 1 has the highest contribution). Overall, 6~14 modes account for 95% of the shape variations for each muscle. The analysis shows that lumbar disc herniation is associated with a globally smaller right multifidus muscle at the L4-L5 level, and larger left psoas and right multifidus muscles at the L5-S1 level. For spinal stenosis, we found a lateral increase in right multifidus muscle and a flattening of the right psoas muscle at the L4-L5 level. At the L5-S1 level for the same condition, there was a reduction at the lateroposterior site of the right multifidus muscle and a thinner right erector spinae muscle.

Discussion: Statistical shape analysis can help reveal detailed morphometric variations of the lumbar paraspinal muscles potentially related to lumbar pathology, in this case disc herniation and spinal stenosis. Further investigation is required to better understand the specific morphometric paraspinal muscle characteristics associated with side and level of pathology, and other lumbar conditions.

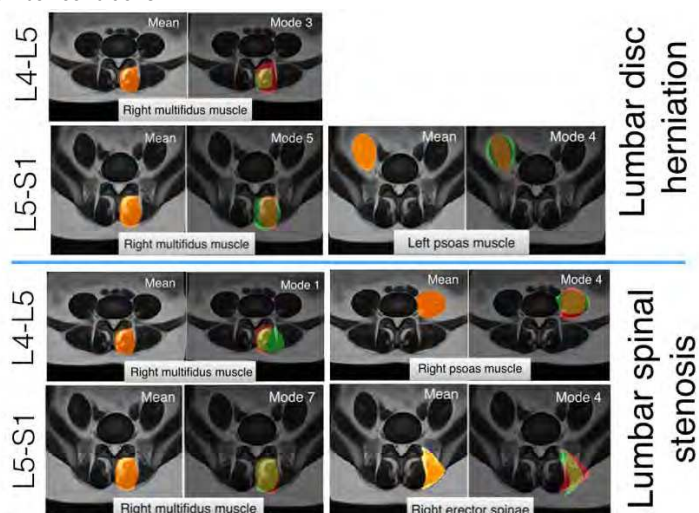


Figure 1. Shape variations linked to significant correlation ($p < 0.05$) with lumbar disc herniation (top rows) and spinal stenosis (bottom rows) at L4-L5 and L5-S1 levels. The mean shapes of the muscles of the cohort are shown in orange while the respective shape variations in two extreme directions (3 standard deviations from the mean) are shown in green and red overlaid together on the right-hand side of the corresponding mean shapes. Here, the green labels represent the trend of shape alteration due to diseases.

1. Y. Xiao, P. Jannin, T. D'Albis, N. Guizard, C. Haegelen, L. Florent, M. Verin, and D. Louis Collins, "Investigation of morphometric variability of subthalamic nucleus, red nucleus and substantia nigra in advanced Parkinson's disease patients using automatic segmentation and PCA-based analysis," *Human Brain Mapping*, 35, 4330-4344, 2014.
2. Y. Xiao, M. Fortin, M. Battie, and H. Rivaz, "Population-averaged MRI atlases for automated image processing and assessments of lumbar paraspinal muscles," *European Spine Journal*, 27(10), 2442-2448, 2018.

Analysis of skeletal muscle mass in women over 40 with degenerative lumbar scoliosis

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Introduction: With an aging society, there is an increasing number of patients who have trouble in their daily lives due to scoliosis. lumbar scoliosis causes low back pain and disrupts activities of daily living (ADLs). As a result of spinal deformities, back pain, low back pain, gait disturbances due to truncal balance failure, reflux esophagitis, and various cosmetic psychological problems, among others become problematic for ADLs. Although spinal muscle degeneration has been implicated in spinal deformity, there are no reports on the relationship between trunk and appendicular skeletal muscle and spinal deformity. We investigated the involvement of sarcopenia and osteoporosis in middle-aged and elderly women with degenerative lumbar scoliosis (DLS).

Methods: 971 women (mean age 70.4 years) were included in our study. These included 87 cases of DLS (mean 73.8 years), and 884 controls (69.8). Lumbar and femur BMD was measured for all participants using dual-energy X-ray absorptiometry (DXA). We used a bioelectrical impedance analyzer (BIA) to analyze body composition, including appendicular skeletal muscle mass index (SMI; appendicular lean mass (kg)/(height (m))²). We determined bone density and skeletal muscle mass in both groups and determined the prevalence of sarcopenia. We examined the correlation between bone density and appendicular muscle mass in both groups. We also examined factors related to scoliosis using logistic regression analysis.

Results: The DLS group showed significantly higher lumbar BMD, lower femur BMD, lower lean mass arm, and lower lean mass leg, and lower lean mass trunk ($p < 0.05$). Sarcopenia prevalence (SMI < 5.75) was 59.8% in DLS subjects and 42.8% in controls, revealing a high prevalence in DLS ($p < 0.05$). In both groups, lumbar and femur BMD were positively correlated with appendicular muscle mass. By logistic regression analysis, trunk muscle mass was detected as a risk factor for DLS independent of age ($p < 0.05$).

Discussion: The result of this study revealed a high prevalence of sarcopenia in DLS in middle-aged and elderly women. A decrease in trunk muscle was a significant risk factor for DLS that was independent of age. To the best of our knowledge, there has been no previous large-scale study on the skeletal muscle mass in patients with degenerative lumbar scoliosis.

Bony stress in the lumbar spine is associated with disc degeneration and pain in the lower back. A retrospective case-control MRI study of patients under 25-years of age.

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Introduction: Abnormal stress in the bone can be a precursor to a bony stress fracture and intervertebral disc (IVD) degeneration. Previous studies have shown an increased prevalence of IVD degeneration in the presence of bony stress. However, the prevalence of bony stress and its relationship with IVD degeneration in the lumbar spine and pain is not well understood. Therefore the aim was to assess the prevalence of bony stress in the lumbar spine and its relationship with IVD degeneration, facet osteoarthritis and lower back pain in patients under 25-years of age.

Methods: A retrospective case-control study of 130 patients under 25-years of age was conducted from a population of 493 patients who had lumbar magnetic resonance imaging (MRI) across three centres over a three-year period. MRI scans and reports were read and evaluated and a cohort of patients (n= 55) with bony stress was identified. A control group of consecutive patients without bony stress (n= 75) was also identified from the population. The prevalence of IVD degeneration, facet osteoarthritis and pain in the lower back were compared between the two groups.

Results: Bony stress was prevalent in 11% (55/493) (95% CI [8.4% - 14.5%]) of patients and was not diagnosed in 36% (20/55) (95% CI [22-55%]) of these cases. Patients with bony stress had over two-fold (OR 2.3 95% CI [1.1 - 4.8]) and five-fold (OR 5.3 95% CI [2.11 – 13.3]) higher likelihood of having IVD degeneration and lower back pain, respectively, when compared to the control group. Bony stress was not associated with facet osteoarthritis ($P=0.07$).

Discussion: Bony stress in the lumbar spine was prevalent in 11% of patients under 25-years of age. It was commonly undiagnosed in radiology reports (not reported in 36% of the cases) and is associated with increased likelihood of IVD degeneration and lower back pain.

Prevention of adjacent segmental disease after fusion in degenerative spinal disorder: correlation between segmental lumbar lordosis ratio and PI-LL mismatch for a minimum 5-year follow-up

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Introduction: Associations among risk factors related to adjacent segmental disease (ASD) are still unclear. This study aimed to evaluate the risk factors and segmental lordosis ratio to prevent ASD developing after lumbar spinal fusion.

Methods: Data of 274 patients who underwent lumbar spinal fusion of three segments or below for lumbar degenerative disease from January 2010 to December 2012, with over 5 years of follow-up, were retrospectively reviewed. Patients with preoperative sagittal vertical axis (SVA) >5 cm were excluded due to sagittal imbalance. Thirty-seven patients with ASD (ASDs) and 40 patients (CTRL) were randomly selected in a similar distribution of matching variables: age, sex, and preoperative degenerative changes. Sex, age, number of fusion segments, radiological measurements, L4-5-S1/L1-S1 lumbar lordosis (LL) ratio, and spinopelvic parameters (PI, pelvic tilt [PT], pelvic incidence [PI], sacral slope [SS], and SVA) were analyzed. Logistic regression was used to analyze the correlation between PI-LL mismatch and L4-5-S1 segmental lordosis rate.

Results: No significant difference was found between ASDs and CTRL groups regarding age, sex, number of fusion segments, fusion method, and preoperative and postoperative spinopelvic parameters (PI, SS, PT, and LL). However, in L4-5-S1/L1-S1 lordosis ratio, 50% (p=.045), 60% (p=.031), 70% (p=.042), 80% (p=.023), and 90% (p=.023) were statistically significant; less than 20% (p=.478), 30% (p=.223), and 40% (p=.089) were not statistically significant. In the postoperative PI-LL <10 group, ASD occurred less frequently than in the PI-LL >10 group, and the difference was statistically significant (p=.048).

Discussion: Patients with postoperative L4-5-S1/L1-S1 lordosis ratio more than 50% were found to have less occurrence of ASD. Correcting LL according to PI and physiologic segmental lordosis ratio is important in preventing ASD.

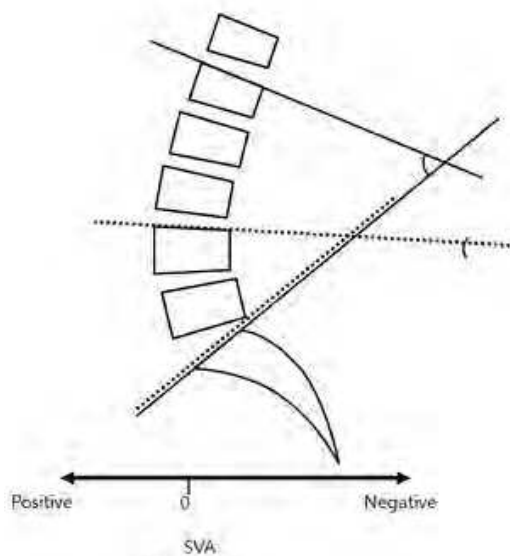
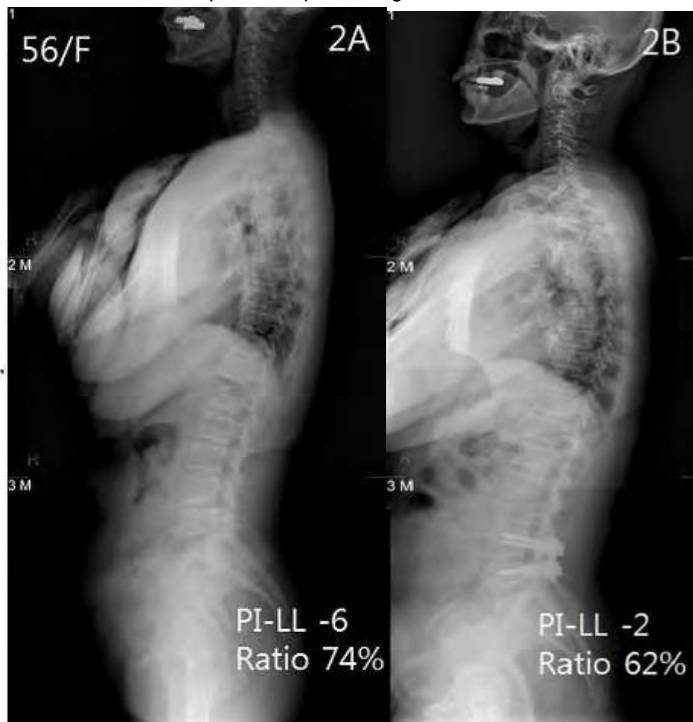


Figure 1



What factors affect low back pain of patients with Adolescent Idiopathic Scoliosis average 35 years after surgery?

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Purpose: Little is known what is affecting low back pain(LBP) with adolescent idiopathic scoliosis(AIS) after surgery. The purpose of this study was to analyze what affects LBP of patients with AIS long term follow up after surgery.

Methods: The subjects were 26 patients who underwent corrective surgery for AIS at university hospital during 1970 and 1987 were reviewed. Among them, 22 people were consecutive who got consent. Twenty-two long-term follow-up AIS patients (3 males, 19 females; average age 49.4 ± 5.4 years) with an average Cobb angle of the main curve of $52.4 \pm 18.4^\circ$ were included. Their average duration of follow-up was 35.5 ± 4.4 (27-44) years. The surgical method was Harrington instrumentation (HI) (9 cases), HI Wiring (8), Chiba solid rod (1), Zielke (1), Dwyer (2), Luque (1). Following parameters at people were investigated : height , weight, current Cobb angle, Cobb angle improvement rate from preoperative, number of fused vertebra, sagittal vertebral axis (SVA), grip strength, flexibility. And LBP was evaluated by Oswestry Disability Index(ODI).ODI score of all cases was defined more than 4.2%(median) as LBP(LBP Group) and less than Non LBP(Non LBP Group) and changes in the parameters were tested using the Wilcoxon rank sum test. And the relationship between objective variables(LBP) and explanation variables(each parameters) was evaluated according to a multivariate logistic model.

Results: In both group (LBP/Non LBP) observed a significant difference at Cobb angle improvement rate from preoperative(42.6%/51.7%), SVA(36.3mm/16.4mm), flexibility: the deviation value was calculated (37.9/43.4).The multiple regression analysis showed that SVA($\beta = -0.25$), flexibility($\beta = -0.29$) were significant associated with LBP.

Conclusion: SVA and flexibility were extracted as a factor influencing LBP in long-term patients. It has already been proved that SVA and LBP correlate. The same result was obtained in this study. In addition , it was suggested that the acquisition of flexibility could lead to the prevention of LBP.It is possible to give accurate information on postoperative LBP for patients scheduled to undergo, postoperative patients and patients who have undergone long-term after surgery. Furthermore, I think that it will also be useful for explanation after preoperative surgery. Based on the results of this study, we also believe that it is important to encourage aggressive flexible exercise in AIS patients.

Spinal alignments of non-fused lumbar curve affect the disc degenerations after selective thoracic fusion in the patients with adolescent idiopathic scoliosis with a minimum 5-year follow-up

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Introduction: The purpose of this study was to investigate the relationship between disc degenerations and spinal alignments in adolescent idiopathic scoliosis (AIS) patients 5 or more years after selective thoracic fusion.

Methods: Subjects were 49 AIS patients who underwent posterior selective thoracic fusion without lumbar curve fusion between 2004 and 2010. Inclusion criteria were: 1) AIS Lenke type 1A, 1B, 2A or 2B; 2) age 10 to 19 years at the time of operation; and 3) 5 or more years follow-up. Exclusion criteria were: 1) neuromuscular scoliosis, congenital scoliosis, or syndromic scoliosis; 2) history of lumbar disc herniation or spondylolysis; or 3) reoperative case. We tried to contact all the 49 patients with postal mail. The following patients were excluded: 20 patients who failed to respond to the mails, 8 patients who refused to participate this research, and 2 patients who had undergone reoperation. Finally, 19 patients agreed to participate in this research. There were 17 females and 2 male. The average age at time of surgery was 15.3 years (range 12 to 18 years); the average age at follow-up was 23.4 years (range 19 to 28 years); the average follow-up interval was 7.7 years (range 5 to 11 years). Whole spine X-rays, lumbar MRI, and SRS-22 questionnaire were evaluated. MRI evaluations were performed by three independent examiners who were not informed about the clinical data of the patients. Disc degeneration in non-fused segments was defined as Pfirrmann grade 3 or higher. Patients with disc degenerations (DD[+] group) were compared to those without disc degenerations (DD[-] group).

Results: The percentage of patients with disc degeneration was 47.4%. There were no significant differences in the preoperative or postoperative 1-week X-ray parameters between both groups. The lumbar curve was significantly larger in DD[+] group compared to DD[-] group at the final observation (DD[+]: 16.8 ± 7.6 degrees, DD[-]: 10.4 ± 5.1 degrees, $p=0.035$). Sagittal vertical axis (SVA) was significantly larger in DD[+] group compared to DD[-] group at the final observation (DD[+]: -4.4 ± 22.9 mm, DD[-]: -34.3 ± 18.2 mm, $p=0.006$). SRS-22 function (DD[+]: 4.6 ± 0.3 , DD[-]: 4.8 ± 0.3 , $p=0.079$), self-image (DD[+]: 3.4 ± 0.5 , DD[-]: 3.9 ± 0.6 , $p=0.079$), and satisfaction (DD[+]: 4.0 ± 0.4 , DD[-]: 4.5 ± 0.6 , $p=0.095$) scores were lower in the DD [+] group compared to the DD [-] group at the final observation, but these differences did not reach statistical significance.

Discussion: In AIS patients who underwent selective thoracic fusion with a minimum 5-year follow-up, disc degeneration was observed in 47.4% of the patients. The patients with disc degeneration had significantly larger lumbar curve and SVA with lower SRS-22 function, self-image and satisfaction scores at the final observation. Even though the non-fused segments were preserved by selective thoracic fusion, spinal alignments of non-fused lumbar curve affect the disc degenerations. It is recommended that lumbar curves should be minimized after AIS surgery to maintain better quality of life over the long-term.

What Made Differences between Best and Worst Clinical Results for Adult Spinal Deformity Patients: 2-Year Follow-Up

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Introduction: Corrective long fusion surgery was frequently performed for adult spinal deformity (ASD) patients. According to the literature, average clinical results are improved following surgical treatment, however, predictable factors associated with either good or poor clinical results, especially in elderly spinal deformity population, have not been determined. The purpose of this study was to investigate which factors affect to the clinical results two years after the corrective long fusion for ASD patients with relatively higher age population.

Materials and Methods: This is a retrospective review of prospectively collected, single center database of consecutively enrolled ASD patients. Inclusion criteria were age>35 years and ASD, fusion range from thoracic spine to pelvis, and minimum 2-year follow-up. The best cases (Group B) were defined for Oswestry Disability Index (ODI) <20%, and the worst cases (Group W) were defined for ODI>50% at 2-year follow-up. These two groups were compared based on the patients' factors (age, sex, body mass index (BMI), habit (Tabaco, alcohol), pathology, comorbidity, and preoperative ODI), surgical factors (fusion range, surgical complications, revision rate), and radiographic parameters.

Results: Of 134 patients who met the inclusion criteria, 45 cases (34%, 38 females, 7 males) were grouped as group B, and 28 cases (21%, 25 females, 3 males) were grouped as group W. In the patients factors, average age was significantly higher in the group W (72.0 vs. 66.1, P=0.02). More patients with Parkinson disease (P=0.06) and iatrogenic sagittal malalignment (P=0.047) were included in group W, and more patients with adult adolescent idiopathic scoliosis (P=0.044) were included in group B. More patients with hypertension (P=0.043) and cerebrovascular diseases (P=0.047) were included in the group W. No other factors were significantly associated with either group. In the surgical factors, fusion range was significantly longer (P=0.043) in group W. Postoperative delirium (28.6% vs. 6.7%, P=0.011) and revision rate (50.0% vs. 22.2%, P=0.014) were significantly higher in group W. In the radiographic parameters, preoperative sagittal vertical axis (SVA) and T1 pelvic angle (TPA) were significantly worse in the group W (SVA; B: 112.6, W: 153.7, TPA; B: 37.0, W: 47.1). First-standing X-rays showed significant deformity correction in both groups (SVA; B: 29.2, W: 62.6, TPA; B: 14.7, W: 20.8), however, the significant correction loss were observed in group W (SVA; B: 43.1, W: 107.9, TPA; B: 19.9, W: 27.9). No patients in group W showed preoperative ODI<40%.

Conclusions: Even in the good deformity correction, significant correction loss within 2 years were associated with poor clinical results. Higher age, longer fusion, comorbidities (hypertension, cerebrovascular diseases), preoperative lower ODI, postoperative delirium, and revision surgery were significantly associated with poor clinical outcomes.

Multimodal Analyses Were Required to Understand the Complaints of Adult Spinal Deformity Patients

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Introduction: In the adult spinal deformity (ASD) studies, the Oswestry Disability Index (ODI) is frequently used and validated in the analyses of clinical results and/or the thresholds for health related quality of life (HRQOL) associated with sagittal spinal malalignment. However, especially in the clinical situations, there are sometimes dissociations among different patient reported outcomes (PROs) for the evaluation of health conditions of ASD patients. According to Fairbank's report, the ODI 20% and 40% are supposed to be the thresholds of moderate, and severe disabilities, respectively. But surgical treatments are sometimes required for the ASD patients with low ODI scores. The purpose of this study was to investigate the features of the ASD patients who underwent corrective long fusion, even with preoperative low ODI scores.

Materials and Methods: This is a retrospective review of prospectively collected, single center database of consecutively enrolled ASD patients. Inclusion criteria were age > 18 years and ASD, fusion range from thoracic spine to pelvis. In all of these ASD patients, ODI scores, SRS-22 (function, pain, self-image, mental health, total), and Numerical Rating Scale (0-10) for socio-mental (appearance), visceral (respiratory and digestive), leg pain, and back pain were acquired preoperatively. The ASD patients with preoperative ODI less than 20% were categorized as low ODI group (Group L), and other HRQOL modalities (SRS-22 and NRS) were compared with the ASD patients with ODI over 40% (Group H). Pathologies of spinal deformity in each group was also compared Group L and H.

Results: Among 216 ASD patients (37 males, 179 females, average age: 67.4 years), Group L included only 16 patients (7.4%, 3 males, 13 females, average age 61.6). Group H included 135 patients (62.5%, 27 males, 108 females, average age 68.9 years). Pathologies of the deformity in Group L were 7 (43.8%) in degenerative kyphoscoliosis (KS), 3 (18.8%) in degenerative kyphosis (K), 3 (18.8%) in Adult idiopathic scoliosis (AIS), 1 (6.3%) in Parkinson (P), 1 (6.3%) in kyphosis with vertebral fracture (VF), and 1 (6.3%) in syndromic scoliosis (SS), while 57 (42.2%) in KS, 25 (18.5%) in K, 21 (15.6%) in P, 13 (9.6%) in VF, 11 (8.1%) in iatrogenic flatback, 5 (3.7%) in AIS, 2 (1.5%) in caries, and 1 (0.7%) in degenerative stenosis with sagittal malalignment. Average ODI score, SRS 22 Function, pain, self-image, mental, total, NRS Socio-mental, visceral, leg pain and back pain in Group L were 13.8, 3.3, 4.4, 2.4, 3.3, 3.3, 6.6, 2.2, 3.1, 4.3, respectively, while they were 55.0, 2.3, 2.7, 1.9, 2.6, 2.4, 7.4, 3.8, 5.9, and 7.7 in Group H, respectively. Almost all scores were significantly higher ($P < 0.0001$) in Group H except SRS-22 self-image ($P = 0.08$) and NRS socio-mental (appearance) ($P = 0.28$).

Conclusions: The ODI 40% is often used as a thresholds of severe disability in the HRQOL evaluation, however, the ODI sometimes cannot detect the severity of cosmetic problems and/or other posture oriented disabilities. Multimodal evaluations are necessary to exactly understand the complaints and troubles of the patients with adult spinal deformity.

Impact of correction surgery on activities of daily living related to Oriental life-style in adult spinal deformity patients. Survey with original ADL questionnaire.

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Introduction: Trunk flexibility may decrease after multilevel fixation in adult spinal deformity (ASD) patients. The impacts of the reduced flexibility on activities of daily living (ADL) are not well evaluated especially for Asian ASD patients with Oriental life-style. The aim of this study was to assess the impact of correction surgery on ADL in Asian ASD patients by a custom-made questionnaire.

Methods: Fifty Asian ASD patients who had correction surgery (> 5 level, mean 8.6 levels) were included in the study (L group: 10 males, 50 females, mean 64.9 years). For comparison, 67 patients with short-segment fusion (1~3 levels, mean 1.4 levels) for lumbar degenerative disease were also included (S group: 34 males, 33 females, mean 68.0 years). They answered the original questionnaire, which consisted of 20 questions on ADLs such as squatting, standing up from the floor, swabbing the floor, clipping toe nails, putting on pants or socks etc. The answers were scored from 1 (very difficult to perform) to 5 (not difficult at all) with full score of 100. The correlation between the score of each question and position of upper (UIV) or lowest instrumented vertebra (LIV) were assessed with Spearman's correlation coefficient test.

Results: Sagittal parameters such as lumbar lordosis (LL), sagittal vertical axis (SVA), and pelvic tilt (PT), significantly improved in L group and remained unchanged in S group after the surgery. ODI significantly improved in both groups after the surgery. In S group, scores for all 20 items of ADL questionnaire improved (statistically significant in 15 items) and total ADL score significantly improved from 62.0% at baseline (BL) to 72.3% at the final follow-up (FFU). In contrast, ADL scores in L group improved in 9 items and deteriorated in 11 items which result in unchanged total ADL score after the surgery (BL 64.9%, FFU 64.1%). In L group, the position of LIV significantly negatively correlated with ADL scores at FFU such as standing up from floor, squatting, swabbing the floor, seiza, using Japanese toilet, clipping toe nails, putting on pants and socks (correlation coefficient all < -0.4). There was no significant correlation between position of UIV and score of each item.

Discussion: Our original questionnaire has been shown to adequately evaluate the ADL impairments which were unable to capture with ODI. Using this questionnaire, our study demonstrated that multilevel fusion (> 5 levels) may have negative impacts on ADLs for ASD patients with Oriental life-style, and the motion which require trunk bending were impaired as the fusion extends distally. It is important to inform the patients with that there is a trade-off between deformity correction and ADL impairment in correction surgery for ASD patients especially with Oriental life-style.

Performance-Based Tests as Predictors of Patient-Reported Outcomes at 1-Year Following Lumbar Spine Surgery

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Introduction: Studies have found that physical performance tests can predict likelihood of successful outcome in surgical orthopedic populations. The primary purpose of this prospective study was to determine whether preoperative performance-based tests could predict patient-reported outcomes at 1-year following lumbar spine surgery.

Methods: This study was a secondary analysis of data from a prospective clinical trial. The trial examined the effectiveness of a psychologically-informed physical therapy program compared to Education. Group differences were not statistically significant for the primary patient-reported outcomes. 248 patients undergoing surgery for a lumbar degenerative condition (spinal stenosis, spondylosis with or without myelopathy, and degenerative spondylolisthesis) using laminectomy with or without arthrodesis were included in the analysis. Patient-reported outcomes were disability (Oswestry Disability Index: ODI) and back and leg pain and pain interference (Brief Pain Inventory). Performance-based tests included the 5 Times Sit to Stand (STS, stand up and sit down 5 times as fast as possible) and Timed Up and Go (TUG, rise from chair, walk 3 meters, walk back and sit down). Patients completed questionnaires and performance-based tests preoperatively and at 1-year after surgery. Separate multivariable linear regression analyses were conducted to determine whether STS or TUG prior to surgery predicted disability, back and leg pain, and pain interference, controlling for age, education, revision, arthrodesis, depressive symptoms, and baseline score of the outcome of interest. Missing data were handled with multiple imputation. Preoperative correlations between physical-performance tests and patient-reported outcomes were assessed with Spearman's Rho. Change scores from preoperative to 1-year follow-up were calculated and minimal clinically important differences (MCID) for all measures were compared using descriptive statistics. The level of significance was set at $\alpha=0.05$. Results: STS test prior to surgery was statistically associated with disability ($b=0.61$; $p=0.045$) and back pain ($b=0.10$; $p=0.019$) at 1-year after lumbar spine surgery. TUG was not statistically significant in multivariable models. Preoperative correlations were weak between performance-based tests and pain outcomes (0.05 to 0.18) and low to moderate between performance-based tests and disability (0.29 to 0.32). 64% of patients reported clinical improvement at 1-year based on achieving MCID with ODI (12.8-point reduction). An additional 19% of patients reported clinical improvement when taking into account achieving MCID for STS (2.3 second reduction).

Discussion: STS test was predictive of disability and back pain at 1-year after surgery. Performance-based tests were not statistically associated with leg pain or pain interference. Correlation results suggest that physical performance and patient-reported measures provide distinct information prior to surgery. MCID values demonstrate that STS test may be able to detect additional clinical improvement when added to patient-reported outcome assessment. Findings support the use of STS test for a comprehensive risk assessment prior to surgery and of physical recovery at long-term follow-up. Research reported in this abstract was funded through a Patient-Centered Outcomes Research Institute® (PCORI®) Award (CER-1306-01970).

Physical capacity tasks assessing functional status in patients scheduled for lumbar fusion surgery were not associated with depression, pain catastrophizing, and fear of movement

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- Publish consent withheld

Introduction. Physical capacity tasks, such as the Timed up-and-go, have support for reliability, validity, and responsiveness in the assessment of functional status in patients who undergo lumbar spine surgery. Physical capacity tasks have been recommended as objective complements to patient-reported outcome measures (PROMs) in patients with low back pain (LBP) since they are suggested to be minimally influenced by education level, language, and cognitive skills. However, the research on the associations between physical capacity tasks and fear-avoidance variables (e.g., depression, pain catastrophizing, and fear of movement) is scarce. The aim was to investigate the associations between physical capacity tasks and fear-avoidance variables in patients scheduled for lumbar fusion surgery, and further to investigate the associations between Oswestry Disability Index (ODI) and fear-avoidance variables.

Methods. One hundred eighteen patients scheduled for lumbar fusion surgery for motion-elicited chronic low back pain with degenerative changes were included. All patients performed physical capacity tasks (1-minute stair-climbing, 5-minute walk, 50-foot walk, and the Timed up-and-go) and PROMs of disability (ODI), back and leg pain intensity (Visual Analogue Scales), depression (Hospital Anxiety and Depression Scale) pain catastrophizing (Pain Catastrophizing Scale), and fear of movement (Tampa Scale for Kinesiophobia) 8-12 weeks before surgery. Multiple linear regression analyses were performed with the scores of the physical capacity tasks and the ODI as the dependent variables in five separate models. The independent variables were depression, pain catastrophizing, fear of movement, back and leg pain intensity, age, gender, and BMI.

Results. The physical capacity tasks were significantly associated ($p < 0.05$) with leg pain intensity, age, gender, and BMI, but not with the fear-avoidance variables depression, pain catastrophizing, and fear of movement. The ODI was significantly associated with depression, fear of movement, and back and leg pain intensity, but not with the fear-avoidance variable pain catastrophizing.

Discussion. The results suggest that fear-avoidance variables, as measured in this study, have a limited influence on the scores of physical capacity tasks for patients with chronic LBP scheduled for lumbar fusion surgery. In contrast, the fear-avoidance variables fear of movement and depression appear to significantly influence the scores of the ODI. The results imply that interventions targeting fear-avoidance variables might be effective for improving scores of the ODI but not for improving the scores of physical capacity tasks. Moreover, the results strengthen previous research in that physical capacity tasks and ODI are complementary as they appear to measure different aspects of a patient's functional status.

1. Gautschi, O. P., Corniola, M. V., Schaller, K., Smoll, N. R., & Stienen, M. N. (2014). The need for an objective outcome measurement in spine surgery--the timed-up-and-go test. *Spine J*, 14(10), 2521-2522.
2. Gautschi, O. P., Smoll, N. R., Corniola, M. V., Joswig, H., Chau, I., Hildebrandt, G., Schaller, K., Stienen, M. N. (2016). Validity and Reliability of a Measurement of Objective Functional Impairment in Lumbar Degenerative Disc Disease: The Timed Up and Go (TUG) Test.
3. Jakobsson, M., Gutke, A., Mokkink, L., Smeets, R., Lundberg M. The Level of Evidence for Reliability, Validity, and Responsiveness of Physical Capacity Tasks Designed to Assess Functioning in Patients with Low Back Pain: A Systematic Review Using the COSMIN Standards (2018). *Physical Therapy Journal*. In print.
4. Smeets, R. J. E. M., Hijdra, H. J. M., Kester, A. D. M., Hitters, M. W. G. C., & Knottnerus, J. A. (2006). The usability of six physical performance tasks in a rehabilitation population with chronic low back pain.
5. Smeets, R. J., van Geel, A. C., Kester, A. D., & Knottnerus, J. A. (2007). Physical capacity tasks in chronic low back pain: what is the contributing role of cardiovascular capacity, pain and psychological factors? *Disabil Rehabil*, 29(7), 577-586.

Predictors of poor Global Alignment and Proportion score after surgery for adult spinal deformity

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Abstract

Study Design: Retrospective observational study of a cohort of consecutive patients.

Objective: To determine (1) the correlation between clinical and radiographic outcomes and Global Alignment and Proportion (GAP) score, and (2) which preoperative radiographical spinal parameters predominantly influence the risk for poor GAP scores.

Summary of Background Data: Although numerous investigators have indicated their criteria for sagittal correction, it is still not unusual to observe poor outcome or complications even after ideal correction. The recently developed GAP score indicates spinopelvic alignment and setting surgical goals according to the score might decrease the prevalence of mechanical complications. However, there is no clear evidence of correlation between the GAP score and clinical outcomes, or which patient factors are preoperative predictors of poor postoperative GAP score.

Methods: We included 110 consecutive patients treated with spinal correction surgery who had a minimum 2-year follow-up. The correlations between clinical outcomes, increased proximal junctional angle and GAP score were determined. Univariate and multivariate logistic regression analyses were conducted to clarify potential preoperative risk factors for poor GAP score.

Results: Based on total GAP score, 27 (24.5%) patients were grouped into proportioned, 46 (41.8%) into moderately disproportioned, and 37 (33.6%) into severely disproportioned spinopelvic alignment. Our present study showed a significantly positive correlation between Oswestry Disability Index (ODI), increased proximal junctional angle 2 year after surgery and total GAP score. Uni and multivariate regression analysis showed potential preoperative risk factors for poor GAP score were a large global tilt and advanced age.

Conclusions: Because GAP score correlated with ODI and increased PJA 2 year after surgery, GAP score might define targets for sagittal spinopelvic alignment for favorable outcomes of corrective spinal surgery. A large preoperative global tilt is a potential predictor of poor postoperative GAP score.

The Spatial and Temporal Expression of Sclerostin and Canonical Wnt Signaling Factors in the Maturing Posterolateral Spine Fusion

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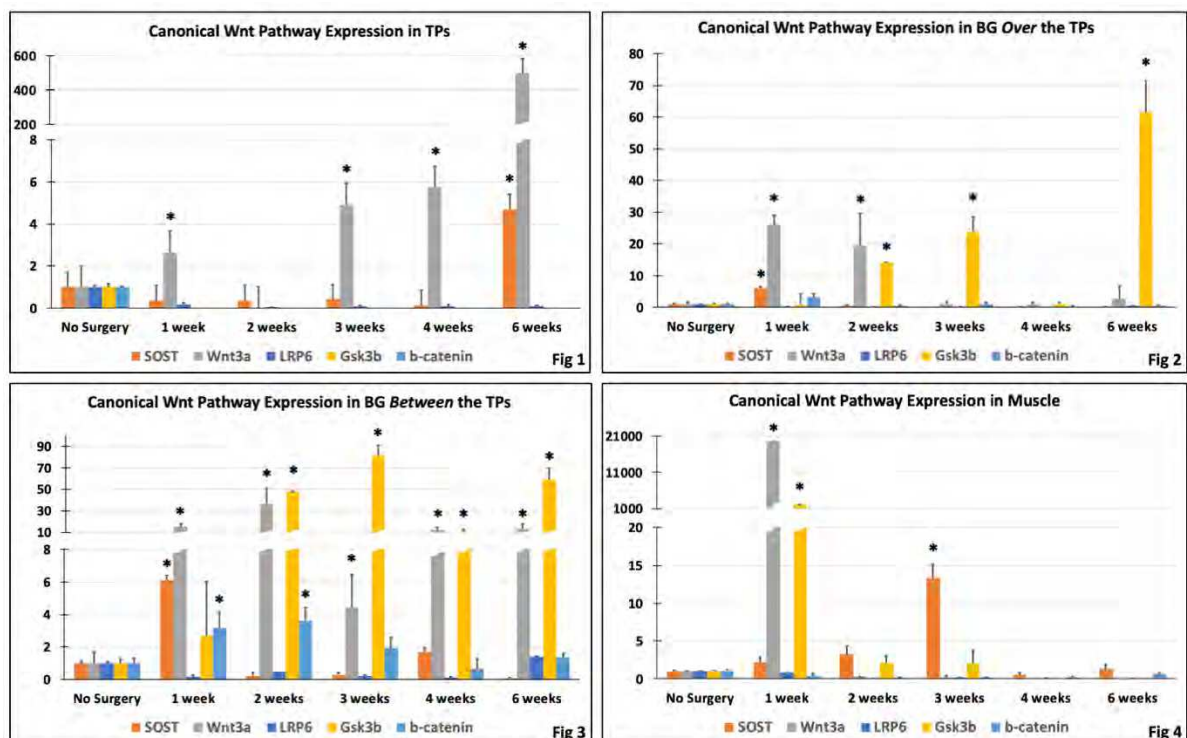
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Introduction: Despite state-of-the-art techniques, nonunion after spinal arthrodesis remains common (10-40%) and is associated with significant morbidity and cost.¹ One promising strategy is to enhance canonical Wnt signaling locally in the fusion bed because it positively uncouples bone formation/resorption. Anti-sclerostin treatments have also been shown to result in greater bone volume after spinal fusion.² Very little, however, is known about sclerostin and canonical Wnt signaling during the fusion process.

Methods: Twenty-two adult female New Zealand White rabbits underwent a bilateral posterolateral intertransverse process arthrodesis at L5-L6 using autologous iliac crest bone graft (ICBG).³ Rabbits were euthanized at 1 week (N=5), 2 weeks (N=4), 3 weeks (N=4), 4 weeks (N=4), and 6 weeks (N=5) after arthrodesis. Immediately following euthanasia, tissue samples were collected from the decorticated transverse processes (TPs), ICBG between the TPs (Inner Zone) and overlying the TPs (Outer Zone), and muscle touching the ICBG. Two control rabbits did not undergo surgery, whereby ICBG, L5/6 TPs, and paraspinous muscle were harvested. All tissue was immediately snap-frozen within minutes of euthanasia. High-quality RNA was isolated using a cryogenic tissue homogenizer. Expression of sclerostin and various canonical Wnt signaling factors (Wnt3a, LRP6, Gsk3b, b-catenin) were measured using real-time qPCR and normalized to GAPDH. An *a priori* power analysis revealed that N=4 provides sufficient power to detect a 25% difference in gene expression ($p < 0.05$).

Results: Successful fusion was confirmed at 6 weeks on uCT in 3/5 rabbits, which is consistent with the known fusion rate in this model (66%).³ The temporal gene expression profiles are shown for the TPs (Fig 1), Outer Zone (Fig 2), Inner Zone (Fig 3), and muscle (Fig 4). The act of harvesting ICBG caused significantly increased expression of sclerostin, with a >6-fold increase in the Outer and Inner Zones at 1 week ($p < 0.05$). The surrounding muscle had a >13-fold increase in sclerostin expression at 3 weeks ($p < 0.05$). Sclerostin was also significantly expressed in the TPs at 6 weeks (~5-fold increase, $p < 0.05$), which could be a signal to stop forming bone once the fusion is complete. Wnt3a was the most dynamically expressed factor assessed, with an almost 20,000-fold increase in the muscle at 1 week and a 500-fold increase in expression in the TPs at 6 weeks ($p < 0.05$).

Discussion: This is the first description of the spatial and temporal expression of sclerostin and canonical Wnt signaling factors in the maturing fusion mass of a posterolateral spine fusion, which fills an important knowledge gap in our understanding of the basic biology of spinal fusion. Sclerostin and canonical Wnt factors seem to play a role in osteogenesis after spinal arthrodesis and their dynamic expression is regulated differently within specific regions of the maturing fusion mass. Understanding these signaling patterns will be critical in aiding in the design of novel local delivery strategies of biologics that modulate canonical Wnt signaling for the purpose of preventing pseudarthrosis (i.e. determining the specific region of the fusion to be targeted with biologics or determining the optimal timing needed for drug release from its carrier).



- Kim YJ, Bridwell KH, Lenke LG, et al. Pseudarthrosis in primary fusions for adult idiopathic scoliosis: incidence, risk factors, and outcome analysis. *Spine*. 2005; 30: 468-474.
- Shaffer AD, Shonuga OA, Hirsch BP, et al. Sclerostin antibody enhances spine fusion in a rat posterolateral transverse process fusion model: preliminary results. Proc 33rd Annual Meeting of the American Society for Bone and Mineral Research, San Diego, CA, 2011, p S517 (Abstract MO0461).
- Boden SD, Schimandle JH, Hutton WC. An experimental lumbar intertransverse process spinal fusion model. Radiographic, histologic, and biomechanical healing characteristics. *Spine (Phila Pa 1976)*. 1995 Feb 15;20(4):412-20.

Intraoperative real-time stress analysis using EEG and heart rate over 800 surgeries; multi-center prospective study among 12 orthopedic surgeons

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Introduction: Increased burnout rate, decreased quality of life, decreased career satisfaction, and increased work-home conflict are related to the physical and emotional burden of surgeons. Numerous reports have utilized various methods to evaluate the stress of surgeons including questionnaire, heart rate, sympathovagal balance, heart rate variability, thermal activity, stress biomarker in saliva and smart patches. In the present study, the intraoperative stresses were measured and analyzed in real-time manner in terms of electro-encephalogram (EEG) and heart rate-heart rate variability.

Methods: From June 2018 to November 2018, 800 cases of surgical stress including intraoperative EEG and heart rate of 12 orthopedic surgeons in 2 independent tertiary hospitals attached to medical college were prospectively measured and analyzed. The orthopedic surgeons' experiences were varied from one year to 35 years. For all surgical cases, the order of surgery during the day, preoperative expected difficulty of surgery, actual difficulty of surgery, duration of surgery, intraoperative bleeding, duration of surgery were recorded. A two-channel EEG device (model: Amp GS5001; SOSO H&C, Korea) was used to measure cortical activity in the frontal lobe for 3 min in a resting state with eyes closed and open each. Dry electrodes were secured using a headband at Fp1 and Fp2 sites according to the 10–20 system. Data were reanalyzed using MATLAB 2012 software (MathWorks, Inc., Natick, MA, USA.) using a Fast Fourier Transform with a bandpass filter of 1–50 Hz to calculate the amplitude values. The frequency power was calculated as the square of amplitudes: relative delta (1–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (12–30 Hz), and gamma (30–50 Hz) signals. The relative frequency power is a power ratio converted into the percentage of the whole frequency, which provides information about interactions between spectral oscillations in each band.

Results: Surgical procedures were divided into 4 categories: Incision; Screw fixation; Decompression; Close. The results are as follows depending on the percentage of relative delta, theta, alpha, beta and gamma. When the screw fixation was performed, the heart rate was 18% higher than the other steps, suggesting that the physical stress is relatively high. For the EEG pattern, H-Beta and gamma waves increased by 1.5% and 2.7%, respectively, when compared with the close phase, when decompression was relatively performed. Surgeons' age, experience, intraoperative bleeding, and duration of surgery were associated with intraoperative stress using multiple linear regression analysis.

Discussion: This is the 1st study to confirm the 'good stress' during surgery to increase focus based on significant increase of SMR, M-beta H-beta and gamma waves during the surgery rather than decrease of delta, theta, alpha waves. The strong point of present study is that intraoperative stress could be monitored in blue-tooth connected computer or smartphone to warn the surgeon and operative team at the same time and could suggest coping strategy on the stressful condition to break for a while or arrange the number of surgical cases based on the difficulty and duration of surgery.

Patient outcomes following short-segment lumbar fusion are not affected by PI-LL mismatch

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Introduction: Mismatch between pelvic incidence and lumbar lordosis has been emphasized as a reason for poor outcomes in deformity surgery and long segment spinal fusions. However, there is a paucity of literature assessing the importance of this spinopelvic relationship on patient outcomes in short segment lumbar fusions for degenerative lumbar disease.

Methods: A retrospective review was conducted at a single center, academic hospital. Inclusion criteria for this study were patients undergoing lumbar spinal fusion at one or two levels for degenerative lumbar disease (e.g. lumbar spondylolisthesis, lumbar spinal stenosis). Patients with a history of previous lumbar surgery, infection, tumor, or trauma and those with less than one year follow-up excluded. For each patient, the following spinopelvic parameters were measured pre- and post-operatively: pelvic tilt (PT), sacral slope (SS), pelvic incidence (PI), lumbar lordosis (LL), PI-LL mismatch (PI minus LL). Patients were separated into two groups based on postoperative PI-LL mismatch $\leq 10^\circ$ (NM) or PI-LL mismatch $> 10^\circ$ (M). Outcomes including the SF-12 physical component score (PCS-12), mental component score (MCS-12), Oswestry disability index (ODI), visual analog scale (VAS) back, and VAS leg scores were evaluated. An independent t-test or Mann-Whitney U test was used to compare means between continuous variables. Multivariate analysis using multiple linear regression was used to determine if postoperative PI-LL mismatch was an independent predictor of change in each patient outcome.

Results: A total of 348 patients were included in this study, with 67 patients in the no mismatch (NM) group compared to 281 patients in the mismatch (M) group. Mean follow-up was 13.0 months and 13.8 months in the NM and M groups ($p = .219$), respectively, with no significant differences between other baseline characteristics. There was a significant difference in PT, PI, LL, and PI-LL between the two groups at baseline and postoperatively (Table 1). Patients in the M group started with a higher degree of PI-LL mismatch compared to the NM group (22.1° vs. 7.8° , $p < .001$) and this difference increased postoperatively (24.4° vs. 2.2° , $p < .001$). There were no differences between the two groups in terms of preoperative or postoperative outcome scores ($p > .05$). In addition, having a PI-LL mismatch postoperatively was not found to be an independent predictor of any health-related outcome score on multivariate analysis (Table 2, $p > .05$).

Discussion: Pelvic incidence minus lumbar lordosis is recognized as an important spinopelvic parameter to normalize in deformity surgery, however this importance is less clear in short-segment lumbar fusions for degenerative pathology. In this study, we found that even though the M group had a higher degree of mismatch pre and postoperatively, there was no difference in their self-reported outcomes before or after surgery. This is one of the first studies to report on short term patient outcomes based on spinopelvic parameters in routine lumbar degenerative cases. Further research is needed to elucidate this important relationship.

Table 1. Pre- and Post-op Spinopelvic Measurements

	Pre-op Measurements			Post-op Measurements		
	No Mismatch	Mismatch	p^1	No Mismatch	Mismatch	p^2
Pelvic Tilt	18.1 [15.9, 20.3]	24.8 [23.7, 25.9]	<.001*	17.7 [16.0, 19.4]	25.6 [24.6, 26.6]	<.001*
Sacral Slope	36.1 [34.1, 38.1]	36.4 [35.2, 37.5]	0.824	36.3 [34.3, 38.3]	36.2 [35.0, 37.3]	0.907
Pelvic Incidence (PI)	54.1 [51.8, 56.5]	61.2 [59.8, 62.6]	<.001*	54.0 [51.7, 56.3]	61.7 [60.3, 63.2]	<.001*
Lumbar Lordosis (LL)	46.4 [43.6, 49.2]	39.1 [37.3, 40.8]	<.001*	51.8 [49.2, 54.4]	37.4 [35.8, 39.0]	<.001*
PI-LL	7.8 [5.0, 10.5]	22.1 [20.7, 23.5]	<.001*	2.2 [0.62, 3.78]	24.4 [23.2, 25.5]	<.001*

Table 2. Pre- and Post-op Patient Reported Outcome Measures

	Pre-op Scores			Post-op Scores			Multivariate Analysis*	
	No Mismatch	Mismatch	p^1	No Mismatch	Mismatch	p^2	β -coeff	p^3
PCS-12	31.4 [29.1, 33.7]	31.1 [30.1, 32.2]	0.875	40.1 [37.6, 42.6]	40.9 [39.6, 42.4]	0.493	-0.03 [-5.4, 4.0]	0.770
MCS-12	49.7 [47.3, 52.1]	49.6 [48.1, 51.1]	0.738	53.2 [51.1, 55.3]	53.1 [51.9, 54.3]	0.585	0.07 [-3.1, 6.7]	0.485
ODI	42.9 [29.8, 46.9]	41.7 [39.6, 73.8]	0.563	21.4 [17.0, 25.9]	20.3 [18.1, 22.5]	0.633	0.05 [-6.4, 11.4]	0.585
VAS Back	5.83 [5.10, 6.53]	5.78 [5.41, 6.16]	0.927	3.32 [2.64, 4.00]	2.63 [2.31, 2.95]	0.063	-0.06 [-1.9, 0.91]	0.486
VAS Leg	6.02 [5.24, 6.79]	6.17 [5.79, 6.54]	0.762	2.92 [2.12, 3.72]	2.28 [1.94, 2.63]	0.339	0.05 [-1.2, 2.0]	0.585

Paraoxonase 1 (PON1) was negatively associated with intervertebral disc degeneration (IVDD).

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Introduction: IVDD is responsible for most of the spinal degenerative diseases. Inflammation and oxidative stress can deteriorate the living environment of nucleus pulposus (NP) cells, leading to IVDD. Paraoxonase 1 (PON1) is an enzyme reported to have anti-inflammatory and anti-oxidative effects. There is no study about the correlation of PON1 expression with IVDD.

Methods: Immunohistochemical (IHC), hematoxylin and eosin (H&E) staining and western blot examined the expression of PON1 in 88 human disc samples (male: female 43: 45) and rat models (n = 5 each group). The level of PON1 is measured in the TNF- α and oxidative stress (H₂O₂)-induced degenerative NP cell models using western blot and RT-qPCR. The TNF- α , IL-1 β , Mito SOX, aggrecan and collagen II are detected in nucleus pulposus (NP) cells transfected with si-RNA of PON1 using ELISA, mitoSOX staining western blot and RT-qPCR.

Results: Western blotting and quantitative analysis of the degenerated human disc tissues showed that the expression of PON1 was significantly decreased in the severely degenerated discs ($p < 0.05$). H&E and immunohistochemical staining showed that the expression of PON1 is significantly suppressed in human degenerative intervertebral discs. H&E staining of rat discs showed larger amounts of NP tissue in the control groups than in the AF puncture group. The expression level of PON1 significantly decreased in AF puncture group compared with control groups ($p < 0.01$). Western blot and quantitative analysis also showed that the expression of PON1 was significantly decreased in AF puncture group compared with control groups ($p < 0.01$). Western blot, quantitative analysis and RT-qPCR showed that the level of PON1 is significantly decreased in TNF- α and oxidative stress (H₂O₂)-induced degenerative NP cell models. ELISA results show that the level of TNF- α and IL-1 β obviously increased; Mito SOX staining indicates that the Mito SOX fluorescence significantly increased, and the expression of aggrecan and collagen reduced in NP cells transfected with si-RNA of PON1.

Discussion: This study provides the first demonstration that PON1's anti-inflammatory and anti-oxidative properties were strongly correlated with the process of IVDD. Our results indicated that the expression of PON1 significantly decreased in the severely degenerated discs and the expression of PON1 was negatively associated with IVDD.

IVDD is a multifactorial disease in which extracellular matrix degradation and a reduction in the number of NP cells are major characteristics. Our data demonstrated that PON1 may improve the microenvironment of discs by reducing inflammation and oxidative stress in discs, leading to the alleviation of inflammation and oxidative stress-induced disc degeneration.

Our study indicates that low PON1 expression is predictive of severe IVDD, and the anti-inflammatory and anti-oxidative effects of PON1 may be a novel target of biological therapy for IVDD.

Figure 1:

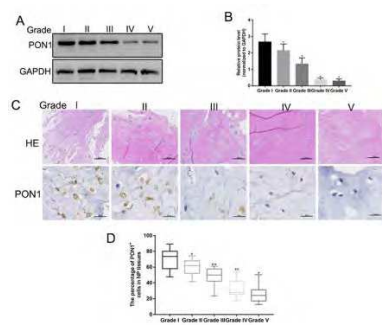


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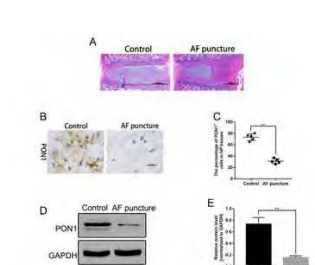


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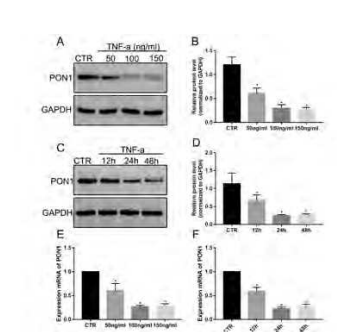


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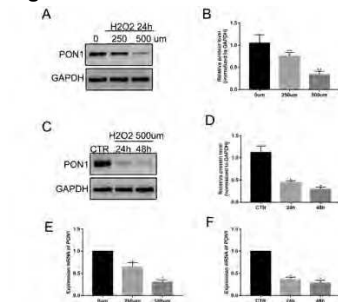
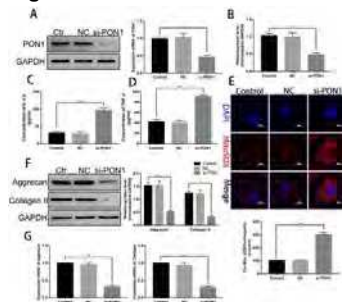


Figure 5:



Notochord-like cell clusters may retard the progression of disc degeneration

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Introduction: Mechanical overloading, catabolic cell response, and degeneration of the water-binding extracellular matrix could result in the disc degeneration. While the intervertebral disc degeneration occurred, the number of nucleus pulposus cells should be generally reduced. However, there were often many proliferating cell clusters in the nucleus and inner annulus regions of degenerative discs. At present, the roles of cell clusters during the disc degeneration was still unknown. Therefore, the main purpose of this article is to discover the roles of cell clusters in intervertebral disc degeneration.

Methods: Firstly, human lumbar disc specimens were collected from patients with lumbar vertebral burst fractures or LBP who underwent anterior vertebral body excision and fusion surgery. All the specimens were extracted, fixed, sectioned, and stained for histologic evaluation. Then, cell clusters were determined using Hematoxylin-eosin staining, safranin O fast green and alcian blue staining. Cytokeratin-8 and vimentin were stained to identify the notochord-like cells or NP cells. CD31, Vwf, neurofilament and PGP9.5 were to identify the neovessels or nerves. Type 2 collagen(Col II) and MMP13 of cell clusters were stained to evaluate the disc degeneration. Finally, we also isolated the notochord-like cells and NP cells from young or old rabbits' lumbar discs to determine the roles of notochord-like cells in inflammatory NP degeneration.

Results: We showed the general structure of cell clusters (especially abundant in Pfirrmann grade III and grade IV disc) according to the abundant H&E slices of the same specimens. Cell clusters wrapped in the degenerative disc showed various shapes composed of many notochord-like cells (cytokeratin-8 and vimentin) and a few NP cells (vimentin, only) compared to the "normal" group. These cells rarely expressed the neovessel markers (CD31, Vwf) and nerve markers (neurofilament, PGP9.5). Interestingly, they could highly express the catabolic molecule MMP13 and lowly express the anabolic molecule Col II, indicating that degenerative disc couldn't be completely repaired or rescued. Finally, the conditioned medium of notochord-like cells could partially slow the IL-1 β -induced NP degeneration by detecting the gene and protein level of MMP3, MMP13, Col II and Sox9.

Discussion: We identified cell types of cell clusters and further confirmed that notochord-like cells were the most major part, not including the neovessel and nerve. We also found the beneficial role of cell clusters in the intervertebral disc degeneration. Cell clusters occurred some of degenerative discs (appropriately 30%) and were regionally or unevenly distributed. Regrettably, we couldn't isolate the cell clusters to further culture *in vitro*. Notochord-like cells and NP cells from young or old rabbits' lumbar discs only could be used to verify the inflammation-associated disc degeneration, but not mechanical or extracellular matrix related disc degeneration. The model was urgent for further studying the role of cell clusters in intervertebral disc degeneration.

Sex differences in the interaction between biomechanical tissue properties of rat intervertebral discs and mechanical pain following annular puncture injury

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Introduction: Low back pain is more common in women than men[1], yet most studies of intervertebral disc (IVD) degeneration do not address sex differences. In humans, there are sex differences in spinal anatomy and degenerative changes in biomechanics[2,3], and animal models of chronic pain have demonstrated sex differences in pain transduction[4,5]. However, there are few studies investigating sex differences in annular puncture IVD degeneration models. IVD puncture is known to result in progressive biomechanical alterations[6], but whether these IVD changes correlate with pain is unknown. This study used a rat IVD injury model to determine if sex differences exist in mechanical allodynia, biomechanics, and the relationship between them, six weeks after IVD injury.

Methods: Procedures were IACUC approved. 24 male & 24 female four-month-old Sprague-Dawley rats underwent a sham or annular puncture injury surgery (n=12 male, 12 female). In injury groups, three lumbar IVDs were each punctured three times with a needle, and injected with tumor necrosis factor-alpha. Mechanical allodynia was tested biweekly using von Frey filaments. Six weeks after IVD injury, rats were euthanized and motion segments were dissected for non-destructive axial tension-compression and torsional rotation biomechanical testing. Two-way ANOVA with Bonferroni corrections identified statistically significant differences (p<0.05) and correlations used Pearson's coefficient.

Results: Annular puncture injury induced a significant increase in mechanical allodynia compared to sham in male but not female rats up to six weeks after injury (Figure 1). There was a significant sex effect on both torque range and torsional stiffness, with males exhibiting greater stiffness and torque range than females, but tensile stiffness, compressive stiffness, and axial range of motion showed no sex difference (Figure 2). Males and females showed similar patterns of correlation between variables when sham and injury groups were analyzed together, but correlations were stronger in males. Most correlations were clustered within testing approach: axial biomechanics negatively correlated, torsional biomechanics positively correlated, and von Frey thresholds positively correlated. Surprisingly, mechanical allodynia did not correlate with any biomechanics after injury, and the axial and torsional biomechanics showed little correlation (Figure 3).

Discussion: This study demonstrates that males and females respond to IVD injury differently. Given the absence of correlation between pain and biomechanics, pain cannot be attributed completely to biomechanical changes. This may explain why spinal fusion surgery, an intervention limited to the spine, has produced inconsistent results and is controversial for patients with low back pain. Thus, in addressing low back pain, we must consider both spinal tissues and the nervous system. Further, the limited correlation between axial and torsional biomechanics indicates that IVD injury may have distinct effects on nucleus pulposus and annulus fibrosus. Biomechanics did not differ between sham and injury at week six, suggesting healing after injury. It remains possible that acute biomechanical changes may initiate chronic pain pathogenesis. We conclude that the observed sex differences demonstrate the need for inclusion of both males and females in IVD injury and pain studies, and suggest that males and females may require different treatments for conditions that appear similar.

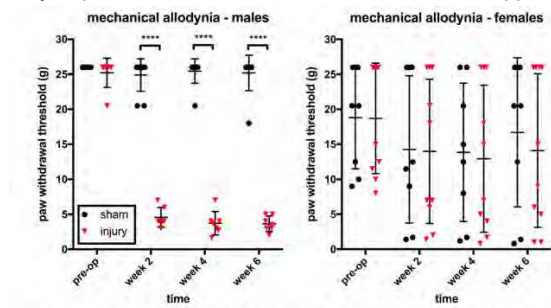


Figure 1. Mechanical allodynia 6 weeks after annular puncture injury. Males exhibited a clear reduction in hindpaw withdrawal threshold after IVD injury compared to sham, but females were more variable and did not differ between sham and injury (n=7-10, ****=p<0.0001).

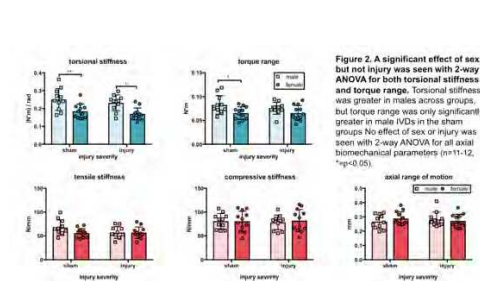


Figure 2. A significant effect of sex, but not injury was seen with 2-way ANOVA for both torsional stiffness and torque range. Torsional stiffness was greater in males across groups, but torque range was only significantly greater in male IVDs in the sham groups. No effect of sex or injury was seen with 2-way ANOVA for all axial biomechanical parameters (n=11-12, *p<0.05).

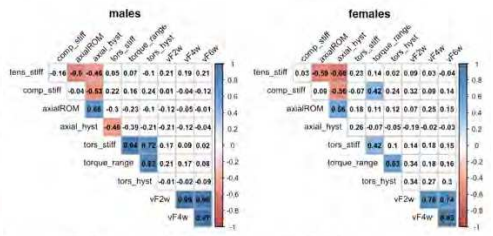


Figure 3. Correlations between biomechanical measures and von Frey thresholds for males and females (sham and injury groups pooled). Pearson's correlation values for two variables are shown at the intersection of labeled columns and rows. Statistically significant correlations shown in blue (positive), and red (negative) (n=23-24, p<0.05). Results showed no relationships between biomechanical properties and allodynia measurements.

- [1] Fillingim RB, King CD, Ribeiro-Dasilva MC, et al. (2009) Sex, gender, and pain: a review of recent clinical and experimental findings. *J Pain* 10:447–485. doi: 10.1016/j.jpain.2008.12.001
- [2] Bailey JF, Sparrey CJ, Been E, Kramer PA (2016) Morphological and postural sexual dimorphism of the lumbar spine facilitates greater lordosis in females. *J Anat* 229:82–91. doi: 10.1111/joa.12451
- [3] Fujiwara A, Lim TH, An HS, et al. (2000) The effect of disc degeneration and facet joint osteoarthritis on the segmental flexibility of the lumbar spine. *Spine* 25:3036–3044. doi: 10.1097/00007632-200012010-00011
- [4] Mogil JS, Bailey AL (2010) Sex and gender differences in pain and analgesia. *Prog Brain Res* 186:141–157. doi: 10.1016/B978-0-444-53630-3.00009-9
- [5] Sorge RE, Totsch SK (2017) Sex differences in pain. *J Neurosci Res* 95:1271–1281. doi: 10.1002/jnr.23841
- [6] Martin JT, Gorth DJ, Beattie EE, et al. (2013) Needle puncture injury causes acute and long-term mechanical deficiency in a mouse model of intervertebral disc degeneration. *J Orthop Res* 31:1276–1282. doi: 10.1002/jor.22355

Cellularity and Matrix Homeostasis during Intervertebral Disc Degeneration is Regulated via Phlpp1

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Introduction: Back pain is a leading cause of global disability and is strongly associated with intervertebral disc (IVD) degeneration (IDD)¹. Hallmarks of IDD include successive cell loss and matrix degradation. The Akt and PKC survival pathways regulate cellularity and matrix production in IVDs and their inactivation likely contributes to cell loss via apoptosis². The phosphatase PH domain leucine rich repeat protein phosphatase-1 (Phlpp1) can directly dephosphorylate Akt and PKC³ and its depletion promoted chondrocyte proliferation in mice after meniscus injury⁴. Phlpp1 depletion can increase IVD cellularity in growing mice IVDs, suggesting a role of Phlpp1 in controlling cell proliferation. We hypothesize that Phlpp1 regulates cell proliferation and apoptosis via the Akt pathway during IDD and injury. This study determined a relationship between Phlpp1 and apoptosis in degenerating human IVDs and evaluated the role of Phlpp1 on IVD cellularity in a mouse needle-puncture IDD model.

Methods: Phlpp1 and cleaved Caspase-3 co-localization was assessed histologically on Human IVD sections from autopsies. Nucleus pulposus and annulus fibrosus cells collected from surgical waste tissues were cultured for protein analyses. Needle puncture injuries were performed in caudal IVDs of 4 month old C57BL/6J wild type (WT) and Phlpp1-knockout (KO) mice. Mice were euthanized at day 3 (n=7/group) or day 56 (n=5-6/group) post injury. Cell proliferation (EdU) and phosphorylated Akt (Ser 473) activity (immunohistochemistry) were measured at day 3. At day 56, IVD structure was assessed by Picrosirius Red/Alcian Blue staining. Differences in human Phlpp1 expression with degeneration grade were evaluated by linear regression, quantitative histological data of mice IVDs were analyzed via 2-way ANOVA and Fisher's LSD ($\alpha = 0.05$).

Results: In human IVDs, Phlpp1 expression correlated with degeneration grade, which was supported by Immunoblotting (Fig. 1A+B). A role of Phlpp1 in apoptosis was suggested by co-localization of Phlpp1 and cleaved Caspase-3 immunostaining (n=6; Fig. 1C). **In Phlpp1-KO mice,** 3 days after needle-puncture, pAkt significantly increased in injured KO compared to WT mice (Fig. 2A+B) and cell proliferation was significantly increased in injured KO mice while minor cell proliferation was observed injured WT, or WT and KO controls (Fig. 2C). At day 56, the IVD matrix structure and cellularity appeared altered in injured KO compared WT mice (Figure 3).

Discussion: Phlpp1 expression strongly correlated with human IDD and co-localization with cleaved Caspase-3 suggested a role of Phlpp1 in regulating apoptosis during IDD. In injured Phlpp1-KO mice, at day 3, pAkt expression was maintained and cell proliferation was increased, suggesting a mechanistic role of Phlpp1 in regulating these early responses. The enhanced proliferation at day 3 may have caused the increased cellularity and improved matrix at day 56. Lack of differences in proliferation between WT and KO control IVDs, as we previously reported⁵, are likely due to the quiescent nature of healthy NP cells at this age. We conclude that Phlpp1 inhibition has the potential to influence IDD progression. Further investigations of Phlpp1 will provide insights into cellular processes at varying IDD grades.

Acknowledgements: NIH/NIAMS R0-AR069315, and R21-AR68103

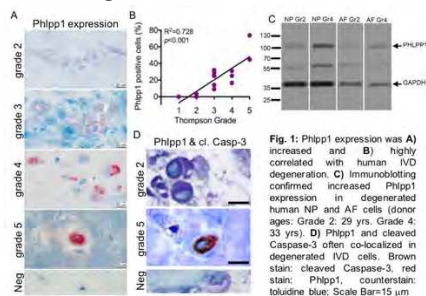


Fig. 1: Phlpp1 expression was A) increased and B) highly correlated with human IVD degeneration. C) Immunoblotting confirmed increased Phlpp1 expression in degenerated human NP and AF cells (donor ages: Grade 2: 29 yrs. Grade 4: 33 yrs). D) Phlpp1 and cleaved Caspase-3 often co-localized in degenerated IVD cells. Brown stain: cleaved Caspase-3, red stain: Phlpp1, counterstain: toluidine blue. Scale Bar=15 μ m

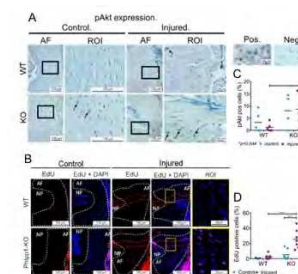


Fig. 2: Phlpp1-KO A) increased phosphorylated Akt and B) promoted increased cell proliferation after needle puncture injury. Images of dorsal AF from (left) control and (right) injured IVDs at the injury site. C-D) Quantification of C) pAkt expression and D) cell proliferation. Boxes mark region of interest (ROI), white dotted lines outline the AF, red dotted lines outline needle injury. Arrows denote pAkt positive cells (brown). Breast cancer tissue = positive control. Bars=100 μ m, ROI: 25 μ m

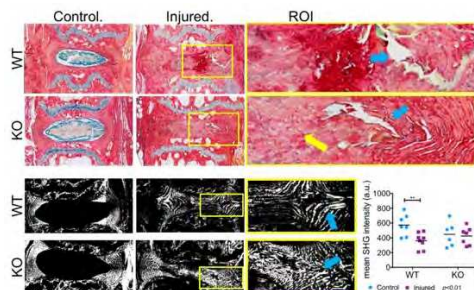


Fig. 3: Representative control & injured IVDs at day 56 A) Picrosirius red & alcian blue staining indicated increased cellularity. B) Second Harmonic Generation imaging indicated increased matrix accumulation in injured Phlpp1-KO mice. Yellow arrow denotes increased cellularity; blue arrows denote needle track. Yellow boxes mark region of interest (ROI)

1. Karpinen+ 2018. What low back pain is and why we need to pay attention. The Lancet 391(10137), pp. 2356–2367
 2. Wang+ 2016. MiR-138-5p promotes TNF-alpha-induced apoptosis in human intervertebral disc degeneration by targeting SIRT1 through PTEN/PI3K/Akt signaling. Experimental cell research 345:199-205
 3. Gao+ 2005. PHLPP: a phosphatase that directly dephosphorylates Akt, promotes apoptosis, and suppresses tumor growth. Molecular Cell 18(1), pp. 13–24.
 4. Bradley+ 2016. Phlpp1 facilitates post-traumatic osteoarthritis and is induced by inflammation and promoter demethylation in human osteoarthritis. Osteoarthritis and Cartilage 24(6), pp. 1021–1028.
- Zhou+ 2018. Role of Phlpp1 in CellProliferation and Apoptosis in Intervertebral Discs. PS1-53, Poster#0750, Transactions of the Orthopaedic Research Society; March 9-13 2018, New Orleans, LA

Injectable RADA16-I hydrogel conjugated with a bioactive short peptide from BMP-7 attenuates intervertebral disc degeneration in canine

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Introduction: Tissue engineering strategies have emerged in response to the growing prevalence of intervertebral disc degeneration (IDD), and many of these regenerative methods are currently being evaluated in translational animal models. To promote various cellular activities, self-assembling peptide (SAP) hydrogels have been functionalized through the incorporation of biological molecules. In our previous study, we developed a novel functionalized SAP hydrogel RADKPS by conjugating the short peptide KPSS of bone morphogenetic protein-7 (BMP-7) into the C-terminal of RADA16-I and then mixed with pure RADA16-I at equal volume, which has the potential of activation of nucleus pulposus cells (NPCs) and synthesis of extra-cellular matrix (ECM) *in vitro*^[1]. In this study, we investigated the regenerative effect of RADKPS on treating the degenerative intervertebral disc (IVD) in canine.

Methods: Four consecutive lumbar IVDs (L3-L4 to L6-L7) in 20 adult beagles were induced to degeneration via aspiration of NP under constant negative pressure by 16-G needle. The intact disc L7-S1 was regarded as the normal control. After 4 weeks, animals were evaluated by radiography and magnetic resonance imaging (MRI). The animals with degenerative IVDs at Pfirrmann II or III were assigned to subsequent animal experiments. Then the four degenerative IVDs in each dog were treated with different approaches: L3-L4 injected with 40 μ L phosphate-buffered saline (PBS) served as sham group, L4-L5 was injected with 40 μ L RADA16-I, L5-L6 was injected with 40 μ L RADKPS, L6-L7 was injected with 40 μ L BMP-7 solution, respectively. At 4, 8, 12, and 16 weeks after treatment, the IVDs were evaluated by radiological parameters including relative Gray Index (RGI) and disc height Index (DHI%). After the last radiological examination, the animals were euthanized to obtain NP tissue for histological and ELISA analyses.

Results: Two dogs were died of septic shock within 2 weeks. Three dogs did not meet the inclusion criteria of subsequent experiments due to the severe IVD degeneration. The remaining 15 dogs were followed up for 16 weeks after the second-time operation. During the entire follow-up period, RADKPS group had significantly higher RGI and DHI% ($P < 0.05$). In addition, the expression levels of aggrecan and collagen II in RADKPS group were significantly higher compared to other degenerative groups ($P < 0.05$). In the early stage, 4-8 weeks after treatment, there were no significant differences in the radiological evaluation between RADKPS group and BMP-7 group. The disc height in RADA16-I group was significantly higher than that in the sham group ($P < 0.05$). However, the radiological, histological, and biochemical analyses demonstrated that the degeneration of the IVDs in the above-mentioned treatment groups were significantly severe than that in the normal group ($P < 0.05$).

Discussion: Taken together, the results from this study suggest that the functionalized self-assembling peptide RADKPS as a nanofibrous scaffold has the most effective and sustained repairing function for the degenerative IVDs in canine, although the biological factor BMP-7 is also beneficial for the degenerative IVDs in short-term. In addition, RADA16-I provides the skeletal network, which has the potential for maintenance of mechanical properties of IVDs.

1. Tao H, Wu Y, Li H, et al. BMP7-Based Functionalized Self-Assembling Peptides for Nucleus Pulposus Tissue Engineering. [J]. *ACS Applied Materials & Interfaces*, 2015, 7(31):17076.

Longitudinal MRI controls of intervertebral discs up to 24 months after transplantation of autologous mesenchymal stromal cells in 10 patients

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Introduction: Low back pain (LBP) is a major cause of disability where intervertebral disc (IVD) degeneration is considered to be central in pain causality.

This study was conducted to examine safety and feasibility of transplantation of autologous mesenchymal stromal cells (MSCs) into degenerated IVDs.

The outcome regarding magnetic resonance imaging (MRI) parameters for the IVDs up to 24 months after transplantation is reported.

Methods: 10 patients (7males/3females, mean age 40 years, range 26-53), on the waiting list for lumbar fusion or disc prosthesis procedures, were included. All had severe LBP and disc degeneration at 1 or 2 levels, classified as Pfirrmann grade 3-4 on MRI. MSCs were harvested from the posterior iliac spine, expanded in an accredited laboratory and labeled with iron sucrose (Venofer®). Cells (1×10^6) were injected at 1 level (2 in one patient) under fluoroscopic control. Eight patients were injected at the L4-L5 IVD, one at the L5-S1 and one at both levels. Labeling was performed in order to facilitate tracking of the injected cells in case of disc retrieval during fusion or disc-prosthesis surgery.

MRI (1.5T scanner, T1- and T2-weighted sagittal sequences) was performed pre-and postoperatively and at 3, 6, 12 and 24 months. All MRIs were reviewed by a senior radiologist with assessment of quantitative and qualitative morphological parameters of the injected and the adjacent IVDs.

Assessed parameters included disc height (anterior, mid, posterior), disc angle, Pfirrmann grade, Modic changes, prevalence of high intensity zones (HIZ), qualitative evaluation of IVD and endplate inhomogeneity.

To enable comparison, relative signal intensity on T2-weighted sequences was calculated by normalizing the IVD signal intensity (entire IVD at midsagittal plane) with cerebrospinal fluid signal intensity (assessed at the IVD level).

Results: MRI was performed up to 6 months for all patients. The patients that postponed originally planned surgery were further followed by MRI at 12 (6 patients, 1 dropout) and 24 months (2 patients, ongoing follow-up).

10/11 injected discs remained without altered degeneration grade at all time points whereas one IVD changed from Pfirrmann grade 3 to grade 4.

No statistically significant differences were detected over time regarding disc height, disc angle or T2-time for the assessed IVDs. IVD inhomogeneity on T1-weighted images increased slightly at the first MRI post-transplantation in 6/11 injected IVDs and in 3/11 IVDs on T2-weighted images. At later time-points no alterations were seen.

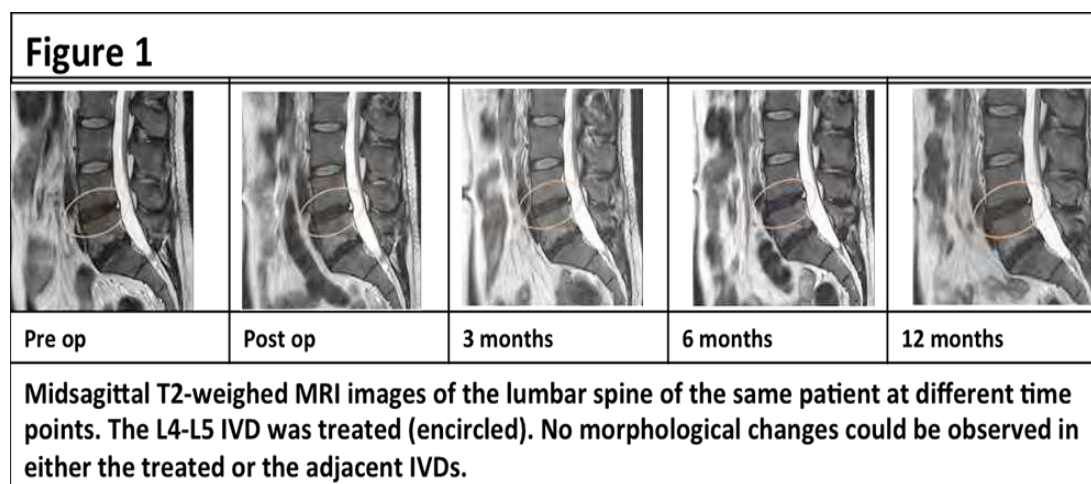
HIZ could be identified in 5/11 IVDs pre-transplantation with only minor changes registered through the study.

Only minor fluctuations compared to baseline were observed regarding Modic and endplate homogeneity.

Discussion: In spite of both quantitative and qualitative MRI evaluation of MSC transplanted IVDs up to 24 months, no significant morphological changes were detected.

The postoperatively increased inhomogeneity in injected IVDs could be attributed to the iron labeling of the cells.

Previous studies have reported some amelioration of radiological parameters. This difference might be attributed to lack of treatment effect, use of iron labeling which can affect the MSCs, short follow-up time or the timing of the intervention in relation to disease progress.



Understanding the Impact of Repetitive Lifting Towards Lumbar Disc Herniation: A Clinically Relevant Biomechanical Cadaveric Study

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Introduction: Repetitive lifting has been shown to lead to lumbar disc herniation (LDH)¹. In-vitro studies have developed a qualitative understanding of the effect of repetitive loading on LDH². However, no studies have measured internal disc strains and subsequently correlated these with disc damage. Therefore, the aim of this study was twofold: 1.) to examine whether unsafe simulated repetitive lifting leads to a greater risk of injury compared to safe lifting 2.) to explore correlations between tissue damage (MRI and macroscopic), internal disc strains, and failure mode; as well as between failure mode, Pfirrmann grade and disc level after simulated repetitive lifting.

Methods: Thirty human cadaver lumbar functional spinal units were subjected to an equivalent of one year of simulated repetitive lifting under safe and unsafe levels of compression, in combination with flexion (13-15°), and right axial rotation (2°) for 20,000 cycles or until failure. Safe or unsafe lifting were applied as a compressive load to mimic holding a 20 kg weight either close to, or at arm's length, from the body, respectively. Maximum shear strains (MSS) were measured, and disc damage scores were determined in nine regions from axial post-test MRI and macroscopic images that were assessed by three independent observers.

Results: Twenty percent of specimens in the safe lifting group failed before 20,000 cycles, compared to 80% in the unsafe lifting group. Significant positive correlations were found between MRI and macroscopic damage scores in all regions ($r_s > 0.385$, $p < 0.049$). A significant positive correlation was observed in the left lateral region for MSS vs. macroscopic damage score ($r_s = 0.486$, $p < 0.037$) and MSS vs. failure mode ($r_s = 0.724$, $p = 0.018$). For the majority of specimens within the disc protrusion and herniation groups, the region of protrusion or herniation was where the highest damage score was found, and the largest MSS (Figure 1). Pfirrmann Grade 3 discs were strongly associated with subsequent LDH ($p = 0.003$).

Discussion: Cadaveric specimens were subjected to an equivalent of one year of safe and unsafe heavy lifting under bending and twisting, showing that unsafe lifting of a 20 kg box away from the body leads to a greater risk of injury. Damage associated with disc protrusion and LDH was predominantly located in the posterior and posterolateral regions, further validating current clinical knowledge. LDH and Pfirrmann grade were associated, where Pfirrmann grade 3 discs were more likely to herniate than normal discs (grades 1 and 2). Increased internal disc strains were associated with progression of disc injury within the left lateral region, which provided evidence that the lateral regions may be more vulnerable than previously understood. Our study suggests there may be a shear strain threshold in relation to LDH, which needs further investigation for determination of the threshold value.

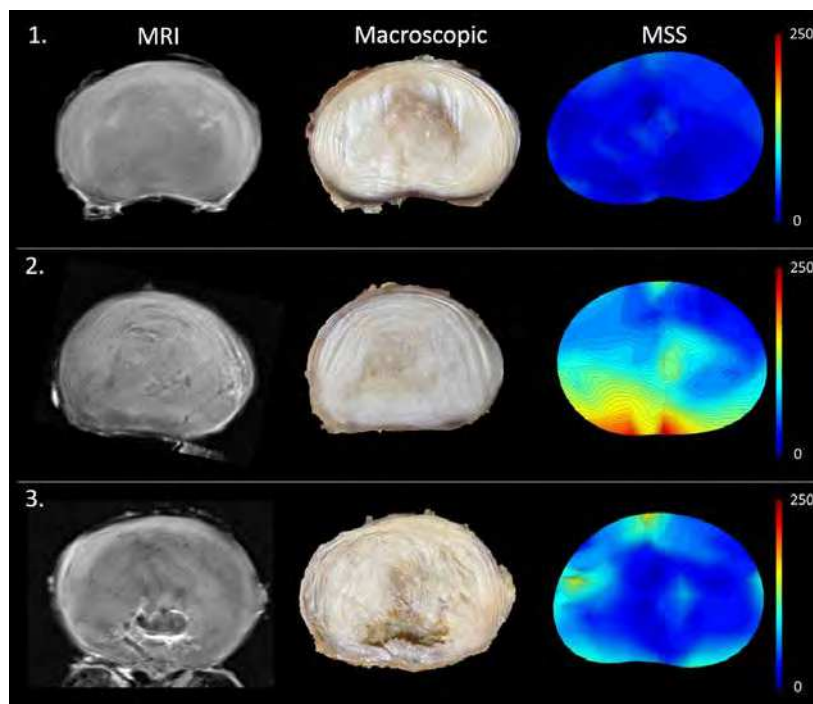


Figure 1. Left to right images: MRI axial slice, macroscopic axial slice, and the maximum shear strain (MSS) map after repetitive loading for example specimens with (1) No injury, (2) Nucleus migration (left and right posterolateral) and (3) A posterior central LDH.

- [1] Kelsey JL, Githens PB, White AA, 3rd, et al. An epidemiologic study of lifting and twisting on the job and risk for acute prolapsed lumbar intervertebral disc. *Journal of orthopaedic research : official publication of the Orthopaedic Research Society* 1984;2:61-6.
- [2] Adams MA, Hutton WC. Gradual disc prolapse. *Spine* 1985;10:524-31.
- [3] Gordon SJ, Yang KH, Mayer PJ, et al. Mechanism of disc rupture. A preliminary report. *Spine* 1991;16:450-6.

Subsidence risk of vertebral body replacements using a new biomechanical in vitro test method

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Introduction: Prevention of implant subsidence in osteoporotic (thoraco-) lumbar spines is still a major challenge in spine surgery. Different groups examined several risk factors that could be related to subsidence risk. The aim of this study was to determine the subsidence risk of vertebral body replacements during physiologic everyday activities of the patient. Therefore, a new biomechanical in vitro test method was developed to simulate distinctive activities and applied to a vertebral body replacement, such as climbing stairs, tying shoes or lifting heavy weights.

Methods: The study included 6 thoracolumbar (T11-L1) and 6 lumbar (L2-L4) human specimens. After dorsal stabilization and removal of the mid vertebra and adjacent discs, vertebral body replacements (VBR) with (a) round centrally located and (b) lateral end pieces with apophyseal support were implanted. The groups have been equally distributed regarding segment, BMD (mean (a) 67.8 mgCaHA/cm³, mean (b) 64.1 mgCaHA/cm³) sex and age (mean age (a) 72 and (b) 69 years). A new test method simulating several physiologic everyday activities was established. In a custom-made dynamic 6 DOF loading machine, the specimens were subjected to maximum axial loads corresponding to the performed activity raised by 50 N each 100 cycles. Combined flexion-extension and lateral bending were applied at 0.5 Hz and increased stepwise by 0.25°. Prior to implantation, subsequently and after simulating 'climbing stairs', 'tying shoes' and 'lifting 20 kg', in all three motion planes, the range of motion (ROM) of the specimens was determined under pure moments of 3.75 Nm for osteoporotic lumbar spines. Additionally, subsidence depth was quantified through fluoroscope films. A mixed model with the significance level set to $\alpha = 0.05$ was established to relate subsidence risk to implant geometries and patients' activities.

Results: Generally, there is a clear trend of increased ROM following severe everyday activities. The lateral end pieces that additionally support the apophysis showed a less pronounced subsidence depth (estimated mean 'round': 3.2 mm vs. 'lateral': 0.4 mm). That led to a decreased ROM in flexion-extension ($p < 0.1$) as well as a significant increase ($p < 0.05$) in axial rotation for the lateral geometry.

Discussion: In this study, a new biomechanical test method was developed that simulates physiologic activities to provoke and examine subsidence of vertebral body replacements. It could be pointed out that subsidence occurs most when lifting heavy weights, and into the ventral part of the caudal vertebra. The observed raise in ROM could be considered as a signal for higher risk of implant subsidence. Further on, the results indicate that lateral end pieces may better prevent from implant subsidence into the adjacent vertebrae, because of the additional lateral support of the cortical bone. Generally, patients that are treated with a vertebral body replacement should avoid activities that create high loadings on the spine.

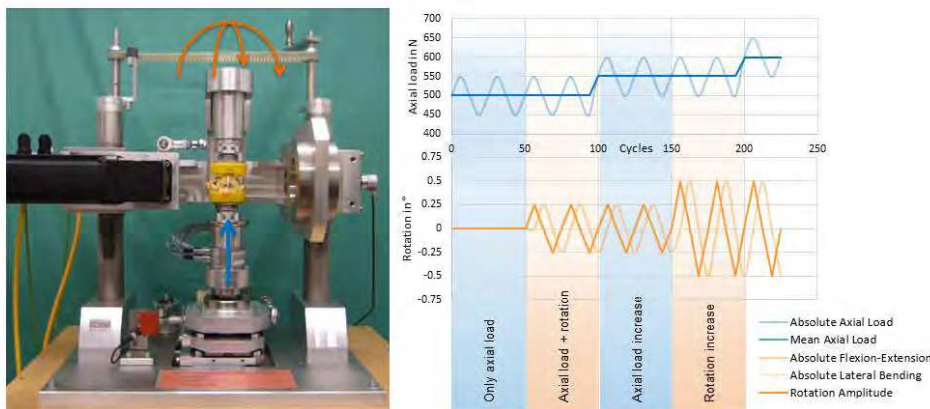


Fig. 1: (a) Dynamic spine tester simulating the different physiologic activities of the patient. (b) The new complex dynamic test protocol combining axial loading with flexion-extension and lateral bending movements according to the activity of the patient. The load and range of motion is applied sinusoidally and raised phase-shifted.

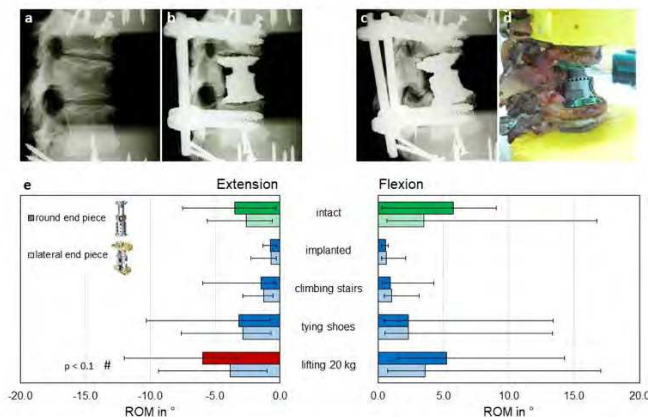


Fig. 2: Subsidence of vertebral body replacement with round end pieces into the adjacent vertebrae following simulation of daily activities (a) intact specimen (b) specimen after implantation of vertebral body replacement (c) and (d) specimen with severe implant subsidence after simulation of lifting heavy weights of 20 kg (e) range of motion in every testing condition for flexion-extension applying ± 3.75 Nm comparing round and lateral end pieces

Complex reorganization of the nociceptive withdrawal reflexes of the trunk in people with chronic low back pain

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Background: People with chronic low back pain (CLBP) move differently. Differences in the brain motor areas might be a mechanism underlying spine movement alteration. In contrast, there is limited evidence regarding potential differences in the function of spinal networks that might contribute to alteration in spine motor control. Recent research used noxious stimuli over different trunk sites to elicit nociceptive withdrawal reflex (NWR). Stimuli evoked NWR organized in *receptive fields* specific to each muscle that were consistent with their mechanical function and were elicited at a latency suggesting a spinal origin. NWR of the trunk might inform about the excitability and organization of spinal motor networks controlling trunk muscles.

Purpose: This study aimed to determine whether the organization and the excitability of the trunk NWR differ between individuals with and without CLBP. The specific aims were to test: (i) whether excitability of the NWR with stimuli provided at different trunk sites differs between groups; and (ii) whether the organization (i.e. pattern of muscle activation) of the NWR of the trunk differed between groups. Based on data from other conditions, we hypothesized that CLBP would involve; (i) a lower threshold for the trunk NWR consistent with sensitization, (ii) lower specificity in the organization of trunk NWR with respect to the site stimulated.

Methods: Noxious electrical stimuli were delivered at 1.2 times the NWR threshold at four sites (S1, L3 and T12, and Right Rib) to elicit NWR in 12 individuals with LBP and 13 healthy controls. Activation of *lumbar multifidus* (LM), *thoracic erector spinae*, *rectus abdominus*, *obliquus internus* and *obliquus externus abdominis* muscles were recorded. Due to large NWR threshold variability in individuals with CLBP, two subgroups were delineated: participants with High- and Low-threshold, and compared with the healthy controls. Independent-test assessed differences in NWR excitability. Generalized estimating equation tested differences in NWR organization.

Results: Although the CLBP group presented with a large difference in NWR threshold compared to controls (CLBP: 24.3 ± 9.1 mA; CTL: 8.3 ± 2.8 mA), it narrowly missed significance due to large inter-subject variability. In High-threshold subgroup, the amplitude of abdominals NWR were larger, especially after stimulation of the Rib. Also, LM NWR was less frequently evoked in both CLBP subgroups than controls, despite the use of a higher stimulus intensity and a similar pain intensity elicited by the noxious stimulation.

Discussion: From one perspective, CLBP presented hyposensitivity to 'local' lower lumbar spine stimulation which might represent an adaptive mechanism to protect spine structures. From another perspective, in a subgroup of CLBP participants, abdominal muscles were overactive following 'remote' Rib stimulation suggesting hypersensitivity. These results in addition with the differences in trunk muscle 'receptive fields' suggest that spinal motor networks controlling trunk muscles may contribute to differences in function/organization in spine sensorimotor control in individuals with CLBP. These results indicate that interpretation of sensitization in people with clinical pain cannot be generalized and may vary between sensory domains and between individuals. This advocates for individualization of interventions to patient's characteristics rather than a one-size-fit-all treatment.

Inter-Level and Intra-pedicle Bone Mineral Density Distribution in the Lumbar Spine Pedicle Cortex

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Introduction: Pedicle screw fixation has become the gold standard method of stabilization for a variety of spinal disorders. Pedicle screw pull-out strength depends on many factors; quality of the pedicle cortex holding the screw is one of the important factors. The thickness of the cortical bone at the pedicular isthmus has been previously described [1], but to the best of our knowledge, no published reports have addressed inter-level and intra-pedicle lumbar spine pedicle cortex regional variation in bone mineral density. The purpose of this study is to investigate these topics *in vivo* based on clinical CT.

Methods: 440 lumbar pedicles (L1-L5) from 44 volunteers (22 females and 22 males; mean age 38.3 years old; range: 23-58 years old) were used in this IRB-approved study. Each subject underwent CT-scans at 1.0 mm slice thickness, no spacing. The resulting DICOM data was analyzed with custom-written visual C++ routines to determine the regional variation in pedicular BMD and was reported in Hounsfield Units (HU). 3D distribution of the pedicular BMD was evaluated in a cylindrical coordinate system with its longitudinal axis along pedicle orientation. The highest HU value was identified at each position on the axis and angle in the cylindrical coordinate system. Four quadrants were determined, namely: cranial, medial, caudal and lateral, and the mean HU values among all four quadrants were calculated for all spine levels (L1-L5). Data was discriminated between right and left pedicles. ANOVA with Tukey's post hoc test and unpaired Student's t-test were used to evaluate differences between quadrants and levels. Results are presented as mean \pm SD. Significance was set at $p < 0.05$.

Results: The mean \pm SD BMD values in L1 (860.6 \pm 99.1 HU) and L5 (878.3 \pm 104.6 HU), respectively were both significantly lower ($p < 0.0001$) than the values between L2-4 (mean BMD range 973-996 HU). Females had significantly higher mean BMD at L1, L2, and L5. By age group, the mean BMD was higher for all levels in 20s/30s than in the 40s/50s. When comparing BMD between the four quadrants, the lateral region was significantly lower than the medial region at L1, L4, and L5 (Fig. 1).

Discussion: There was a decrease in BMD at L5 with respect to a very much consistent plateau of data between L2 and L4, and this was verified in males as well. These unexpected results may be explained by larger pedicle dimensions of L5 pedicles than those at L2-4 and in males [4], which provide greater structural mechanical properties at L5 with lower bone mineral density. In other words, the structural properties of the pedicles at L2-4 especially in females may be compensated by increasing bone mineral density in the pedicle cortex. The HU distribution in the lateral region at L5 was lowest among all regions in the L1-L5 pedicles, except the lateral region at L1. Since mineral density reflects material properties of bone tissue, bone mineral density distribution and screw entry points should be considered for pedicle screw planning and insertion.

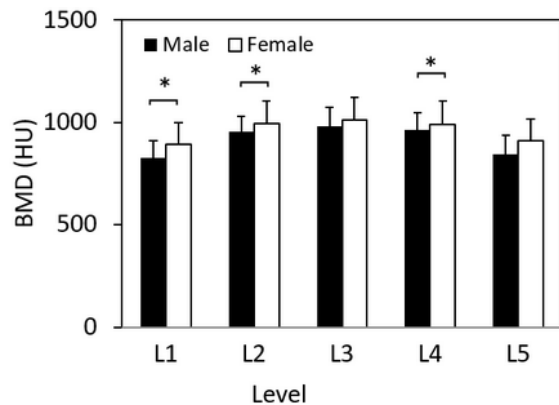


Fig. 1A BMD by lumbar level and gender.

* Significant difference $p < 0.05$

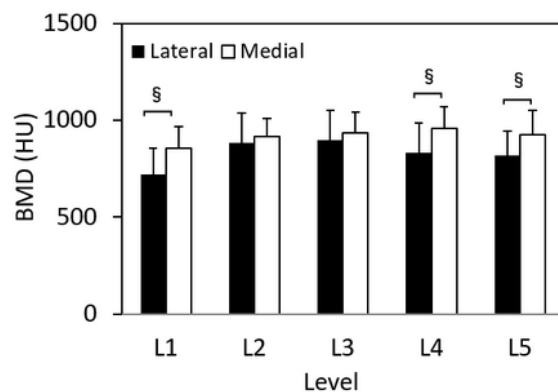


Fig. 1B Regional BMD by anatomical side

§ Significant difference $p < 0.0001$

- [1] Li B, et al. Spine 2004;29:2438-2444
- [2] Kothe R, et al. Spine 1996;21:264-270
- [3] Crawford N, et al. J Neurosurg Spine 2009;10:486-491
- [4] Sugisaki K, et al. Spine 2009 Nov 15;34(24):2599-604

A novel small compound prevented intervertebral disc degeneration via PI3K/AKT pathway.

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Introduction: Regenerative medicine targeting nucleus pulposus (NP) is drawing attention for intervertebral disc degeneration (IDD) therapy. Recently, a drug screening study using the COL2-GFP-ATDC5 monitoring system identified thienoinadazole derivative compound (TD-198946 [TD]) as a novel drug for osteoarthritis from 2500 natural and synthetic small compounds.¹ Because of the similarity of NP cells with chondrocyte, the TD is also expected to have efficacy on prevention of IDD. The purpose of this study aimed to evaluate the effects of the TD on IDD.

Methods: For in vivo assay, a tail-disc puncture model with 33-gauge needle was used to create IDD on 10-week-old male C57BL6J mice.² The control solution or 5µl of the TD (100nM) was injected into the disc space immediately after the puncture (prevention model) or 2 weeks after the puncture (treatment model). Mice were sacrificed at 6 weeks after the injection. Micro-CT scanning was performed to evaluate the disc height at 2, 4 and 6 weeks after the injection and the disc height index (DHI: disc height / vertebral body length x100) was calculated.³ Histological grading scale evaluation was also performed.³ For in vitro assay, human NP cells were cultured in 2D micromass. Alcian blue staining, glycosaminoglycan (GAG) production, and expression of genes related to NP were assessed. Furthermore, total RNA from the two groups were sequenced, and KEGG (Kyoto Encyclopedia of Genes and Genomes) pathway analysis was performed to assess differential expression genes (DEGs) numbers of each pathway. Western blot (WB) was performed based on the KEGG pathway results. The differences in the measured variables were calculated by Mann-Whitney U test.

Results: In vivo assay; the DHI in the TD group was significantly higher compared to that of the control group at every time points in both models (P<0.01). The results of histological grading scale in the TD group was also significantly better than that of the control group at all points in both models (P<0.01). In histology, the NP structure in the TD group was well preserved in both models, but the NP structures of the control group was almost lost and is replaced with fibrous tissue in both models. (Figure 1A, 1B) In vitro assay; the alcian blue staining (Figure 2) and the GAG production (p<0.05) was enhanced in the TD group and the expression of aggrecan and hyaluronan synthase 2 (HAS2) was increased in the TD group (p<0.05) compared to the control group. KEGG pathway analysis revealed that DEGs number of PI3K/AKT signaling pathway was the most changed. The expression of phospho-AKT was increased in TD group by WB assay.

Discussion: The TD showed the effects on the preservation of disc height and NP structure in mouse IDD model. The results in vivo were supported by the results of in vitro study that the TD enhanced extracellular matrix production in human NP cells via PI3K/AKT signaling pathway. The TD is a novel promising small compound targeting mild to moderate IDD.

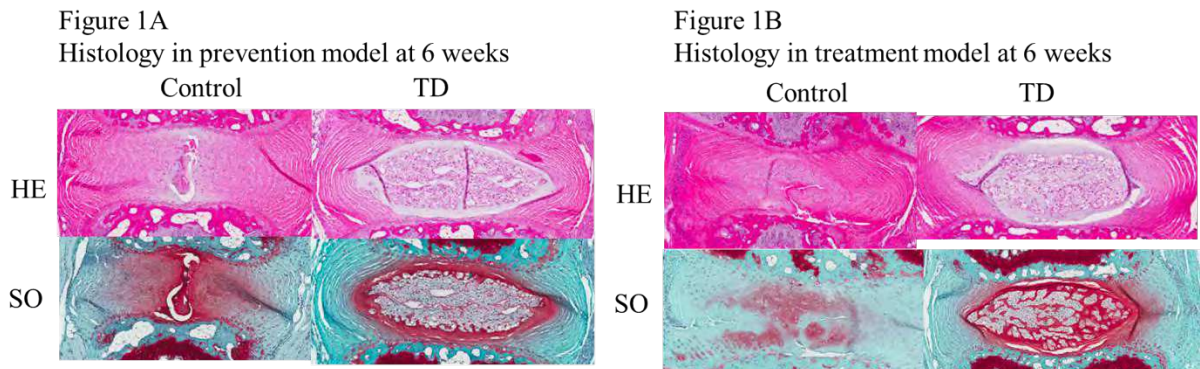
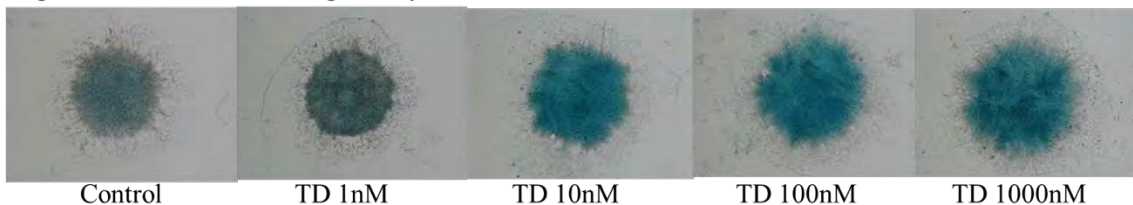


Figure 2. Alcian Blue staining at 7days



1. Yano F, et al. Ann Rheum Dis. 2013 May;72(5):748-53. 2. Yang F, et al. J Pathol. 2009 May;218(1):113-21. 3. Masuda K, et al. Spine (Phila Pa 1976). 2005 Jan;30(1):5-14.

Lactate as a carbon biofuel for annulus fibrosus cells

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Introduction: Intervertebral disc cells reside in an environment that subjects them to low glucose and oxygen and high lactate concentrations. The current prevailing theory posits that accumulation of lactate, a consequence of NP cell anaerobic respiration, is a toxic waste byproduct which contributes to disc degeneration by reducing cell metabolism and viability¹. However, disc cells can survive high lactate milieu for decades, yet the mechanisms by which they do so remains unclear. We propose a new hypothesis that predicts that annulus fibrosus (AF) cells are metabolic flexible and capable of importing and metabolizing lactate as a carbon source.

Methods: AF cells were isolated from lumbar discs of skeletally immature (6-9mo) New Zealand White rabbits (n=4-6 per group). Cells were cultured at 5% O₂, passaged, plated for 48h and treated for 24h without or with exogenous lactate (2-20 mM, Sigma) in DMEM media containing low glucose (1mM) to mimic *in vivo* conditions. Following treatment, lactate import into AF cells (¹⁴C-lactate tracing), lactate conversion to Krebs cycle intermediates (¹³C-lactate labeling and mass spectrometry), cell viability (MTT assay), collagen synthesis (³H-L-proline incorporation assay), and bioenergetics profiles (Seahorse XFe 96 extracellular flux analyzer) were measured. Gene and protein expression of the lactate importer (MCT1) and lactate dehydrogenase isoform B (LDH-B) that preferentially converts lactate into pyruvate were measured by qRT-PCR and Western.

Results: AF cell viability remained unchanged when cultured in the presence of lactate up to 10mM but decreased slightly (18%) at 20mM lactate. At 4mM lactate, AF cells up took lactate (¹⁴C-lactate tracing) and converted it to glutamate, a product derivative of the Krebs cycle intermediate a-ketoglutarate (¹³C-lactate labeling and mass spectrometric analysis). Treatment of AF cells with 2-4 mM exogenous lactate modestly increased collagen synthesis (16%) and rates of both basal oxygen consumption (oxidative phosphorylation) and extracellular acidification (glycolysis). AF tissue as well as cell culture robustly expressed MCT1 and LDH-B mRNAs and proteins.

Discussion: Our findings demonstrate that AF cells possess the molecular machineries for importing lactate (MCT1) and converting it to pyruvate (LDH-B) for further metabolism. Exposure of AF cells to physiologic lactate concentrations² (2-6mM) does not affect AF cell viability; it actually improves AF cell bioenergetics and matrix collagen synthesis. Together, these results support the predictions of our hypothesis that state that AF cells are capable of importing lactate and utilizing it as a carbon source to generate energy and matrix synthesis. Our study identifies an important metabolic adaptation of the intervertebral disc to its unique environment. Further experiments are being done to dispel or confirm the long-standing notion that lactate is a waste product in the disc.

1. 1) Yong-Can Huang et al., Nature Reviews Rheumatology volume 10, pages 561–566 (2014) 2) Bartels EM et al., Spine (Phila Pa 1976). 1998 Jan 1;23(1):1-7

Clinical differences of each item of Oswestry Disability Index between the patients with lumbar spinal stenosis and lumbar disc herniation

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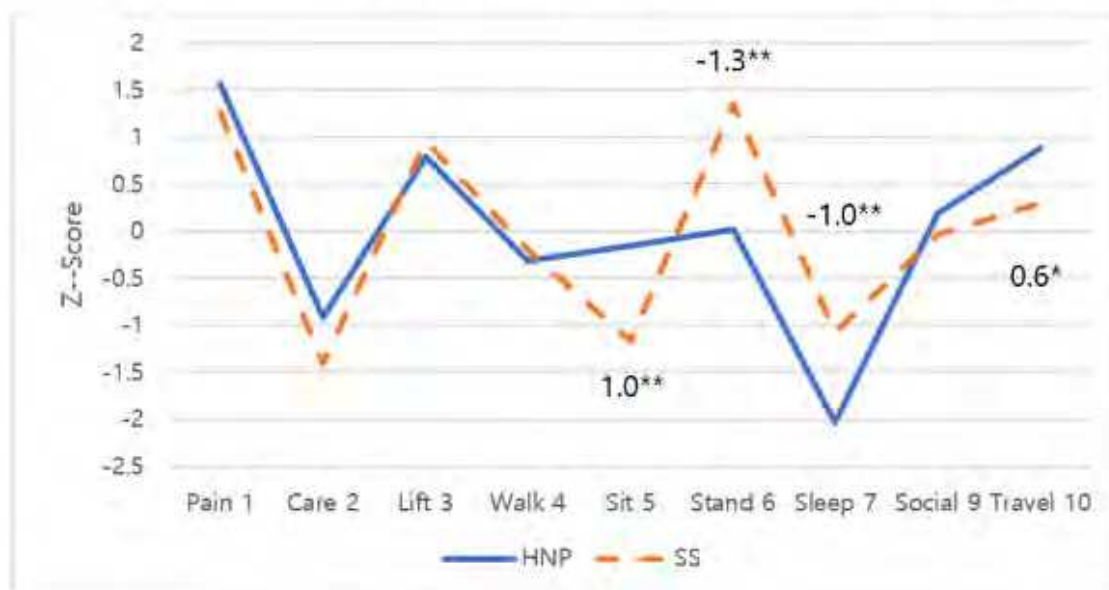
Introduction: Oswestry disability index (ODI) has been widely used to evaluate the disability of patient with degenerative lumbar disease due to its reliable, well-responsive, easy-to-use, and robust psychometric features. ODI score is calculated by the summation of 10 sections, which cover major features of daily activity very well. Although many studies have focused on total sum of ODI score, there is a paucity of literature highlighting the clinical importance of each ODI item in individual lumbar degenerative disease. We evaluate the clinical differences of each ODI item score between the lumbar disc herniation (HNP) and the lumbar spinal stenosis.

Methods: We analyzed 67 patients who were diagnosed of HNP (n=37) and SS (n=30) and screened with ODI (2.0 version, validated in Korean). We also collected visual analogue scale (VAS) of back and leg from the patients' medical records. We conducted statistical tests with repeated measured t-test and Cohen's effect sizes (Cohen, 1977) to examine ODI total and individual item score differences for HNP and SS. Effect sizes are usually assumed to represent real differences (Cohen, 1977). Also, we examined correlation between VAS and certain ODI items to study their relationships.

Results: There were no significant differences in ODI sum scores ($p=0.65$), VAS back ($p=0.87$) and leg ($p=0.74$) scores between HNP and SS. When we examined each item score of ODI, there were statistically significant differences at $\alpha=0.05$ in 4 ODI items, such as sit, stand, sleep, and travel and their effect sizes were between 0.6 to 1.3. According to Cohen (1977), these effect sizes were between medium and large sizes (Figure 1). Also, these four items were all positively related with VAS (of back and leg) ($0.22 \leq r \leq 0.41$, $P \leq 0.05$). Note that we excluded item 8 (sex function) because few patients responded it.

Discussion: Based on our results, we recommend that the evaluation of the personal state of patients should include not only ODI sum scores but also ODI item scores to increase evaluate the characteristics of each lumbar degenerative disease. More difficulties in "Sit" and "Travel" was found in HNP than in SS, whereas more difficulties in "Stand" and "Sleep" was found in SS than in HNP. While no ODI sum scores were different between HNP and SS, but there was significant item score differences between two groups.

Fig 1. Effect Size of ODI Each Item Differences between HNP and SS



The numbers included in the figure were effect sizes. According to Cohen (1977), the effect size between 0.3 to 0.5 is small; between 0.5 to 0.8 is medium; and equal to or larger than 0.8 is large.

Therapeutic advantages of frequent physical therapy sessions for patients with lumbar spinal stenosis

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Introduction: Supervised physical therapy for patients with lumbar spinal stenosis (LSS) has been reported to lead to better short-term outcomes in terms of disability and leg pain than unsupervised exercise. However, no studies have investigated the relationship between the number of physical therapy sessions and the therapeutic effects in patients with LSS. The purpose of this study was to identify the effects of the number of physical therapy sessions on clinical outcomes of patients with LSS.

Methods: This was a retrospective study of a randomized clinical trial and a prospective study of patients with LSS. Patients presenting with symptoms of neurogenic claudication caused by LSS, which was confirmed by magnetic resonance imaging (MRI), were enrolled from September 2011 to May 2018. All patients received exercise therapy for 6 weeks. Included were 43 patients receiving supervised physical therapy twice a week (P2 group), 38 patients receiving supervised physical therapy once a week (P1 group), and 43 patients receiving a home exercise program alone (HE group). Clinical outcomes were measured using the Zurich Claudication Questionnaire (ZCQ), a numerical rating scale (NRS) of low back pain, leg pain, and leg numbness, the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), the Medical Outcomes Study 36-item Short-Form General Health Survey (SF-36), the Hospital Anxiety and Depression Scale (HADS), the Pain Catastrophizing Scale (PCS), and the Pain Anxiety Symptoms Scale (PASS-20) at baseline and at 6 weeks. A Kruskal-Wallis test using a post hoc Steel-Dwass test was performed to compare the three groups. $P < 0.05$ was considered significant.

Results: At baseline, there were no significant differences in age, sex, body mass index, duration of symptoms, MRI findings, or outcome measures between the three groups ($P > 0.05$). At 6 weeks, compared with the HE group, the P2 group showed significant improvements in ZCQ symptom severity (mean difference -0.4 ; 95% confidence interval [CI] -0.6 to -0.2), ZCQ physical function (mean difference -0.4 ; 95% CI -0.6 to -0.2), leg pain on the NRS (mean difference -1.4 ; 95% CI -2.5 to -0.3), gait disturbance on the JOABPEQ (mean difference 16.0; 95% CI 5.4 to 26.7), physical functioning (mean difference 9.2; 95% CI 2.1 to 16.3), and bodily pain (mean difference 10.4; 95% CI 3.3 to 17.5) ($P < 0.05$). The P2 group showed significant improvements in ZCQ physical function (mean difference -0.3 ; 95% CI -0.5 to -0.1), low back pain (mean difference -1.6 ; 95% CI -2.9 to -0.3), and leg pain (mean difference -1.4 ; 95% CI -2.6 to -0.6) on the NRS and bodily pain on the SF-36 (mean difference 11.5; 95% CI 3.2 to 19.7) compared with the P1 group at 6 weeks ($P < 0.05$). There were no significant differences in mean changes after 6 weeks between the P1 and HE groups.

Discussion: Six weeks of supervised physical therapy twice a week resulted in significant short-term improvements in physical function and back and leg pain compared with once a week. Supervised physical therapy for patients with LSS should be performed more than once a week for 6 weeks.

Advanced Glycolysation End Products (AGEs) in Hypertrophied Ligamentum Flavum of Diabetes Mellitus and Non Diabetes Mellitus

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Background: Lumbar spinal stenosis (LSS) is one of the most common disorders in elderly, and ligamentum flavum (LF) hypertrophy has a dominant role in LSS. The diabetes mellitus (DM) is a systemic disease, and it has been reported that the prevalence of lumbar spinal stenosis is higher in the patients with DM than in those without. However, the pathomechanism of stenosis in DM has not been well understood. The formation of advanced glycolysation end products (AGEs) is an important biochemical abnormality in DM, and cause tissue damage through degeneration and/or inflammation in various organs. The purpose of this study is to analyze the histology of LF focused on AGEs and to compare between the control, LSS patients with DM and those without.

Material and Method: Ten LF specimens from LSS with DM (DM group, mean age 71.4), 10 LF from LSS without DM (non-DM group, mean age 71.2), and 9 LF from lumbar disc herniation or cauda equina tumor (control group, mean age 49.0) were harvested during the surgery and histologically analyzed in this study. In addition to hematoxylin-eosin staining, Masson's Trichrome staining and immunohistochemistry (IHC) of AGEs were performed. The percentage of elastic fibers area (%EF) was measured on MT staining, and the percentage of AGEs immune-positive area (%AGEs) was measured on IHC of AGEs using computer software.

Result: The %EF was 12.8% in DM group, 17.1% in non-DM group, and 24.9% in control group. The decrease of elastic fibers was significantly severer in DM group than non-DM ($p < 0.01$) and control group ($p < 0.001$). The AGEs is positive especially in the extracellular matrix with elastic fiber disruption. The %AGEs was 18.3% in DM group, 12.1% in non-DM group, and 4.6% in control group, and significantly larger in DM group than in non-DM group ($p < 0.01$) and control ($p < 0.01$). The %AGEs has also the correlation with the patient ages ($p < 0.01$, $R = 0.47$).

Discussion: The histological finding of this study clarified that the elastic fibers significantly decreased in LF of LSS patients, and more obviously in those with DM. High localization of AGEs in disrupted elastic fibers and its relationship with patients' age suggest that AGEs may play a role in the process of degeneration and hypertrophy in LF. In conclusion, The AGEs accumulation is more in the LF of DM patients, and it also correlate with patient age. The AGEs may accelerate the degeneration process and hypertrophy of LF with age, and this may lead to high prevalence of LSS in the patients with DM.

Risk factors for occurrence of lumbar lesion in patients with rheumatoid arthritis

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Introduction: Rheumatoid Arthritis (RA) frequently involves to lumbar spine, so called lumbar lesion in RA. The lumbar lesion includes spondylolisthesis, scoliosis, or vertebral fracture. Recent studies have reported that there were more surgical complications in procedures for lumbar spinal stenosis in patients with lumbar lesion in RA than those in patients without RA. On the other hand, no study has reported about longitudinal study focused on lumbar lesion in RA, and the cause of lumbar lesion in RA has not been clarified. The purpose of this study was to investigate risk factor of new occurrence of lumbar lesion in RA by a longitudinal cohort study.

Methods: This study included a total of 87 patients with RA who were performed secondary radiological and clinical examination between 2017 and 2018, out of 201 patients who were enrolled to the initial survey at out-patients clinic of RA in our institution between 2010 and 2011. Radiological examinations were performed in cervical and lumbar spine by standing plain radiographs and MRI at both survey. Lumbar lesion in RA was defined as spondylolisthesis: ≥ 3 mm anterior slip, scoliosis: $\geq 10^\circ$ of Cobb angle, or vertebral fracture: \geq Grade 2 of semiquantitative technique by standing plain radiographs. New occurrences of lumbar lesion were investigated between initial and secondary survey. Risk factors for occurrence were investigated by univariate and multiple logistic regression analysis. The explanatory variables were examined in demographics, RA-related parameters, MRI findings (lumbar endplate erosion score/ facet erosion score; Yamada K. J Spinal Disord Tech 2014) at the baseline, and treatment effect of RA. Disease activity was evaluated by DAS28-CRP. Poor treatment effect of RA was defined as worse than moderate disease activity at the secondary survey or ≥ 1 level deterioration of disease activity between initial and secondary survey.

Results: There were 10 male and 77 female, and mean age at the initial survey was 60.9 years. There were 42 patients (48%) who showed lumbar lesion at the initial survey (spondylolisthesis 21/ scoliosis 25/ vertebral fracture 14). Lumbar lesions have occurred in 32 patients (37%); spondylolisthesis 24/ scoliosis 13/ vertebral fracture 5, during mean 6.8-year period. Univariate analysis indicated that significant associations with occurrence of spondylolisthesis were found in disease activity, VAS for LBP, and poor treatment effect ($p=0.02, 0.03, \text{ and } <0.01$, respectively). Significant associations with occurrence of scoliosis were found in disease activity and poor treatment effect ($p=0.01 \text{ and } <0.01$, respectively). Multivariate analysis showed that the independent risk factor of the occurrence of lumbar lesion were disease activity (OR 2.04, 95%CI 1.13-3.69) and non-use of biologic agents (OR 3.18, 95%CI 1.03-9.80). Patients with occurrence of lumbar lesion exhibited more severe LBP (26.3 vs 16.4, $p=0.021$) and lower QOL (EQ5D: 0.67 vs 0.75, $p=0.016$) than those without at the secondary survey.

Discussion: This study elucidated patients with higher disease activity and without administration of biological agents for any reason were likely occurred lumbar lesion in RA. Control of disease activity of RA might be most important to prevent occurrence of lumbar lesion in RA.

Comparison of Analgesic Effects between Chimera Decoy Oligodeoxynucleotide and Corticosteroid in the Rat Thrombin-induced Facet Joint Pain Model

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Introduction: Treatment of facet joint pain with corticosteroid injections is a commonly used procedure; however, steroids are known to have side effects, such as injection-site infection and suppression of matrix synthesis. The novel chimera decoy oligodeoxynucleotide (chimera decoy), developed to bind to both NF-kB cis lesions and STAT6 binding sites, shares a similar anti-inflammatory effect to that of steroids without inhibiting matrix synthesis. Thus, we hypothesized that chimera decoy is a novel local therapeutic for facet joint pain. The purpose of this study is to test whether facet injections of chimera decoy and dexamethasone can inhibit thrombin-induced pain in the rat.

Methods: Rat thrombin-induced facet pain model: Under general anesthesia, two μ l of each drug (Thrombin group [20U Thrombin], Dex group [20U Thrombin + 5 μ g dexamethasone] and Chimera group [20U Thrombin + 10 μ g chimera decoy]) were injected into the right L4/5 facet joint of Sprague-Dawley rats. The rats were sacrificed at day 10 or at 4 weeks ($n \geq 6-7$ at each time point).

Outcome Measures: Mechanical allodynia (von Frey test), change in body weight, general activities (HomeCageScan[®]) were assessed during the course of study. After sacrifice, the immunopositivity of Iba-1, and CGRP were semi-quantitatively analyzed in L4 dorsal root ganglia and correlated with the results of the von Frey tests. Histological analyses of synovial membranes are also conducted.

Results: In the von Frey test, withdrawal threshold in the Chimera and Dex groups were higher than that of the thrombin group at most time points from day 10 to day 28 ($P < 0.05$ Fig.1). Both body weight changes and HomeCageScan results showed significant differences between the groups: At day 10, body weight increase in the Chimera group was higher than that in the Thrombin group ($P < 0.05$ Fig.2a). Travel distance measured using HomeCage Scan in the Chimera group was higher than that in the Thrombin group ($P < 0.05$ Fig.2b). These results were supported by the immunohistochemical (IHC) analyses in DRGs. At the 4-week time point, Iba-1-positive microglia in the Chimera group was less than that in the Thrombin group ($P < 0.05$). At day 10 and 4 weeks, CGRP-positive neurons in the Dex and Chimera groups was fewer than those in the Thrombin group ($P < 0.05$ Fig.3a). IHC data for Iba-1 and CGRP were significantly and negatively correlated with von Frey test results ($P < 0.05$ Fig.3b). Histological results in synovial hyperplasia of facet joint were generally observed in the thrombin-injected side, but no significant differences among the group were observed.

Discussion: Both chimera decoy and dexamethasone significantly suppressed thrombin-induced mechanical allodynia. This analgesic effect was further supported by the results of general condition/activity in the Chimera group. Interestingly, the quantitative/semi quantitative measurement of IHC staining of DRGs showed the significant negative correlation with mechanical allodynia. These results support our contention that Chimera decoy shares similar therapeutic effects without the side effects seen with steroid injections. Further detailed studies on cartilage damage progression using long-term experiments may differentiate the effect of these two compounds on matrix synthesis and currently are ongoing to prove this concept.

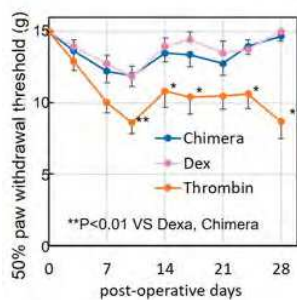


Fig.1: Von Frey

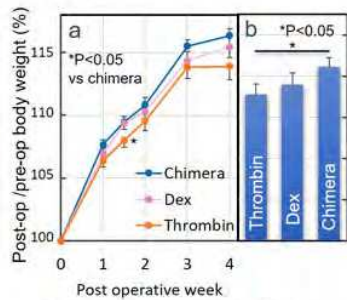


Fig.2a: Body weight 2b: Travel distance

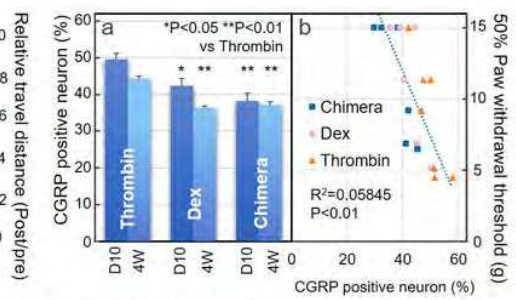


Fig.3a: IHC of CGRP 3b: Correlation between Von Frey and CGRP IHC

Effects of exogenously administered basic fibroblast growth factor and Heme oxygenase-1 in a rat sciatic nerve injury model

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Introduction: We previously studied the mechanism of vein wrapping, one of the surgical procedures for recurrent chronic constriction neuropathy. Favorable clinical results have been reported following this procedure, in terms of nerve functional recovery and the effects of reducing hyperalgesia. However, this procedure is sometimes invasive because a long incision in a normal part is needed to obtain a long vein. We previously reported that basic fibroblast growth factor (bFGF) is possibly secreted from veins wrapped around injured nerves, inducing the release of heme oxygenase-1 (HO-1), which is an antioxidant and has neuroprotective effects. In this study, we examined whether the same effect could be obtained when bFGF is exogenously administered by mimicking the method of vein wrapping in a rat sciatic nerve injury model.

Methods: Chronic constriction injury (CCI) was induced in 60 8-week-old male Wistar rats. In the first experimental group, a collagen sheet graft impregnated with bFGF was applied to the injured sciatic nerve after CCI (group bFGF/CS; n=20), while the second group received a collagen sheet impregnated with phosphate buffered saline after CCI (group PBS/CS; n=20); control group who only underwent CCI (group C; n=20), was also prepared for comparisons. Pain behavior evaluation (von Frey test) was performed on postoperative days 1, 5, 7, and 14 (n=5). RNA was extracted from the sciatic nerve, polymerase chain reaction was performed, and the expression level of HO-1 was examined on postoperative days 1, 5, 7, and 14. Moreover, HO-1 protein expression in the sciatic nerve was examined using the enzyme-linked immunosorbent assay (ELISA), and HO-1 positive cells in the sciatic nerve were counted using immunohistochemical staining on postoperative day 1.

Results: In the von Frey test, group bFGF/CS exhibited significantly more pain hypersensitivity than did groups PBS/CS and C on postoperative days 1 and 5. HO-1 RNA expression in the sciatic nerve was also significantly higher in group bFGF/CS than in groups PBS/CS and C on postoperative days 1 and 5. Further, ELISA and immunohistochemical staining revealed the presence of HO-1 protein and HO-1 positive cells in the sciatic nerve on postoperative day 1.

Discussion: This study suggested that bFGF increases the pain threshold, suggesting the possibility that it can counter hyperalgesia through the action of HO-1. Several recent reports show that exogenously administered bFGF with a carrier induced nerve regeneration in rat sciatic nerve resection models. Furthermore, Hayato et al. showed the efficacy of bFGF local administration in a patient with Bell palsy and paralyzed facial nerve after nerve decompression surgery. They used biodegradable hydrogel as a drug carrier. In consideration of these findings, exogenous administration of bFGF may play an important role in the therapeutic effect of injured nerves. Additionally, the findings showed that a collagen sheet graft impregnated with bFGF may be a viable alternative to vein wrapping.

Comparative Effectiveness of Expandable versus Static Lateral Lumbar Interbody Fusion Devices: Two Year Clinical and Radiographic Outcomes

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Introduction: Minimally invasive (MIS) lateral lumbar interbody fusion (LLIF) procedures using large interbody static spacers may require excessive trial and forceful impaction, leading to iatrogenic endplate disruption, excessive neural retraction, and implant subsidence. The in situ expansion capability offered by expandable interbody spacers facilitates insertion to help reduce endplate damage and optimize endplate contact. This study reported radiographic and clinical outcomes of static and expandable interbody spacers following MIS LLIF, and device-related complications including implant subsidence.

Methods: This study included 48 patients with degenerative disc disease who underwent MIS LLIF at 1-2 contiguous level(s) using a polyether-ether-ketone static or titanium expandable intervertebral spacer. Twenty-one patients were treated with static spacers, and 27 with expandable spacers. All spacers had supplemental posterior stabilization. Clinical and radiographic outcomes were analyzed at 12 and 24 months postoperatively.

Results: Mean patient age was 66.6±9.7 years, 72.9% of patients were female. No significant differences were observed between static and expandable groups in operative time (64.0±39.2min, 73.7±39.7min), estimated blood loss (35.6±29.2cc, 40.0±30.8cc), or length of hospital stay (2.0±1.3days, 2.4±1.3days), respectively (p<0.05). Mean VAS pain and ODI, and RAND 36 scores improved significantly (p<0.05) at 24-month follow-up. Patients treated with expandable implants were found to have significantly lower scores for VAS back pain (n=39, 1.3±1.7, 3.8±3.0, p<0.05) VAS leg pain (n=40, 1.4±2.3, 3.6±3.6, p<0.05), and ODI at 24-month follow-up (n=42, 13.8±14.2, 27.9±19.4, p<0.05) compared to static implants. Intervertebral disc height increased significantly (p<0.05) from baseline for expandable and static groups at each follow-up through 24 months. At 12-month follow-up the static group had significantly higher subsidence rates. No new subsidence cases developed between 12-month and 24-month follow-up.

Discussion: In this cohort, clinical use of expandable interbody spacers resulted in better outcomes through 24-month follow-up compared to static interbody spacers, with expandable group showing significant improvements in pain and disability than the static group at 24 months.

Fusion technique does not affect short-term patient-reported outcomes for lumbar degenerative disease

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Introduction: Degenerative lumbar pathology can be addressed via an anterior or posterior approach, and with or without the use of an interbody cage. While several studies have compared the type of approach and technique, there is a lack of literature assessing patient reported outcomes between types of fusion.

Methods: Patients that underwent lumbar spinal fusion between one to three levels were identified retrospectively identified at a single center, academic hospital. Patients with a history of previous lumbar surgery, infection, tumor, or trauma and those with less than one year follow-up excluded. Demographic and operative variables were noted for each patient. Spinopelvic parameters were measured pre- and post-operatively. Patients were separated into three groups based on the type of fusion they underwent: posterolateral fusion (PLF), anterior lumbar interbody fusion (ALIF), or transforaminal lumbar interbody fusion (TLIF). Outcome measures including the SF-12 physical component score (PCS-12), mental component score (MCS-12), Oswestry disability index (ODI), visual analog scale (VAS) back, and VAS leg scores were evaluated. One-way ANOVA U test was used to compare means between continuous variables, with a Bonferroni post-hoc test. Multivariate analysis using multiple linear regression was used to determine if type of fusion was an independent predictor of change for each HRQOL.

Results: A total of 403 patients were included in this study with an average follow-up of 13.8 months. There were 225 patients in the PLF group, 36 patients in the ALIF group, and 142 patients in the TLIF group. The PLF group was significantly older at baseline ($p < .001$), whereas the ALIF group underwent a higher proportion of 3 level fusions ($p < .001$). There was no significant difference in spinopelvic parameters preoperatively, however postoperative sacral slope was significantly higher in the ALIF group ($p = .039$, Table 1). Comparing outcome measures, only VAS leg scores were significantly different preoperatively, with the ALIF group having lower pain scores ($p = .015$, Table 2), however this difference resolved postoperatively. With multivariate analysis, type of fusion was found to be an independent predictor of ODI ($p = .034$, Table 2), with the ALIF group having the greatest change in ODI.

Discussion: Lumbar degenerative pathology can be treated with several different fusion techniques, however the relationship between type of fusion and patient reported outcomes is not established. Based on our findings in this study, we found that while the ALIF group had some perioperative differences compared to the PLF and TLIF groups, the majority of spinopelvic and outcome measures remained similar between all three fusion types. This is one of the first studies to show that fusion technique does not affect patient reported short-term outcomes. Further studies are needed explore this relationship.

Table 1. Pre-op and Post-op Spinopelvic Measurements

	Pre-op Measurements				Post-op Measurements			
	PLF	ALIF	TLIF	p^1	PLF	ALIF	TLIF	p^1
Pelvic Tilt	23.8 [22.5, 25.1]	25.3 [21.4, 29.2]	23.0 [21.2, 24.7]	0.430	24.4 [23.2, 25.6]	24.5 [21.0, 28.1]	23.7 [22.3, 25.1]	0.732
Sacral Slope	35.9 [34.6, 37.1]	36.8 [33.0, 40.6]	36.0 [34.2, 37.8]	0.871	35.8 [34.5, 37.1]	40.2 [36.3, 44.0]	35.8 [34.3, 37.4]	0.039*
Pelvic Incidence (PI)	59.7 [58.1, 61.2]	62.1 [57.1, 67.1]	59.0 [56.9, 61.1]	0.393	60.2 [58.6, 61.8]	64.7 [59.4, 70.0]	59.5 [57.4, 61.7]	0.090
Lumbar Lordosis (LL)	39.9 [37.9, 41.8]	40.7 [33.6, 47.8]	39.1 [36.6, 41.7]	0.838	40.3 [38.4, 42.2]	44.6 [39.3, 50.0]	38.1 [35.6, 46.7]	0.055
PI-LL	19.8 [18.0, 21.6]	21.4 [15.2, 27.6]	19.9 [17.5, 22.2]	0.817	19.9 [18.3, 21.6]	20.1 [15.3, 24.9]	21.4 [19.1, 23.7]	0.575

Table 2. Pre- and Post-op Patient Reported Outcome Measures

	Pre-op Scores				Post-op Scores				Multivariate Analysis*	
	PLF	ALIF	TLIF	p^1	PLF	ALIF	TLIF	p^1	β -coeff	p^2
PCS-12	31.6 [30.4, 32.9]	29.2 [26.2, 32.2]	30.7 [29.2, 32.1]	0.246	40.0 [38.6, 41.3]	39.5 [35.0, 44.1]	40.2 [38.5, 41.9]	0.946	-0.025	0.700
MCS-12	50.7 [49.1, 52.4]	49.2 [45.2, 53.1]	48.7 [46.8, 50.6]	0.260	54.1 [52.9, 55.3]	52.5 [48.6, 56.3]	52.6 [50.9, 54.3]	0.304	0.048	0.468
ODI	40.9 [38.4, 43.4]	44.2 [39.6, 48.8]	42.1 [39.2, 45.0]	0.536	21.1 [18.8, 23.4]	21.6 [14.3, 28.9]	22.4 [19.2, 25.6]	0.808	0.136	0.034*
VAS Back	5.74 [5.31, 6.16]	5.76 [4.81, 6.71]	6.04 [5.51, 6.58]	0.652	2.79 [2.45, 3.14]	2.89 [1.94, 3.83]	3.16 [2.70, 3.61]	0.448	0.016	0.808
VAS Leg	6.14 [5.69, 6.58]	4.71 [3.61, 5.81]	6.42 [5.90, 6.93]	0.015*	2.43 [2.06, 2.81]	2.05 [1.15, 2.94]	2.57 [2.09, 3.05]	0.620	-0.057	0.381

Effect of Cage Type on Immediate Post-operative Radiographic Outcomes in Single-level Minimally Invasive Transforaminal Lumbar Interbody Fusion (MI-TLIF)

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Introduction: The goals of MI-TLIF include restoration of disc height and foraminal dimensions, interbody fusion, and improvement or maintenance of sagittal balance. One variable that may impact several of these goals is the type of cage used during surgery. The purpose of this study was to assess if cage type has an impact on immediate radiographic outcomes in single-level MI-TLIF.

Method: Upright lateral radiographs obtained pre- and post-operatively of patients who underwent single-level MI-TLIF were reviewed. Segmental Lordosis(SL), Lumbar Lordosis(LL), Posterior Disc Height(PDH), summarized as 'median [IQR]', were compared using non-parametric tests. Regression analyses were conducted to assess the impact of demographic factors (age, sex, BMI), pre-operative radiographic parameters (SL, LL and PDH) and operative variables (cage-type, cage-width and cage-position) on radiographic outcomes.

Results: Of the 154 patients in this study, 55 received a Static Oblique, 63 a Static Articulating, and 36 an Expandable Articulating cage. There was no significant difference in SL pre-(p=0.389) or post-operatively(p=0.613). A significant difference was seen in change in SL(p=0.023), with the expandable articulating cage showing the greatest increase in SL, and a significant improvement from pre- to post-operatively(p=0.033). While a significant difference in LL was seen pre-operatively(p=0.006), there was no difference post-operatively(p=0.216). A significant difference was seen in change in LL(p=0.050), with the static oblique and expandable articulating groups maintaining LL(p=0.238 and p=0.873), but the static articulating group showing a decrease in LL(p<0.0001). There was a significant difference in PDH between groups pre- and post-operatively(p<0.0001 and p=0.045). All three cage types showed a increase in PDH from pre- to post-operatively(p<0.0001), with the expandable articulating cage showing the greatest increase(p=0.009). Regressions showed that pre-operative SL was the only significant predictor of post-operative SL(p<0.0001;R2=0.418) and change in SL(p<0.0001;R2=0.247); pre-operative LL of post-operative LL(p<0.0001 R2=0.609) and change in LL(p<0.0001;R2=0.227); and pre-operative PDH of post-operative PDH(p<0.0001;R2=0.360) and change in PDH(p<0.0001;R2=0.299). Cage type, cage position and cage width were not significant predictors of post-operative radiographic parameters or change in radiographic parameters.

Conclusion: Pre-operative radiographic parameters were the strongest predictors of post-operative parameters, as well as change in parameters. The static cages maintained SL, whereas the expandable cage demonstrated an improvement in SL. The expandable cage had the lowest pre-operative PDH, likely reflective of the fact that the expandable technology allows for cage-insertion even in collapsed disc spaces. Additionally the expandable articulating cage demonstrated benefit in terms of increasing the segmental lordosis, maintaining the regional lumbar lordosis and causing the greatest increase in disc height.

Table 1: Radiographic Measurements

	Static Oblique	Static Articulating	Expandable Articulating	p-value ^a	Significant post-hoc comparisons, if any	Adjusted p-value
Segmental Lordosis						
• Pre-operative	18.60 [13.90 – 23.00]	20.00 [15.25 – 24.00]	16.60 [13.70 – 19.85]	0.389		
• Post-operative	18.55 [14.50 – 23.00]	19.50 [14.00 – 23.00]	18.10 [14.80 – 22.65]	0.613		
• Change	0.00 [-4.00 – 3.90]	0.00 [-4.00 – 3.00]	2.25 [-1.90 – 4.60]	0.023	Static Articulating vs Expandable Articulating	0.091
p-value ^b	p = 0.789	p = 0.505	p = 0.033			
Lumbar Lordosis						
• Pre-operative	48.55 [41.00 – 58.10]	58.00 [45.85 – 63.00]	50.35 [42.70 – 57.80]	0.006	Static Oblique vs Static Articulating	0.012
• Post-operative	47.00 [43.00 – 56.00]	53.00 [44.00 – 59.00]	50.90 [45.95 – 60.05]	0.216	Static Articulating vs Expandable Articulating	0.045
• Change	-0.80 [-5.70 – 4.00]	-4.00 [-7.00 – 1.00]	-1.20 [-4.25 – 3.95]	0.050	Static Articulating vs Expandable Articulating	0.019
p-value ^b	p = 0.238	p < 0.0001	p = 0.873			
Posterior Disc Height						
• Pre-operative	5.90 [4.39 – 7.09]	7.48 [5.84 – 8.72]	4.85 [3.50 – 5.55]	<0.0001	Static Oblique vs Static Articulating	0.005
• Post-operative	8.58 [7.29 – 9.85]	9.83 [8.44 – 11.50]	8.75 [7.05 – 9.80]	0.045	Static Oblique vs Expandable Articulating Static Articulating vs Expandable Articulating	0.047 <0.0001
• Change	2.45 [1.52 – 4.30]	2.20 [1.18 – 3.87]	3.90 [2.55 – 5.55]	0.009	Static Oblique vs Static Articulating Static Articulating vs Expandable Articulating	0.049 0.021
p-value ^b	p < 0.0001	p < 0.0001	p < 0.0001		Static Articulating vs Expandable Articulating	0.008

Results are represented as Median [25th – 75th percentile]

^ap-value for comparison between groups; ^bp-value for change from pre-operatively to post-operatively

Table 2: Linear Regressions for predictors of post-operative radiographic parameters (only significant regressions included)

	B	S. E.	Beta	t	p	R ²	Adjusted R ²
Post-operative Segmental Lordosis							
• Pre-operative Segmental Lordosis	0.566	0.078	0.575	7.270	<0.0001	0.418	0.393
Change in Segmental Lordosis							
• Pre-operative Segmental Lordosis	-0.391	0.063	-0.450	-6.226	<0.0001	0.247	0.227
Post-operative Lumbar Lordosis							
• Pre-operative Lumbar Lordosis	0.750	0.057	0.816	13.085	<0.0001	0.609	0.595
Change in Lumbar Lordosis							
• Pre-operative Lumbar Lordosis	-0.239	0.057	-0.363	-4.199	<0.0001	0.227	0.206
Post-operative Posterior Disc Height							
• Pre-operative Posterior Disc Height	0.547	0.066	0.596	8.239	<0.0001	0.360	0.334
Change in Posterior Disc Height							
Pre-operative Posterior Disc Height	-0.431	0.068	-0.484	-6.311	<0.0001	0.299	0.275

The factor lowering the cost-utility of surgical treatment for patients with metastatic spinal tumor

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Introduction: In many countries worldwide, including Japan, the rise in medical expenses and health insurance are serious problems. Economic evaluation is essential for orthopedic surgeons and policymakers to make more effective decisions regarding the care of individual patients. The authors had reported the surgical treatment for spinal metastasis provides favorable economic value over a limited 1-year time frame. The aim of this study was to evaluate the factors lowering the cost-utility of surgical treatment for patients with spinal metastasis.

Methods: A prospective study of 90 patients (56 male, 34 female, mean age 65.1 years) with spinal metastasis from 2008 to 2016, who met the surgical indication, was studied. EuroQol 5D (EQ-5D) and relevant cost were measured at 1, 3, 6, 12, and 24 months after surgery. Health state values was obtained by Japanese EQ-5D scoring and quality-adjusted life year (QALY) gained were calculated. Medical costs were calculated by medical remuneration points and included inpatient and outpatient treatment costs, such as ward costs, medication, radiation, rehabilitation, nursing home days, diagnostic tests, instrumentation, in-hospital services, and procedural costs, as well as any treatment for peri- and postoperative complications. Cost-utility was expressed as the incremental cost-utility ratio (ICUR) and was calculated for each patient treated with surgical treatment by comparing with patients (16 patients) treated with non-surgical treatment during same follow-up period. Accepted threshold was defined as \$130,000 per QALY gained. Statistical analysis was done using multivariable logistic regression. The p value of less than 0.05 at 95% confidence interval (CI) was considered statistically significant.

Results: The median survival time was 11.6 months. The mean QALY gained was 0.87 ± 1.14 QALY and the mean total cost per patient who performed surgical treatment was $\$60,871 \pm 61,573$. Of the 90 patients, 39 cases (43%) showed that the ICUR was more than \$130,000 per QALY gained relative to non-surgical treatment or that QALY gained was less than that in non-surgical treatment which was 0.02 ± 0.03 QALY. Multivariable logistic regression analysis revealed that preoperative neurological function (Frankel A, B, or C) was significantly related to non-acceptable ICUR (odds ratio [OR]=4.03, 95% CI: 1.02-8.18), whereas, sex, age, location of the tumor, primary site of the tumor, the number of the fusion levels, metastasis to major internal organ, previous chemotherapy, previous radiation therapy, use of molecular targeted drugs, and general condition (performance status[PS]) were not factors associated with non-acceptable ICUR preoperatively. Death within 6 months after surgery (OR=9.53, 95% CI: 2.11-28.77), radiation therapy (OR=7.70, 95% CI: 0.04-0.57), and PS 3 or 4 (OR=4.95, 95% CI: 1.45-358.50) were postoperative factors associated with non-acceptable ICUR.

Discussion: Based on this study, preoperative neurological conditions revealed to be the risk factor lowering the ICUR of surgical treatment for metastatic spinal tumors. Patients with severe neurological dysfunction might be poor general condition even after surgical treatment and could not survive much longer. Therefore, in those case, medical costs were low because of their short-term prognosis. However, the ICUR was relatively high, since QALY gained was relatively low compared with medical costs.

Correlation of automated lumbar MRI grading with microdecompression surgical level

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Introduction. Lumbar spine MRI interpretations have a high prevalence of variability and interpretive errors.¹ Machine learning software for automated image analysis could provide for reliable, reproducible, standardized grading of lumbar MRI examinations. The objective of this study was to correlate MRI grading data obtained from an automated software program in patients that underwent a lumbar decompression procedure.

Methods. Patients undergoing either unilateral or bilateral microdecompression surgery via unilateral laminotomy site between January 2014 and August 2018 were included in this study. Need for surgical intervention was based on clinical symptoms related to some degree of central/lateral recess narrowing, with one surgeon evaluating each patient and performing the surgical procedure. Patients excluded from the study included those undergoing the procedure at more than one level and patients that did not have an MRI within 1 year of the surgery date. The sagittal T2 images were processed with SpineNet (<http://zeus.robots.ox.ac.uk/spinenet/>); an automated software program that provided grading at each lumbar level (T12/L1 through L5/S1) for the following metrics: central canal stenosis and disc narrowing (1-4, i.e. absent/mild/moderate/severe); disc degeneration (Pfirrmann grading system, 1-5); spondylolisthesis, upper/lower endplate changes, and upper/lower marrow changes (absent/present). SpineNet was analyzed retrospectively for its ability to correctly identify the surgical site as the level with the highest grade for each radiologic metric. Additional investigation determined whether this grade was unique to the surgical level.

Results. 141 patients met the inclusion criteria (82 women, 59 men). The average patient age was 64 (range of 28-89). SpineNet did not detect central canal stenosis at any level within 32 cases (23%). Of the remaining 109, 95 patients (87%) had operations at the level of greatest stenosis. The stenosis grade was unique in 82 of these 95 cases (86%). SpineNet detected disc narrowing and disc degeneration at some level in every patient. Surgery was performed at the level of greatest disc narrowing in 88/141 cases (62%); 34/88 cases (39%) were unique to the operated level. Surgery was performed at the level of greatest disc degeneration in 93/141 patients (66%), with 29 of these 93 cases (31%) unique to the operated level. 86/141 (61%) demonstrated spondylolisthesis at the operated level. 63/141 (45%) had upper and/or lower endplate changes; 86/141 (61%) had upper and/or lower marrow changes.

Discussion. In order for MRI reports to reliably and consistently inform patient management, variability in image interpretation needs to be limited. Automated programs that generate standardized grading may facilitate improved report reliability, as well as augment follow-up consistency, system efficiency, and multicenter research with large scale data analytics for improved public health.^{2,3} SpineNet yielded data that correlated well with the operative level selected by the surgeon. The operative level was found to have a higher degree of central stenosis when compared to the remaining levels. A high percentage of the operated levels also demonstrated findings such as disc narrowing and degeneration, spondylolisthesis, and vertebral body marrow changes.

1. Herzog R, Elgort DR, Flanders AE, Moley PJ. Variability in diagnostic error rates of 10 MRI centers performing lumbar spine MRI examinations on the same patient within a 3-week period. *Spine J.* 2017;17(4):554-561.
2. Jamaludin A, Lootus M, Kadir T, et al. ISSLS PRIZE IN BIOENGINEERING SCIENCE 2017: Automation of reading of radiological features from magnetic resonance images (MRIs) of the lumbar spine without human intervention is comparable with an expert radiologist. *Eur Spine J.* 2017;26(5):1374-1383.
3. Jamaludin A, Kadir T, Zisserman A, Urban J, Fairbank J, Williams F. Adapting a deep learning model to a different grading system in a new dataset. ISSLS Annual Meeting; 2018; Banff, Canada.

Back pain improves after lumbar disc herniation surgery

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Introduction: Lumbar disc herniation (LDH) surgery is usually performed to relieve symptoms of long-term sciatica, but prevalent lumbar back pain (LBP) may also decrease. Our objective with this study was thus to: Evaluate if (i) also back pain is reduced after LDH surgery and if so, (ii) to what extent compared to the reduction in sciatica and (iii) how many patients that reach minimal clinical important difference (MCID) in leg- and back pain reduction after LDH surgery.

Methods: In the national Swedish register for spinal surgery (SweSpine) we identified 14097 patients aged 20-64 years with LDH surgery during 2000-2016. For these patients we extracted data on pre- and 1-year postoperative leg and back pain (NRS graded 0-10) and a variety of preoperative variables which we then analyzed in a multivariate model to calculate odds ratios (OR) for reaching MCID in leg and back pain.

Results: Before surgery, leg pain was 6.7±2.5 (mean±SD) and back pain 4.7±2.9 (p<0.001). Surgery reduced leg pain NRS with 4.5 (4.5-4.6) (mean(95% CI) and back pain with 2.2 (2.1-2.2). The mean 67% reduction in leg pain was greater than the mean 47% reduction in back pain (p<0.001). 71% of patients experienced improvement exceeding MCID for leg pain and 43% for back pain. One year after surgery leg pain was NRS 2.1±2.7 and back pain 2.5±2.7 (p<0.001). Non-smoking (compared to smoking) was associated with pain reduction ≥MCID one year post-operative for both leg pain (OR 1.49 (95% CI 1.36, 1.65)) and back pain (OR 1.22 (95% CI 1.11, 1.34)). Shorter preoperative duration of pain (leg pain < 3 months compared to > 24 months) was also associated to leg pain reduction ≥MCID (OR 2.85 (95% CI 2.47, 3.28)). The same was evident for back pain (OR 1.15 (95% CI 1.01, 1.30)).

Discussion: Both leg and back pain improves after LDH surgery, for leg pain in about three out of four patients ≥ MCID and in close to half for back pain.

Epidemiology and Risk factors of Multidrug-Resistant Pyogenic Spondylitis in Thoraco-Lumbar spine

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Introduction: Spinal infections caused by multidrug-resistant (MDR) bacteria often become intractable and requires long-term antibiotics therapy and multiple surgeries. Therefore, it is of great importance to understand epidemiology and risk factors for MDR spinal infections. In the current study, we performed retrospective case control study to elucidate the risk factors for MDR bacterial spinal infection by comparing treatment protocols and comorbidity between the patients with confirmed MDR spinal infections and those with other spinal infections.

Methods: Between 2001 and 2016, a total of 115 patients (77 males, 38 females; average age: 63.6 y) with thoracic/lumbar spinal infections who underwent percutaneous endoscopic debridement and irrigation were included in this study. Yeung Endoscopic Spinal System (Richard Wolf Co., IL) were used for posterolateral spinal endoscopic equipment. Aggressive debridement of both infected disc material and vertebral bodies was conducted.

The organisms detected by this endoscopic procedure were investigated and the incidence of MDR bacterium infection was evaluated. Patient factors (age, comorbid medical problems, and previous spinal surgery) and preoperative antibiotic therapy (administration periods and spectrum of antibacterial agents) were compared between MDR bacterial spinal infection group and other bacterial spinal infection group.

Results: The average periods of antibiotics therapy by previous physicians were 8.3 weeks (range 0-103 weeks). Cultures of specimens obtained by endoscopic procedure were positive in 76 (66.1%) of 115 patients. A total of 81 causative organisms were identified. Gram-positive coccus were isolated from 56 patients (61.9%), and 30 of 56 isolated organisms were methicillin-resistant staphylococcus (MRS) strains. Six patients (7.4%) were infected with gram-negative rods, 9 (14.8%) with mycobacterium and 4 (4.9%) with fungus.

Among 65 isolated bacteria, MDR bacteria accounted for 55.4%. Statistically significant risk factor for MDR bacterium infection included the existence of comorbidity ($P=0.04$), advanced age ($P=0.03$), previous thoracic/lumbar surgery ($P=0.045$) and collagen disease ($P=0.049$). The rate of MDR bacteria in patients who were administered a broad-spectrum antibiotic for more than 1 month preoperatively was 65.3% (17 of 26 cases), which was significantly higher than in the patients who were administered a broad-spectrum antibiotic for less than 1 month and the patients who were administered a narrow-spectrum antibiotic ($P=0.01$, 0.036, respectively).

Discussion: Our data that patients who had longer administration periods of a broad-spectrum antibiotic were significantly related to the MDR bacterium infection suggest two possibilities. One is that long-term empiric antibiotics therapy for spinal infection induces microbial substitution, resulting in intractable MDR spine infection. Another is that MDR bacteria was originally causative microorganism and therefore had been resistant to empiric antibiotics therapy. This retrospective study cannot make a conclusion which idea is correct but, from our epidemiological data, we recommend initiating therapy with first-generation cephalosporin targeting gram-positive bacteria. If resistant to cephalosporin, we should consider switching to anti-MRSA antibiotics therapy.

Other risk factors for MDR bacterial infection, which were identified in this study, included immune suppressed conditions such as advanced age and collagen disease, previous spinal surgery. The patients with spinal infection who have these risk factors, would need administration of anti-MRSA antibiotics.

Is the sandwich vertebra at a higher risk of further fracture? -A retrospective analysis of 1,347 patients undergoing cement augmentation for osteoporotic vertebral compression fracture in a single medical center in Taiwan

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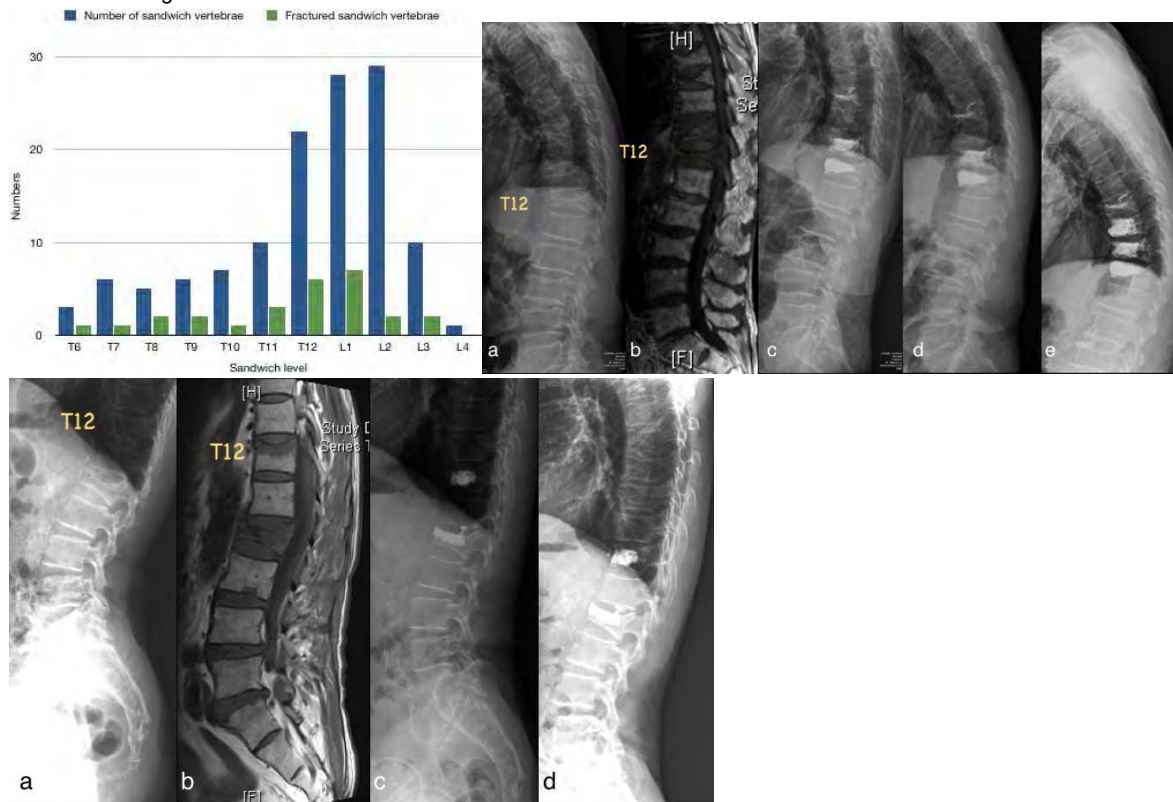
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Introduction: Cement augmentation for vertebral compression fracture may leave a sandwich vertebra. Whether the sandwich vertebra is at a higher risk of further fracture remains unknown. The aim of this study is to compare the incidence of further fractures of sandwich vertebra and adjacent vertebra, and to identify the potential risks for sandwich vertebral fractures.

Methods: Patients underwent cement augmentation for intractably painful osteoporotic vertebral compression fractures (OVCFs) in a single medical center between January 2012 and December 2015 were included. A sandwich vertebra was defined as an intact vertebral body located between two previously cemented vertebrae. The demographic data and image studies were recorded. All patients were followed-up for at least 24 months. If the patient reported new-onset of back pain with corresponding image findings, the diagnosis of sandwich vertebral fracture was made.

Results: Among the 1347 patients underwent vertebroplasty/kyphoplasty for OVCFs, 127 patients with 128 levels met the criteria of sandwich vertebra (female/male 100/27, average age 77.8 ± 7.7 years old). Locations of the sandwich vertebra were 27 in T1 ~ 10, 87 in T11 ~ L2, and 13 in L3 ~ 5. Collapse of sandwich vertebrae in the follow-up period occurred in 27 patients (21.3%), and the difference was not significant to the incidence of adjacent fractures (96/1194, 16.41%, $p=0.165$). Fifteen sandwich vertebral fracture (55.6%) occurred in the first year, and 24 (88.9%) in the first two years. Significant difference was found only in the gender distribution (fracture group, male/female 11/16; non-fracture group, male/female 16/84, $p=0.008$).

Discussion: The incidence of sandwich vertebral fracture is 21.3% in the first two-year follow-up, and the risk of fracture is not higher than the other adjacent level. Compared with adjacent fracture, the predictable factor related to further sandwich vertebral fracture is male gender.



1. Hsieh MK, Chen LH, Chen WJ. Current concepts of percutaneous balloon kyphoplasty for the treatment of osteoporotic vertebral compression fractures: evidence-based review. *Biomed J.* 2013 Jul-Aug;36(4):154-61. Epub 2013/08/31
2. Rho YJ, Choe WJ, Chun YI. Risk factors predicting the new symptomatic vertebral compression fractures after percutaneous vertebroplasty or kyphoplasty. *Eur Spine J.* 2012 May;21(5):905-11. Epub 2011/12/14.
3. Rho YJ, Choe WJ, Chun YI. Risk factors predicting the new symptomatic vertebral compression fractures after percutaneous vertebroplasty or kyphoplasty. *Eur Spine J.* 2012 May;21(5):905-11. Epub 2011/12/14.
4. Wang L, Yang H, Shi Y, Luo Z, Jiang W, Bao Z, et al. Sandwich vertebral fracture in the study of adjacent-level fracture after vertebral cement augmentation. *Orthopedics.* 2012 Aug 01;35(8):e1225-30.
5. Lee DG, Park CK, Park CJ, Lee DC, Hwang JH. Analysis of Risk Factors Causing New Symptomatic Vertebral Compression Fractures After Percutaneous Vertebroplasty for Painful Osteoporotic Vertebral Compression Fractures: A 4-year Follow-up. *J Spinal Disord Tech.* 2015 Dec;28(10):E578-83. Epub 2013/11/06.

Iodine-supported spinal instruments reduce surgical site infection in total en bloc spondylectomy for spinal tumors.

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Introduction: Surgical site infection (SSI) in total en bloc spondylectomy (TES) for spinal tumors represents the serious and common postoperative surgical complication which compromises the quality of treatment outcome. Several biomaterial surface treatments have been proposed as a means of reducing instruments-associated infections. We have developed the antibacterial iodine-supported titanium instruments to reduce the SSI rate. The antibacterial spectrum of iodine is very broad, and iodine does not cause phenomena such as drug resistance induced by the administration of antibiotics.

We performed TES with iodine-supported spinal instruments in a clinical trial. However, there are no prospective study to evaluate the effect of the iodine-supported instruments to prevent SSI, comparing with the control.

Thus, the aim of this prospective study was to evaluate the effect of iodine-supported spinal instruments for preventing SSI in the patients who underwent TES for spinal tumors.

Methods: Ninety-seven patients underwent TES with iodine-supported spinal instruments in a clinical trial between May 2010 and May 2014. The later 54 patients underwent TES with ordinary spinal instruments between June 2014 and February 2018. All surgeries were operated by a single surgeon. The demographic data, medical history, operative information, and the SSI rate were compared between the two groups using the chi-square test and two-sample t-test.

Results: The SSI rate in a total of 151 patients was 7.3% (11/151 patients). The SSI rate in the patients treated with iodine-supported instruments was significantly lower than that in the patients treated with ordinary instruments (4.1% (4/97 patients) versus 13.0% (7/54 patients)). The operative blood loss and the rate of diabetes mellitus in the patients using iodine-supported instruments were significantly greater than that in the patients using ordinary instruments. There were no significant differences between the groups in age, gender, body mass index, smoking status, level of the tumor, operating time. No abnormalities of thyroid gland function were detected in all 97 patients treated with iodine-supported instruments.

Conclusion: This study demonstrated that iodine-supported spinal instruments were effective for preventing SSI in TES for spinal tumors.

The effect of peri-operative adverse events on long-term patient reported outcomes after lumbar spine surgery

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Introduction: Peri-operative adverse events (AE) lead to patient disappointment, increased resource utilization and greater healthcare costs. There is a paucity of data on how adverse events affect long-term patient reported outcomes (PRO). The purpose of this study is to examine peri-operative adverse events and their long-term impact on PROs after lumbar spine surgery.

Methods: 3556 consecutive patients undergoing elective spine surgery for degenerative lumbar spine disorders enrolled in the Canadian Spine Outcomes and Research Network (CSORN) prospective database were analyzed. Adverse events (AEs) were classified using the validated Spine Adverse Events Severity system (SAVES), as minor (grade 1-2) or major (grades 3-6). Perioperative adverse events were analyzed for lumbar disc disease, degenerative spondylolisthesis, spinal stenosis, and lumbar deformity. We assessed the impact of AEs on the following PROs at 3 and 12 months post-operatively: Oswestry Disability Index (ODI), SF-12 Physical and Mental Component Summary (PCS;MCS), leg and back pain visual analog scale (VAS), Euroqol-5D (EQ5D), and satisfaction.

Results: Adverse events occurred in 767 (21.6%) patients, 85 (2.4%) suffered major AEs, and 682 (19.2%) experienced minor AEs. Patients with major AEs had significantly worse post-operative ODI scores and did not reach minimum clinically important differences at 1 year (Baseline: no AE: 47.5±15.5, major: 48.2±14.8, vs. 1 year: no AE 25.5±19.5, major: 37.3±19.3, p<0.001). On VAS leg and back, EQ5D, and SF12 PCS the 1 year PROs were significantly different between the major AE group and the no AE group (<0.01) but these differences were small and not likely clinically relevant (VAS Leg: Baseline: no AE: 7.3±1.9, major: 7.0±2.5, vs 1 year: no AE: 3.2±2.9, major: 3.9±3.1,) VAS back (Baseline: no AE 6.9±2.2, major: 7.5±1.9, vs 1 year: no AE: 3.3±2.6, major: 4.3±2.6), EQ5D (Baseline: no AE: 0.5±0.2, major: 0.49±0.2, vs. 1 year: no AE: 0.75±0.2, major: 0.66±0.2), and SF12 PCS (Baseline: no AE 32.6±8.2, major: 30.4±7.9, vs. 1 year: no AE: 43.6±9.6, major: 37.7±8.5) SF12 MCS scores were not significantly different between the major and no AE cohorts at 1 year (Baseline: no AE 48.1±8.5, major: 48.2±9.5, vs. 1 year: no AE: 51.8±7.43, major: 50.5±9.0). At 1 year post-operatively patients that faced a major AE had significantly lower rates of satisfaction (no AE: 83.5%, major: 71.6%, minor: 82.8%, p<0.01).

Conclusions: Major adverse events during hospital admission after elective lumbar spine surgery lead to significantly worse long-term functional outcomes and lower rates of patient satisfaction. This information highlights the need to implement strategies aimed at reducing in-hospital adverse events.

The Regional Effect of Lumbar Fusion Surgery on Volumetric Bone Mineral Density measured by Quantitative Computed Tomography in Adjacent Vertebrae: A Longitudinal Cohort Study

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Introduction: Previous studies reported that lumbar spine surgery has a negative effect on bone mineral density (BMD) in the lumbar spine. Dual X-ray absorptiometry (DXA) was generally used for following BMD change in these studies, however; DXA has several limitations for measuring BMD in the vertebrae with morphological changes and metal implants, which are often associated with lumbar spine surgery. Also, it is still unclear if this BMD change is caused by a local mechanical effect or a systemic physiological insult associated with the surgery. In this study, we investigated the change of BMDs in multiple adjacent vertebrae utilizing quantitative computed tomography (QCT).

Materials and Methods: Institutional ethics board approval was obtained for this study. We reviewed clinical records and images of 296 consecutive patients who underwent posterior lumbar spine surgery between 2014-2017 at a single academic institution. Patients who underwent posterior fusion surgery with instrumentation and had both pre-operative and secondary postoperative computed tomography of the lumbar spine between 6 to 12 months were included. Volumetric bone mineral density (vBMD) measurements by QCT were conducted in L1 to S1 vertebral trabecular bone. The change of vBMD in the vertebrae one or two-level above the upper instrumented vertebra (UIV+1, UIV+2) and one level below the lower instrumented vertebra (LIV+1) were analyzed. Statistical analyses were conducted utilizing paired t test, one-way/repeated-measures ANOVA, and Pearson's correlation test. The statistical significance level was set at $p < 0.05$.

Results: A total of 91 patients met our inclusion criteria. Mean age (\pm SD (range)) was 61.9 ± 11.9 . 55.6% of the patients were female. Median interval between the surgery and the secondary CT was 248 (180-364) days. Volumetric BMD (\pm SD) in UIV+1 was 113.1 ± 32.6 mg/cm³ preoperatively and 102.4 ± 32.2 mg/cm³ (percent change: $-10.5 \pm 12.6\%$) postoperatively ($p < 0.001$). No correlation was observed between percent vBMD change in UIV+1 and interval between operation and postoperative CT ($r = 0.15$, $p = 0.15$). This trend of vBMD change was similar regardless of UIV level and number of fused level. The change of vBMDs in UIV+2 and LIV+1 appeared similar as UIV+1 (UIV+2: $-11.9 \pm 12.3\%$, $p = 0.19$, LIV+1: $-7.2 \pm 20.7\%$, $p = 0.40$).

Discussion: Posterior lumbar fusion surgery negatively affected the regional vBMDs measured by QCT in adjacent levels. BMDs in UIV+1, UIV+2, and LIV+1 were equally affected by the surgery. Our finding suggests that the postoperative decrease of regional BMDs in the lumbar spine dominantly occurs in the early postoperative phase (within 6 months) and a systemic effect has a greater role, rather than a regional mechanical one, in this postoperative BMD decline.

National Adverse Event Profile After Lumbar Spine Surgery for Lumbar Degenerative Disease and comparison of complication rate between hospitals: A COSRN Registry Study

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Introduction: Most of the previous work investigating the rates of adverse events (AE) in spine surgery have been retrospective, with data collection from administrative databases, and often from single centers. To date, there have been no reports utilizing a rigorous and prospective analysis to capture adverse events in spine surgery on a national level or compare the rates of AEs between each center.

Methods: The incidence and severity of AEs after spinal surgery was captured using the Spine AdVerse Events Severity system, version 2 (SAVES), in 14 spine centers from the Canadian Spine Outcomes and Research Network (CSORN) prospective registry. Data on consecutive patients undergoing elective spine surgery for degenerative conditions were collected prospectively and included demographic variables as well as medical and surgical AEs during hospital admission. Minor and major AEs were defined by SAVES grades 1-2 and 3-6, respectively.

Results: A total of 3556 patients were enrolled in this cohort. As defined by SAVES, there were 85 (2.4%) patients with major AEs and 682 (19.2%) with minor AEs. There were no mortalities. There were 25 patients with major intraoperative AEs and 262 with minor intraoperative AEs. Post-operatively there were 61 patients with major AEs with a total of 80 major AEs and 84 minor AEs. Of the 487 patients with minor AEs post-operatively there were 698 total AEs. The rate of AEs varied by each hospital site. Of the 11 sites with more than 10 patients enrolled in the registry (3 sites had 10 or fewer patients enrolled) the average enrollment was 321 patients (range: 47-1237) per site. The rate of major AEs was consistent between sites (mean: 2.9±2.4%, range 0-9.1%). However, the rate of minor AEs varied widely between sites from 7.9-42.5% with a mean of 18.8±9.7% (site A: 25.5% B: 13.8% C: 21.3% D: 11.5% E: 7.9% F: 9.1% G: 18.7% H: 14.5% I: 20% J: 21.7% K: 42.5%).

Conclusions: Reporting of adverse events is consistent amongst centers when reporting major adverse events but there is a wide discrepancy when reporting minor adverse events after lumbar spine surgery. These data have implications for the reporting of adverse events and designing strategies to identify interventions to reduce adverse events in hospital.

The association between pre-operative MRI findings and surgical revision within three years after surgery for lumbar disc herniation

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Introduction: Recurrent lumbar disc herniation (LDH) is a known complication after lumbar discectomy. Because of a risk of poorer outcome in patients receiving revision surgery compared to first-time discectomy, there is a need to identify patients with LDH in risk of surgical revision prior to the primary discectomy. The association between pre-operative MRI findings and revision surgery in patients with LDH has not been thoroughly studied. Therefore, analyzing pre-operative magnetic resonance imaging (MRI) and prospectively collected data in the DaneSpine database, the objective was to determine whether MRI findings were associated with the frequency of surgical revision due to recurrent LDH at same level within three years after first-time, single-level, open or micro-endoscopic limited discectomy.

Methods: Following an inter-observer reliability study pre-operative MRIs were evaluated using a standardized protocol. Potential predictive variables for surgical revision were evaluated using univariate and multivariate logistic regression analysis. Also, a sum-score of the number of MRI findings at the involved level was created and assessed.

Results: In a study population of 451 operated patients 10% had revision discectomy and 2% had fusion surgery within three years after primary discectomy. Those who had surgical revision were significantly younger and were significantly less likely to have vertebral endplate signal changes Type 2 (OR 0.36 (95% CI 0.15-0.88)) or more than five MRI findings (OR 0.45 (95% CI 0.21-0.95)) at the involved level than the patients not undergoing surgical revision. Surgical revision was not significantly associated with any other MRI findings.

Discussion: In general, pre-operative MRI findings have a limited explanatory value in predicting surgical revision within three years after first time, single-level, simple lumbar discectomy. The single variable VESC Type 2 was found to be negatively associated with patients undergoing surgical revision, and as it is plausible to interpret the different VESC types as a proxy for time(1), the VESC Type 2 could represent the “burned out” aged disc being less likely to re-herniate. Multiple MRI findings at a segmental level could indicate a “burned out” disc complex as well, and the association found in this study emphasizes the importance of evaluating groups or sum-scores of MRI-findings besides evaluation of single factors.

1. Albert HB, Briggs AM, Kent P, et al. The prevalence of MRI-defined spinal pathoanatomies and their association with modic changes in individuals seeking care for low back pain. *Eur Spine J.* 2011;20(8):1355-62.

Systemic diclofenac reduces post-operative rhBMP-2 induced neuroinflammation at lumbar nerve root in a rodent model

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Introduction: Recombinant human bone morphogenetic protein 2 (rhBMP-2) is used clinically to augment spinal fusion. This increases the rate of fusion, avoids donor site morbidity, and reduces the need of allograft. However, complications of postoperative new onset of lower limb radiculitis in up to 11.4%¹ of patients have been reported. The known dose-dependent inflammatory effect of rhBMP-2 extends locally to the adjacent nerve roots to cause such a complication. We hypothesize that administration of systemic NSAIDs will reduce the local undesirable neuro-inflammatory effects. Hence, this study aims to explore in an in vivo rat model, the dose and effectiveness of systemic administration of anti-inflammatory agents in reducing neuro-inflammation caused by rhBMP-2.

Methods: 18 rats were randomized into 3 groups as follows: Group 1(HD), using high-dose diclofenac as post-operative treatment. Group 2 (LD): treated with low-dose diclofenac. Group 3 (Control group) treated with saline injection. An absorbable collagen sponge (ACS) containing rhBMP-2 was surgically wrapped around the L5 nerve root. All rats were administered the respective treatment doses for a week before being sacrificed. We performed quantitative, qualitative and behavioral analyses: volume of seroma, histology, RT-PCR (Biomarkers: MMP12, MAPK6, GFAP, CD68, IL1-beta), immunohistochemical staining (IHC) with DAB stain for CD68, and Hargreaves behavioural tests. Results were analysed with SPSS ver 23.0.

Results: Seroma formation: There was a dose dependent relationship with the use of diclofenac; HD: 0.19± 0.22ml, LD: 0.21 ± 0.24ml; Saline: 0.29 ± 0.34ml. Histology and IHC: There was an observable decrease in density of inflammatory cells and disruption of nerve architecture (Fig.1) with increasing doses of diclofenac. RT-PCR: There were quantifiable decreasing trends across multiple markers with increased doses of diclofenac, with that of MMP12 being statistically significant (p-value =0.02). MMP12: 4.7/ 23.6/ 202.4 (HD/LD/Saline); MAPK6: 0.52/ 2.04/ 3.36; GFAP: 2.16/ 5.68/ 4.51. Upregulation of MMP-12 matched with the pattern of myelin loss in low dose diclofenac and saline group. No appreciable trend was found in the other biomarkers. Hargreaves test: There is a reduction in thermal withdrawal latency, with it being lowest in saline group (65%), followed by LD (72%) and HD group (92%). Diclofenac treatment inhibited the development of thermal hyperalgesia of rats in a dose-dependent manner, with a statistically significant difference between HD and Saline groups at Day 5, when compared to pre-operative baseline (p<0.05). Our results suggest that systemic diclofenac is effective in reducing local neuro-inflammation caused by rhBMP-2.

Discussion: Our study shows that systemic diclofenac reduces local neuroinflammation caused by rhBMP-2. This has clinical significance in the prevention and management of rhBMP2-induced radiculitis post-operatively.

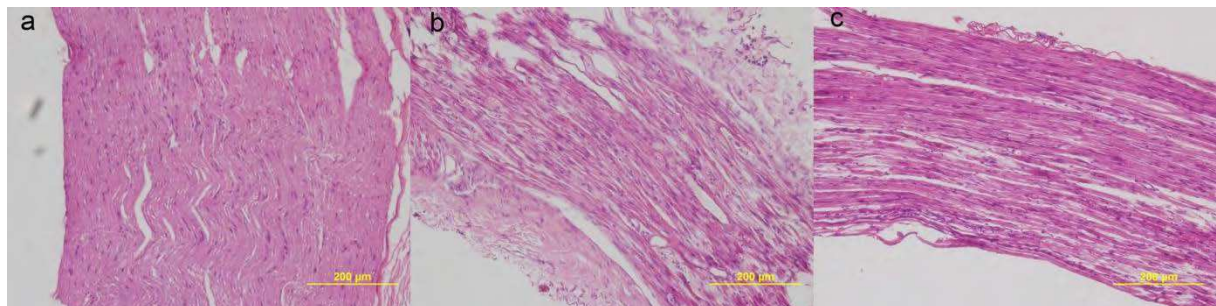


Figure 1. Hematoxylin and eosin-stained sections of 10 mg BMP-2 wrapped nerve. a) High dose diclofenac, b) Low dose diclofenac c) Saline. The arrows indicate macrophages. The density of macrophages is lowest in the HD diclofenac treatment group compared to the diclofenac group, with disruption of the regular architecture of the nerve structures in the saline group.

The influence of the intervertebral disc height and intervertebral disc height index in the single segmental lumbar fusion on the radiographic adjacent segment degeneration (rASD)

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Introduction:

To explore the influence of intervertebral disc height and intervertebral disc height index on rASD

Methods: 354 patients conducted with SL4-5 segment standard TLIF operation in our hospital from March 2008 to March 2014 were collected. a total of 58 patients were incorporated into the group. These patients were also divided into young group (20-40 years) and middle-aged group (40-60 years). According to whether the intervertebral disc height index would be returned to the normal reference range during the operation, the young group was divided into two groups: A1 group (intraoperative L4-5 intervertebral disc height index returned to the normal reference value) and A2 group (intraoperative L4-5 index of intervertebral disc height was not returned to the normal reference value), the middle aged group was divided into B1 group (with the L4-5 intervertebral disc height index returned to the normal reference value) and B2 group (intraoperative L4-5 index of intervertebral disc height was not returned to the normal reference value). The incidence of each subgroup of rASD was analyzed. On this basis, the risk factors of rASD after single segmental L4-5 fusion were explored and the effect of intervertebral disc height index on rASD was analyzed.

Results: In the 58 taken SL4-5 segment standard TLIF patients, there were 11 patients occurred with rASD and the incidence rate was 26.2%. Among them, there was no patients occurred with rASD in the young group, but 11 patients were found in the middle-aged group and the incidence rate was 30.6%, which indicated that the age was significantly associated with the occurrence of rASD. There were 6 patients in the A1 group and 10 patients in the A2 group, both had no rASD occurrence. There were 16 patients in the B1 group and 1 was occurred with rASD, the incidence rate was 6%. There were 26 patients in the B2 group and 10 were occurred with rASD, the incidence rate was 35.5%. The incidence of ASD between B1 and B2 group had statistical significance ($P < 0.05$). When analysis of the risk factors for rASD was conducted in the middle-aged group, it was found that: age, duration of follow-up, L4-5 intervertebral disc height index and PI were risk factors. Logistics regression analysis indicated that: $p < 0.00001$ in the wald test of L4-5 intervertebral disc height index and OR odds ratio was 172.16. L4-5 intervertebral disc height index was the main risk factors.

Conclusion: Age and intervertebral disc height index are the significant risk factors of postoperative rASD. the short term follow-up indicated that no rASD occurred to the patients of or below 40 years old no matter whether the intervertebral disc height index of the patients was increased to the normal range during the operation or not. But for patients over the age of 40, the recovery of intervertebral disc height index to normal reference range during the operation reduced the incidence of rASD, which may result from the change of the adjacent segment degeneration process.

Clinical characteristics and risk factors for subsequent vertebral body fractures in patients with lumbar degenerative disease treated with transforaminal lumbar interbody fusion.

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Introduction: Vertebral fracture sometimes occurs subsequent to spinal fusion surgery and balloon-kyphoplasty. Few studies have described the details of postoperative subsequent vertebral fracture following short-segment transforaminal lumbar interbody fusion (TLIF). The purpose of the present study is to clarify the prevalence, clinical characteristics, and risk factors for subsequent vertebral fractures following TLIF.

Methods: Patients with lumbar degenerative disease who underwent 1 or 2 level TLIF were included. Patients receiving additional fusion surgery other than TLIF (anterior, lateral or posterolateral fusion), and patients with a history of previous fusion surgery were excluded. We examined the prevalence and clinical characteristics of subsequent vertebral fractures (T10-S1) in 155 patients followed up at least one year postoperatively. Age, gender, number of fusion segments, diabetes mellitus, steroid use, and history of vertebral fracture (T10-S1) were candidates for risk factors influencing the prevalence of subsequent fractures; statistical analyses were performed using the Chi-square test, Spearson's test, and multiple regression analysis. The level of significance was set at $p < 0.05$.

Results: The patients' mean age was 67.3 ± 11.5 years-old with 68 males and 87 females. The mean follow-up period was 40.9 (12-92) months. Of the 155 patients, subsequent fractures occurred in 11 patients (7.1%). In 4 patients, 4 fractures occurred within 1 year after surgery (early fractures), and in 7 patients, 11 fractures occurred over 1 year after surgery (late fractures). The number of fractures at each level was 3 at T12, 5 at L1, 5 at L2, 1 at L4, and 1 at S1. No fracture occurred at the fused segments. Three of the 4 early fractures occurred at a level adjacent to the fused segments, whereas 1 of the 11 late fractures occurred at an adjacent level (non-significant tendency, $p = 0.058$). When all the fractures were utilized in the analyses, none of the candidates were determined as significant risk factors. When only the 4 early fractures were analyzed, the early fractures occurred significantly more often in patients receiving steroid medication ($p < 0.01$). Multiple regression analysis also showed a significant correlation between steroid use and subsequent postoperative vertebral fractures ($p < 0.001$).

Discussion: Our results showed that steroid use is a risk factors for early subsequent postoperative vertebral fracture. Early fractures tend to occur at levels adjacent to a fused segment, suggesting that early fracture is more closely related to surgical intervention with TLIF than late fracture. Our study has a limitation that bone mineral density was not included in the analysis because this study included relatively young patients. However, a history of vertebral fracture, age, gender, and diabetes mellitus, all of which were generally recognized as risk factors related to the prevalence of future vertebral fractures, showed no correlation with subsequent vertebral fractures. We suggest that the reason for this may be that patients received adequate osteoporosis treatment. Because of osteoporosis medications, a significant increase of the risk for vertebral fracture may be reduced in such patients. The present study indicates that steroid use is a strong risk factors related to subsequent postoperative vertebral fractures after short-segment TLIF.

Remaining of endplate is a risk factor of delayed osseous union after posterior lumbar interbody fusion: a multicenter, prospective, randomized study.

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Introduction: Posterior lumbar interbody fusion (PLIF) is usually performed to treat lumbar degenerative diseases in elderly patients. However, some patients exhibit pseudo-arthrosis after undergoing such procedures. Our previous multicenter, prospective randomized study assessed the effect of once-weekly teriparatide administration on patient outcomes after PLIF. The present study aimed to investigate the predictors of osseous union within 6 months after PLIF in elderly patients with osteoporosis.

Methods: The study was conducted in women aged >50 years who had a bone mineral density of <80% of the young adult mean and had a lumbar degenerative disease. Patients were randomly allocated to receive either weekly teriparatide treatment, starting at 1 week postoperatively, or no teriparatide. From 2011 to 2014, 75 patients were randomized to receive treatment, of whom 66 (mean age, 71 years) completed the treatment. Postoperative lumbar computed tomography (CT) 2 months postoperatively were obtained and examined for remaining of endplate (more than 50% of vertebral diameter), autograft position with bone bridging (anterior, center, or posterior), and amount of autograft (occupancy of autograft in coronal and sagittal center slices). Osseous union was assessed by 4 independent, blinded physicians by using dynamic radiography and CT 6 months postoperatively. Osseous union was defined when upper and lower fusions were observed in both the sagittal and coronal center slices of CT. The patients were retrospectively divided into two groups based on the presence of osseous union.

Results: Thirty-three patients (50%) showed complete osseous union, while 33 did not. Postoperative remaining of endplate was observed in 9 patients (27%) of the union group and in 23 (70%) of the non-union group ($p<0.01$). Teriparatide was administered in 20 (61%) patients of the union group and in 9 (27%) patients of the non-union group ($p<0.01$). Autograft position with bone bridging 2 months postoperatively were anterior in 17 (52%), center in 30 (91%), posterior in 20 patients (61%) of union group, and anterior in 12 (36%), center in 20 (61%), and posterior in 7 patients (21%) of non-union group ($p=0.22$, $p<0.01$, and $p<0.01$), respectively. Multivariate logistic regression analysis showed that remaining of endplate (odds ratio, 0.1; 95% confidence interval: 0.026–0.398; $p<0.01$) and teriparatide administration (odds ratio, 8.8; 95% confidence interval: 2.222–34.936; $p<0.01$) were independently associated with osseous union within 6 months after PLIF. Amount of autograft had decreased by 3% (from 56% to 53%) in the union group and decreased by 8% (from 53% to 45%) in the non-union group from 2 months to 6 months postoperatively ($p<0.05$).

Conclusions: Remaining of endplate and weekly teriparatide administration were independent predictors of osseous union 6 months after PLIF. Our findings suggest that it is important to remove the hyaline cartilage of endplates possibly and pack the autogenous bone behind the spacer for osseous union enhancement after PLIF.

Does L4/5 pose additional neurologic risk in lateral lumbar interbody fusion?

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Introduction: Lateral lumbar interbody fusion (LLIF) has been increasingly used for the treatment of various lumbar diseases. Using a retroperitoneal transpsoas approach, LLIF circumvents some of the challenges associated with anterior or posterior interbody fusion techniques. However, LLIF has its unique set of complications with nerve-related motor deficits of the quadriceps and tibialis anterior muscle being of major clinical concern. Incidence rates of postoperative motor weakness vary significantly throughout the literature. Several risk factors for nerve-related motor weakness have been proposed including performance of the procedure at the L4/5 level. Anatomical and radiologic studies clearly show that the surgical safe working zone to perform LLIF narrows from cranial to caudal. However, clinical studies assessing the neurologic safety profile of LLIF at L4/5 show conflicting results. The aim of the current study was to compare the rate of nerve-related motor deficits in patients undergoing LLIF with and without L4/5 involvement.

Methods: A review of prospectively collected clinical data from a single, academic institution was performed. All patients treated surgically for lumbar spine pathology that underwent LLIF with or without supplemental posterior fixation from 2006 to 2016 at our institution were eligible for inclusion. Patients with missing pre- or postoperative motor exams were excluded. New postoperative motor deficits were defined as a decrease in motor strength in the tibialis anterior or quadriceps femoris muscle at first postoperative visit compared to preoperative baseline. Resolution of motor deficits at last follow-up was defined as return to preoperative baseline or recovery of full motor strength. Regression analysis was performed to examine the association of LLIF at L4/5 and the risk of new motor deficits.

Results: 872 patients treated with LLIF (57.2% female) met inclusion criteria. Mean age was 62.2 years (range 21–90 years). 543 patients underwent LLIF including the L4/5 level and 329 patients underwent LLIF without the involvement of L4/5. The rate of new motor deficits at the 6 week postoperative visit in the L4/5 group was 13.1%, which was significantly higher compared to the non-L4/5 group with 5.5% ($p < 0.001$). After adjusting for potential confounders in multivariate logistic regression models, L4/5 was still significantly associated with an increased risk for new motor deficit (OR = 2.285; $p = 0.008$). At last follow-up (mean = 16.6 months), 2.6% of the patients in the L4/5 group and 0.3% of the patients in the non-L4/5 group had remaining deficits.

Discussion: To our knowledge this is the largest study to date comparing postoperative motor deficits after LLIF in patients with and without involvement of L4/5. Our results are in line with previous studies which report an initial increased risk of new motor deficits for LLIF performed at L4/5. However, the majority of new motor deficits was transient in nature and resolved over time. Our findings will hopefully act as a basis to improve clinical decision making and counseling of patients undergoing LLIF at L4/5.

Cost-effectiveness of lumbar surgery in the Japanese universal health insurance system

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Introduction: Globally, the economic value of spinal surgery is becoming increasingly important. However, these data are limited to a few countries. Additionally, the cost-effectiveness of instrumented fusion is unclear. The universal health insurance system in Japan provides quality healthcare with comparatively low costs. However, Japan also confronts a growth in healthcare costs with a rapidly aging population. The purpose of this study was to examine the cost / quality adjusted life year (cost / QALY) gained for fenestration (partial laminectomy) and posterior lumbar interbody fusion (PLIF) in the Japanese universal health insurance system.

Methods: One hundred and three patients (48 fenestration and 55 PLIF) who underwent surgery for lumbar degenerative spinal canal stenosis in a single hospital between 2013 and 2015 were included. Only direct costs were included on the basis of actual reimbursements. Effectiveness was measured using Euro QOL 5-dimension (EQ-5D), Short-Form 8 physical component summary (PCS), and visual analog scale (VAS). Effectiveness and cost were measured one year after surgery. Cost / QALY at a 5-year time horizon with a 2% discount rate was estimated.

Results: For fenestration, mean cost 1 year after surgery was \$12543. Operative cost was \$4068 and inpatient cost was \$6207. Mean gained score was 0.21 in EQ5-D, 11.1 in PCS, and -42 in VAS. Cost / QALY for fenestration was \$12686. For PLIF, mean cost was \$28029. Operative cost was \$17797 and inpatient cost was \$7178. Mean gained score was 0.22 in EQ-5D, 10.3 in PCS, and -44 in VAS. Cost / QALY for PLIF was \$26975. Sensitivity analysis demonstrated that cost / QALY at a 2-year time horizon was \$27316 for fenestration and \$64354 for PLIF.

Conclusions: Although PLIF was more costly than fenestration, cost / QALY was below the widely-accepted benchmark (cost / QALY < \$50000) for both procedures. These surgeries could be regarded as cost-effective interventions.

Clinical outcomes and union rate of 2-level PLIF ~Comparison between the lumbar segments and the lumbosacral segments~

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Introduction: Posterior lumbar interbody fusion (PLIF) provides an excellent bone union rate and surgical outcomes. However, these data are based on studies about single level PLIF. There have been few reports about focusing on the clinical results of 2-level PLIF. The purpose of this study was to compare the clinical outcomes and union rate of 2-level PLIF between the lumbar segments and the lumbosacral segments.

Methods: This was a retrospective study of the prospectively collected data in a single spine center during November 2008 and May 2016. Inclusion criteria of the study were: (1) diagnosis of degenerative spondylolisthesis, isthmic spondylolisthesis, and/or foraminal stenosis; (2) planned two-level PLIF with cages, local bone grafts, and pedicle screw (3) a minimum follow-up period of 2 year. Seventy-three patients met the inclusion criteria and these patients were divided into 2 groups. The Lumbar group included 48 patients (9 males) who underwent L3/4/5PLIF. The Lumbosacral group included 25 patients (10males) who underwent L4/5/S PLIF. Clinical outcomes (Japanese Orthopaedic Association back Evaluation Questionnaire: JOABPEQ and VAS) and union rate were compared between the groups. Union was assessed with flexion-extension radiographs and computed tomography.

Results: There was 1 case with non-union in the Lumbar group and 9 cases with non-union in the Lumbosacral group. Union rate was significantly lower in the Lumbosacral group (Lumbar 95.8 % vs. Lumbosacral 64 %; $p < 0.001$). In 9 cases of non-union in the Lumbosacral group, 8 cases occurred at the L5/S segment.

In the Lumbar group, the score change was 30 in "Low back pain", 13 in "Lumbar function", 45 in "Walking ability", 26 in "Social function", and 16 in "Mental health". In the Lumbosacral group, the score change was 36 in "Low back pain", 22 in "Lumbar function", 36 in "Walking ability", 23 in "Social function", and 10 in "Mental health". There was no significant difference in "Low back pain", "Lumbar function", "Walking ability", or "Social function" between the 2 groups. However, the change in "Mental health" was significantly lower in the Lumbosacral group ($p = 0.02$).

In the change of VAS, pain in low back (Lumbar -38 vs. Lumbosacral -23; $p = 0.004$), pain in buttocks or lower leg (Lumbar -48 vs. Lumbosacral -29; $p = 0.04$), and numbness in buttocks or lower leg (Lumbar -44 vs. Lumbosacral -33; $p = 0.04$) was significantly worse in the Lumbosacral group than in the Lumbar group.

Discussion: Our results suggested that high non-union rate of lumbosacral segment caused a decrease of the clinical outcomes. To improve union rate at lumbosacral segment, some reinforcement combined with S1 pedicle screw would be recommended.

Psychologically informed physical therapy for patients following lumbar spine surgery: a randomized clinical trial

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Introduction: Studies have found that patient psychosocial characteristics are strongly related to surgical spine outcomes. Limited evidence exists on the potential benefit of physical therapist-delivered cognitive-behavioral therapy (CBT) treatments for patients following lumbar spine surgery. The purpose of this trial was to compare which of two treatments delivered by telephone – a CBT-based physical therapy program (CBPT) or an Education program - are more effective for improving patient-centered outcomes after lumbar spine surgery.

Methods: A randomized controlled trial was conducted at 2 medical centers. 248 patients undergoing surgery for a lumbar degenerative condition (spinal stenosis, spondylosis with or without myelopathy, and degenerative spondylolisthesis) using laminectomy with or without arthrodesis were randomized into CBPT (n=124) or an attention-matched Education group (n=124). Patient-reported outcomes were disability (Oswestry Disability Index: ODI), pain intensity (Brief Pain Inventory), and physical health (SF-12). Observed physical activity was assessed using accelerometers and health care utilization data were collected from patients and hospital billing records. Patient assessments occurred preoperatively and at 6 weeks (baseline) and 6 and 12 months after surgery. Assessors and patients were unaware of the treatment condition. Patients were randomized at baseline using a stratified design based on age and type of surgery. Six treatment sessions were delivered by a physical therapist over the telephone. The CBPT intervention focused on walking and functional goal setting, relaxation techniques, symptom management through problem solving, and replacing negative thoughts about activity with positive ones. Separate multivariable regression analyses were conducted on the total sample and on those who completed all 6 sessions (n=179). Intent-to-treat models adjusted for the outcome at baseline, age, study site, depressive symptoms, and type of surgical procedure. Missing data were handled with multiple imputation. The level of significance was set at $\alpha=0.05$.

Results: No significant group differences were found for patient-reported outcomes and physical activity in the total sample. However, CBPT participants were 69% less likely to have a re-hospitalization compared to Education participants between 6 weeks and 12 months after surgery ($p=0.02$). In completer analyses, statistically significant differences across groups were noted for disability and physical health, with CBPT participants having an ODI score 4.3-points lower [95% CI, -8.5 to -0.03] and a SF-12 physical health score 3.2-points higher [95% CI, 0.16 to 6.3] than the Education group at 12 months ($p<0.05$).

Discussion: Results from a multi-center trial found that a physical therapist-delivered cognitive-behavioral intervention reduced the odds of re-hospitalization and improved disability and physical health for patients who completed the 6-session program. Telephone delivery appears to be an effective platform for incorporating CBT-based strategies into rehabilitation for engaged participants. Future work is needed to determine how to implement a CBPT approach in a typical clinic setting and maintain patient engagement in self-management strategies. Research reported in this abstract was funded through a Patient-Centered Outcomes Research Institute® (PCORI®) Award (CER-1306-01970).

Autologous mesenchymal stromal cells labeled with iron used for transplantation to intervertebral discs in patients with chronic low back pain.

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Introduction: Low back pain (LBP) represents a major socioeconomic burden worldwide. In recent years stem cell transplantation to the intervertebral disc (IVD) has emerged as a possible therapeutic procedure aiming to reverse or slow down IVD degeneration in patients with severe LBP.

We conducted a safety and feasibility pilot study regarding the transplantation of expanded autologous mesenchymal stromal cells (MSCs), labeled with iron into IVDs in patients with LBP. The aim of this study was to investigate adverse events and clinical outcome in this pilot cohort.

Methods: 10 patients from the waiting list for lumbar fusion or disc prosthesis surgery were recruited, 7 males, 3 females, mean age 40 years (range 26-53). All had severe LBP with no radiating leg pain below knee level, refractory to conservative treatment. Degenerative IVDs at 1 or 2 levels were identified on Magnetic Resonance Imaging (MRI). Informed consent was obtained from all patients. The study was approved by the regional ethics committee.

MSCs were harvested from the posterior iliac spine and expanded in an accredited laboratory. MSCs were labeled with iron sucrose (Venofer®) prior to percutaneous injection at 1 level (2 in one patient) under fluoroscopic control. Labeling was performed in order to facilitate identification of the injected cells on histology in case of fusion or disc prosthesis surgery with retrieval of the injected disc.

Patients were followed up 3, 6 and 12 months postoperatively. If unsatisfied at 6 months they continued with the initially planned surgical procedure. Follow up consisted of patient reported outcome measures-PROMs used within the Swedish Spine Registry-SWESPINE (EQ-5D index score, Oswestry Disability Index-ODI, VAS-Visual Analogue Scale for low back and leg pain) and routine MRI with T1- and T2-weighted sequences. MRI controls were reviewed by an independent radiologist. The results of the PROMs were analyzed using Friedman's two-way analysis of variance by ranks for related samples.

Results:

No adverse events could be identified clinically or on MRI. One patient sustained a tibial fracture during the follow-up period, unrelated to the spine intervention. Three patients opted for surgery after the 6 month follow-up. Two more patients chose to proceed with surgery at later time points (>12months).

No difference of statistical significance could be observed between different time points, numerically however some improvement was seen for most PROMs on a group level over time (Table 1).

Discussion: In our cohort we could assert that injection of autologous, expanded, iron labeled MSCs to degenerated IVDs is a safe procedure. This is in accordance with similar cell transplantation studies examining autologous and allogeneic MSCs.

No significant differences in PROMs were seen, however the study was not designed/powerd to address such a question. It is noteworthy that our cohort consisted of patients already waiting for surgical intervention and 7/10 postponed planned surgery for over 1 year. These results warrant further research in the field of MSC transplantation to explore whether this might be a therapeutic intervention that can bridge the gap between conservative treatment and major spinal surgery.

Table 1

	Pre op (n=9)	3 months (n=7)	6 months (n=10)	12 months (n=6)
VAS back pain	7,4 (6,3-8,6)	6,4 (3,9-8,9)	6,1 (4,3-7,9)	4,3 (0,7-8,0)
VAS leg pain	4,9 (2,6-7,2)	4,9 (1,6-8,1)	4,2 (1,7-6,7)	2,2 (-1,9-6,2)
EQ-5D index	0,432 (0,255-0,610)	0,484 (0,214-0,754)	0,526 (0,295-0,757)	0,624 (0,267-0,981)
ODI	40 (38,9-58,8)	41,4 (15,9-66,9)	39 (21,5-56,5)	30,3 (-7,6-68,2)

Results presented as mean value and 95% confidence interval

Machine learning for predictive modeling of 90-day readmission, major medical complication, and discharge to a facility in patients undergoing surgery for adult spinal deformity: logistic regression vs. random forest

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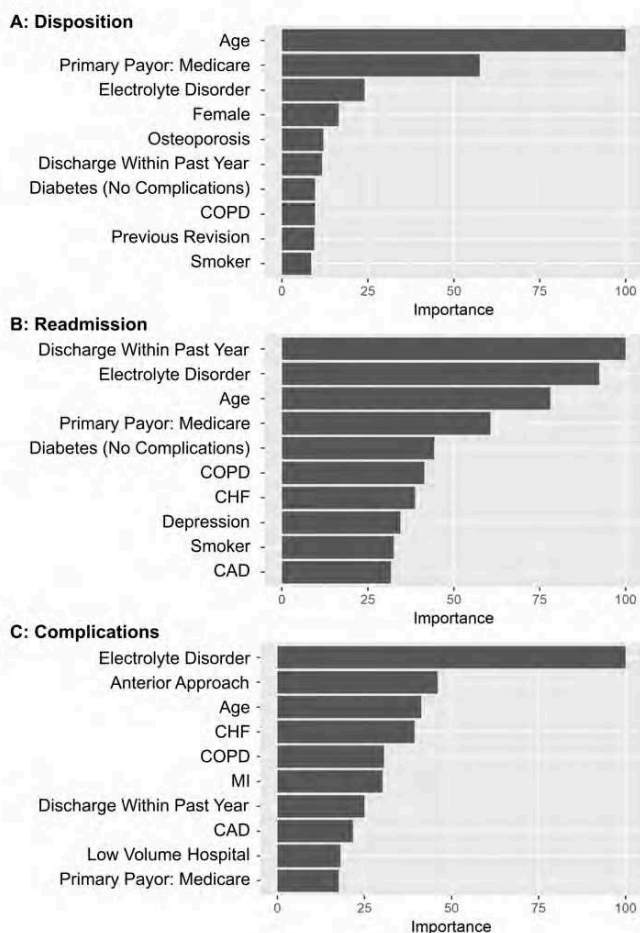
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Background: Surgery for adult spinal deformity has been proven to be effective for treating spine related disability, however is associated with high complication rates and readmission rates. The literature examining predictive models for outcomes after adult spinal deformity surgery is limited. The purpose of this study was to develop predictive models for post-operative outcomes after surgery for adult spinal deformity and to compare two machine learning techniques, logistic regression and random forest.

Methods: This was a retrospective case control study. Patients who underwent posterior spinal fusion for adult spinal deformity, as defined as 3 or more levels fused, were identified in the State Inpatient Database using ICD-9 codes. Patients who underwent surgery for non-elective indications were excluded. Data was queried for discharge to facility (DTF), 90-day readmission, and 90-day major medical complications including death, deep vein thrombosis, pulmonary embolism, respiratory failure, myocardial infarction, and cerebrovascular accident, as well as demographic data, comorbid data, and surgical data. Data was partitioned in training and testing sets. Both stepwise multivariate logistic regression analyses and random forest analyses were performed on the training sets. Models were then applied to the testing sets to generate AUCs. AUCs between logistic regression and random forest were compared using the method by DeLong et al. There were no sources of funding and there were no potential sources of conflict of interest for this study.

Results: There were 40,822 patients who met inclusion/exclusion criteria. After patients with missing data were excluded, there were 37,852 patients available for examination. The DTF rate was 35.4%. The 90-day readmission rate was 19.0%. The 90-day major medical complication rate was 13.0%. For DTF, the logistic regression model AUC was 0.77 compared to 0.75 for the random forest model (p<0.01). For 90-day readmission, AUC for the logistic regression model was 0.65, compared to 0.63 for random forest (p<0.01). For 90-day major medical complications, the AUC for logistic regression was 0.70, compared to 0.69 for random forest (p<0.01).

Conclusion: This study created the most comprehensive models to date to predict discharge to facility, 90-day readmissions, and 90-day major medical complications after undergoing surgery for adult spinal deformity. This information can be used to guide decision making between the surgeon and patient, as well as provide information for structuring value based payment models.



Vertebral augmentation with bone cement cannot stop creep deformation of the fractured vertebra but may accelerate adjacent disc degeneration

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Introduction: Percutaneous vertebral augmentation with bone cement has been commonly used to treat symptomatic vertebral compression fractures. Although vertebral augmentation can alleviate back pain symptoms, reportedly the augmented bone cement may predispose the adjacent vertebra to fractures. Relatively little is known about the impacts of bone cement augmentation on the adjacent intervertebral discs. Recent studies suggested that bone cement augmented in the vertebra may alter segmental stress distributions, impair nutrient supply to the avascular disc, and eventually, may lead to accelerated degeneration in the adjacent disc. Yet, clinical evidence to support this view is lacking. Using routine magnetic resonance (MR) imaging and quantitative image analysis, the purposes of this study are to determine the effects of vertebral augmentation in the adjacent discs, augmented vertebra and involved spinal segment.

Methods: At a territory hospital, patients with AO type A fresh vertebral compression fractures (T11-L5) between 2010 and 2017 who had follow-up MR images, either underwent vertebral augmentation procedure or conservative treatments, were recruited in the present study. Using *Mimics* (Version 20.0, Materialise Corp, Belgium), quantitative measurements of disc degeneration, including disc height, bulging, and signal intensity, were acquired on the mid-sagittal T2W MR image for the cranial and caudal discs of the fractured vertebra. In addition, a disc proximal to the fractured spinal segment was also measured as a self-control. Kyphotic angle of the fractured vertebra, vertebral body heights of the adjacent vertebrae, and sagittal Cobb angle of the fractured spinal motion segment were measured to depict creep deformation of the fractured and adjacent vertebrae and progression of segmental kyphosis. Paired t-tests were used to determine the changes of the adjacent discs, vertebrae, and spinal segment over time.

Results: In the defined period, 101 patients were included (31 men and 70 women, mean age 71.6 years, range 55 to 90 years). There were 112 fresh vertebral compression fractures in the baseline, among which 72 were treated with vertebral augmentation and the other 40 with conservative treatments. The mean follow-up time was 21.5 months (range 3 to 65 months). In follow-up, the cranial disc of the augmented vertebra decreased in height (0.46 ± 1.04 mm, $p < 0.001$) and signal intensity ($2.97 \pm 9.63 \times 10^{-2}$, $p = 0.01$), and the caudal disc of the augmented vertebra decreased in signal ($2.09 \pm 6.95 \times 10^{-2}$, $p = 0.02$) but not in height ($p = 0.07$). Moreover, the vertebra caudally adjacent to the augmented vertebra significantly decreased in height (0.64 ± 1.68 mm, $p = 0.003$). The disc and vertebra adjacent to conservatively treated vertebra did not significantly change in height and signal in follow-up. Kyphotic angle of the fractured vertebra significantly increased, regardless of augmentation or conservative treatments ($p \leq 0.01$ for both). Sagittal Cobb angle significantly increased in spinal motion segments with vertebra augmentation ($3.50 \pm 4.46^\circ$, $p < 0.001$), but not in those underwent conservative treatments.

Discussion: Vertebral augmentation with bone cement can lead to accelerated adjacent disc degeneration. Vertebral augmentation cannot stop creep deformation of the fractured vertebra and progression of kyphosis in the involved spinal segment.

1. Trout AT, Kallmes DF, Kaufmann TJ (2006) New fractures after vertebroplasty: adjacent fractures occur significantly sooner. *AJNR Am J Neuroradiol* 27 (1):217-223 doi:10.13004/kjnt.2016.12.1.18
2. Feng Z, Chen L, Hu X, Yang G, Wang Y, Chen Z (2018) Vertebral Augmentation can Induce Early Signs of Degeneration in the Adjacent Intervertebral Disc: Evidence from a Rabbit Model. *Spine (Phila Pa 1976)*. doi:10.1097/BRS.0000000000002666
3. Oh HS, Kim TW, Kim HG, Park KH (2016) Gradual Height Decrease of Augmented Vertebrae after Vertebroplasty at the Thoracolumbar Junction. *Korean J Neurotrauma* 12 (1):18-21.

Comparing different chronic preoperative opioid use definitions on outcomes after spine surgery

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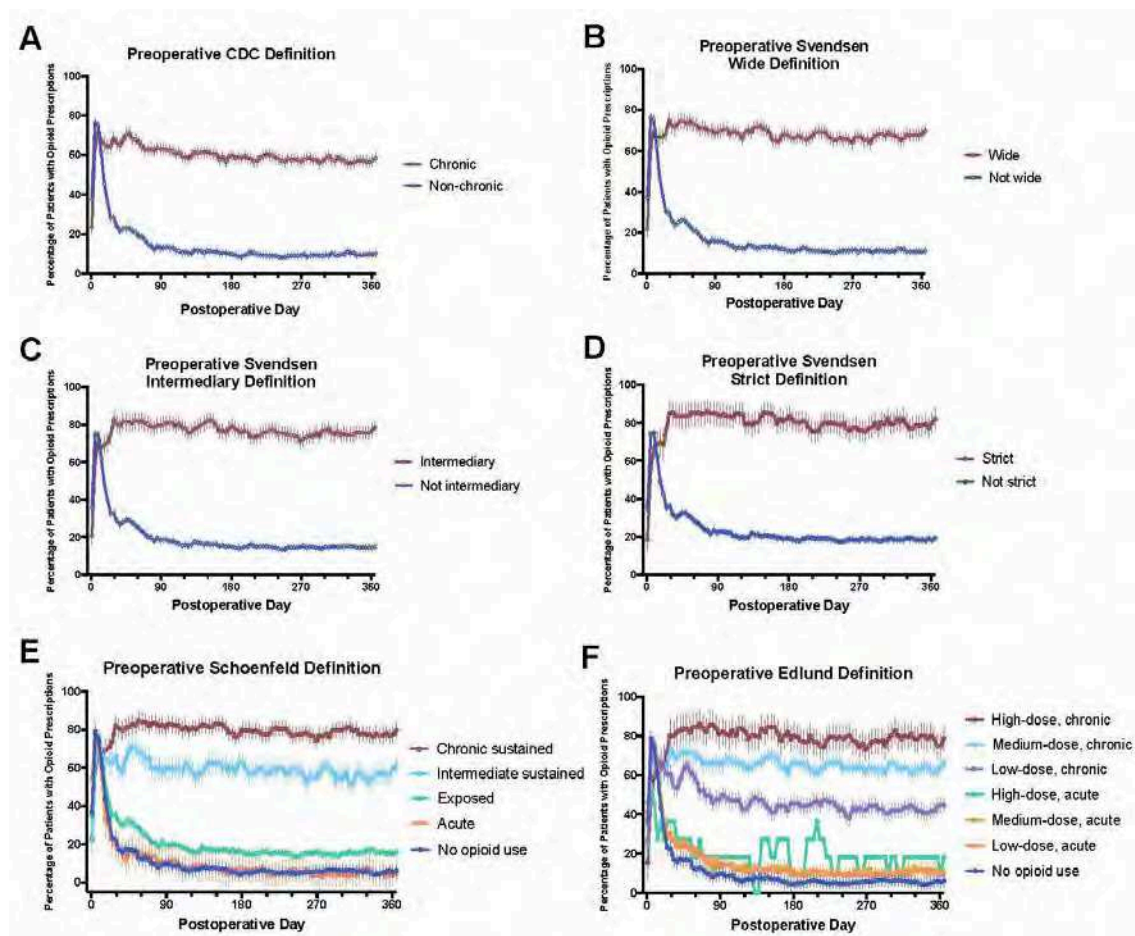
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Introduction: No consensus exists for defining chronic preoperative opioid use. Most spine studies rely solely on opioid duration or yes vs. no opioid use to stratify patients into preoperative risk categories. The purpose of this study was to compare established definitions of chronic opioid use that contain both duration and dosage to opioid models that rely solely on duration, including the CDC guideline for prescribing opioids for chronic pain, in patients undergoing spine surgery.

Methods: This study was a retrospective cohort study that used opioid data from the Tennessee Controlled Substance Monitoring Database (CSMD) and prospective clinical data from a single-center academic spine registry. The study cohort consisted of 2,373 patients who underwent elective spine surgery for degenerative conditions between January 2011 and February 2017 and who completed a follow-up assessment at 12 months after surgery. Six different chronic preoperative opioid use variables were created based on the number of times a prescription was filled and/or daily morphine milligram equivalent for the one year before surgery. These variables defined chronic opioid use as 1) most days for > 3 months (CDC), 2) continuous use for ≥ 6 months (Schoenfeld), 3) >4,500 mg for at least 9 months (Svendsen wide), 4) >9,000 mg for 12 months (Svendsen intermediary), 5) >18,000 mg for 12 months (Svendsen strict), 6) low-dose chronic (1-36 mg for >91 days), medium-dose chronic (36-120 mg for >91 days), and high-dose chronic (>120 mg for >91 days) (Edlund). Outcomes included postoperative opioid use, collected from patient interviews and CSMD, and patient-reported satisfaction (NASS Satisfaction Scale), disability (Oswestry/Neck Disability Index), and pain (Numeric Rating Scale) at 12 month follow-up. Multivariable regression models yielding C-index and R² values were used to compare chronic preoperative opioid use definitions by postoperative outcomes, adjusting for type of surgery (lumbar vs. cervical).

Results: Chronic preoperative opioid use was reported in 470 to 725 (19.8% to 30.6%) patients, depending on definition. The Edlund definition, accounting for duration and dosage, had the highest predictive ability for postoperative opioid use (77.5%), followed by Schoenfeld (75.7%), CDC guideline (72.6%), and Svendsen (59.9% to 72.5%) definitions. A combined Edlund and Schoenfeld duration and dosage definition in post-hoc analysis, that included 3 and 6 month duration cut-offs, performed the best overall with a C-index of 78.4%. Both Edlund and Schoenfeld definitions explained similar amounts of variance in satisfaction, disability, and pain (4.2% to 8.5%). Svendsen definitions and the CDC guideline demonstrated poorer performance for patient-reported outcomes (1.4% to 7.2%). **Discussion:** The Edlund definition is recommended for identifying patients at highest risk for postoperative opioid use. When opioid dosage is unavailable, the Schoenfeld definition is a reasonable choice with similar predictive ability. For patient-reported outcomes, either the Edlund or Schoenfeld definition is recommended. Future work should consider combining dosage and duration, with 3 and 6 month cutoffs, into chronic opioid use definitions.

Figure 1. Percentage of Patients with Opioid Prescriptions in the Postoperative Year by Chronic Preoperative Opioid Use Definition



Pre-operative evaluation by the Brief Scale for Psychiatric problems in Orthopaedic Patients (BS-POP) relates to poor surgical outcomes of lumbar decompression surgery

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Introduction: It is widely accepted that psychiatric problems are related to poor surgical outcomes of lumbar surgery. These problems should be assessed before surgery. However, assessment of psychiatric problems can be difficult for orthopedic surgeons. Therefore, we originally developed easy and simple questionnaire, the Brief Scale for Psychiatric Problems in Orthopaedic Patients (BS-POP) to evaluate psychosocial problems in orthopedic patients (Table1,2). The purpose of this study was to clarify the relationship between BS-POP scores and surgical outcomes in patients with lumbar spinal stenosis (LSS).

Methods: This study was a prospective cohort study. One hundred and sixty-three patients with LSS were included. All patients received decompression surgery for symptomatic levels. Fusion surgery and second surgery were excluded. The patients with cervical and thoracic spinal disease, rheumatoid arthritis, or destructive spondyloarthropathy were also excluded. Primary outcome was numerical rating scale (NRS) of satisfaction with surgery (0: not satisfied, 10: completely satisfied). NRS of 8 or more was defined as satisfied group in this study. Secondary outcomes were NRS for low back pain, leg pain, and leg numbness and Roland Morris Disability questionnaire (RDQ). BS-POP was used to detect psychiatric problems before surgery. It consists of two components; 8 questions in physician version (Table1) and 10 questions in patient version (Table2). The score of BS-POP with ≥ 11 physician version points or ≥ 10 physician version points and ≥ 15 patient version points indicate the presence of psychiatric problems. Subjects were divided into two groups according to preoperative BS-POP scores and compared prospectively. For other preoperative assessment, presence of spondylolisthesis (grade I or more), degenerative scoliosis (cobb angle over 10 degrees), and lumbar kyphosis (lumbar lordosis under 0 degree) were examined in preoperative X-ray. In neurological findings, presence of cauda equina symptoms was evaluated. Statistical analysis was performed by Chi-square test and Wilcoxon test for univariable analysis. To estimate relationship between preoperative BS-POP evaluation and surgical outcomes, logistic regression analysis was performed including other preoperative assessment as confounding factors. A p-value less than 0.05 was considered significant.

Results: Preoperatively, 22 patients showed abnormal BS-POP scores and 141 patients showed normal BS-POP scores. There were no significant differences in preoperative assessment between two groups. One year after surgery, patients with abnormal BS-POP scores showed significantly higher NRS of low back pain, leg pain, and leg numbness, and lower satisfaction with surgery compared with patients with normal BS-POP scores ($p < 0.05$). The RDQ deviation score was significantly lower in abnormal BS-POP group ($p < 0.05$). As a result of multivariable analysis, only preoperative abnormal BS-POP score was independently associated with low satisfaction with surgery ($p < 0.05$, Odds ratio 4.46, 95% confidence interval 1.33-16.04).

Discussion: Abnormal preoperative BS-POP score was associated with poor outcomes of decompression surgery for LSS 1 year after surgery. BS-POP is a useful tool to evaluate preoperative psychiatric problems for patients undergoing decompression surgery for LSS.

Questions	Responses and scores		
1. The patient's pain appears uninterrupted	1 That is not the case	2 The pain is intermittent	3 The patient appears to be almost always in pain
2. The patient has a specific way of indicating the symptomatic area(s)	1 That is not the case	2 They rub the symptomatic area(s)	3 Without instruction, they begin to remove their clothes and show the symptomatic area(s)
3. The patient appears to have pain over the whole symptomatic area	1 That is not the case	2 They sometimes do	3 Almost all the time
4. When examination or treatment is recommended, the patient becomes badly tempered, easily angered, or argumentative	1 That is not the case	2 They show slight resistance	3 They show significant resistance
5. When having their senses assessed, the patient responds excessively to stimulation	1 That is not the case	2 Their response is slightly excessive	3 Their response is quite excessive
6. The patient repeatedly asks questions regarding their condition or surgery	1 That is not the case	2 They sometimes do	3 Almost all the time
7. The patient changes their attitude depending on the medical staff member	1 That is not the case	2 They do somewhat	3 They do significantly
8. The patient wishes that their symptoms were gone, even with regard to slight symptoms	1 That is not the case	2 They do somewhat	3 They do significantly

Numbers indicate scores

Table 1. Questionnaire for medical personnel (BS-POP for use by physicians), English version

Questions	Responses and scores		
1. Do you ever feel like crying, or do you cry?	1 No	2 Sometimes	3 Almost all the time
2. Do you always feel miserable and unhappy?	1 No	2 Sometimes	3 Almost all the time
3. Do you always feel nervous and irritated?	1 No	2 Sometimes	3 Almost all the time
4. Do you feel annoyed and aggravated over small things?	1 No	2 Sometimes	3 Almost all the time
5. Do you have a normal appetite?	3 No	2 I sometimes lose my appetite	1 Yes
6. Are you in your best mood in the morning?	3 No	2 Sometimes	1 Almost all the time
7. Do you get somewhat tired?	1 No	2 Sometimes	3 Almost all the time
8. Are you able to put your usual effort into your work?	3 No	2 I sometimes can't	1 Yes
9. Do you feel satisfied with the sleep you are getting?	3 No	2 I sometimes don't feel satisfied	1 Yes
10. Do you have trouble falling asleep for any reason other than pain?	1 No	2 Sometimes	3 Almost all the time

Numbers next to responses indicate scores

Table 2. Questionnaire for patients (BS-POP for use by patients), English version

A new anatomical consideration on foraminal decompression for lumbar foraminal stenosis

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Introduction: There are two surgical options for decompressing lumbar foraminal stenosis (LFS). One is unroofing of the spinal canal and the other is lateral fenestration, and it has been a longstanding debate as to which method is better. Here we describe our new anatomical classification based upon surgical strategy for LFS and discuss the better surgical option for decompressing LFS.

Methods: We present a retrospective cohort study of surgically treated patients at a single spine center. A total of 78 consecutive patients, who received spinal microendoscopic decompression surgery for LFS, were enrolled in this study. There were 47 men and 31 women with a mean age of 69.1 years (range 33–88). The inclusion criteria of LFS were as follows: 1) unilateral L5 radiculopathy, 2) the stenosis was recognized as LFS during the operation, 3) the improvement of visual analogue scale (VAS) more than 20 mm after surgery, and 4) the symptom was in concordance with the radiological finding. The narrowest part, range of stenosis, and its constriction element (bony tissue or soft tissue) around the lumbar foramen were investigated using CT-MRI image fusion software (Fujifilm; Vincent[®], Japan). Based on our surgical strategy for LFS, the anatomy of the lumbar foramen was classified into three categories. 1) Stenosis from the inner edge of the pedicle to the center was defined as medial intervertebral foraminal stenosis (MF), 2) stenosis from the center to the outer edge of the pedicle was defined as lateral intervertebral foraminal stenosis (LF), and 3) stenosis outside the outer edge of the pedicle was defined as extraforaminal stenosis (EF).

Results: Of the 78 patients, 44 had degenerative spondylosis (57%), 26 had degenerative scoliosis (33%), and 8 had disc herniation (10%). The narrowest part was seen in MF in 5 cases (6.4%), LF in 45 cases (57.6%), and EF in 28 cases (35.9%). The range of stenosis was MF in 3 cases (3.8%), MF + LF in 2 cases (2.6%), LF in 45 cases (57.7%), LF + EF in 4 cases (5.1%), and EF in 24 cases (30.8%). The prevalence of LF and/or EF was 73 cases (93.6%) in this study. Constriction elements consisted of bony tissue alone in 42 cases (53.8%) and soft tissue alone in 36 cases (46.2%).

Discussion: This study revealed that almost all cases of LFS involved the outer edge of the pedicle and the frequency of stenosis inside the center of the pedicle was extremely small. Therefore, nerve decompression should be done not from the spinal canal but from outside the intervertebral foramina.

Acellular nerve allograft seeded with SDF and autogenic ADSCs for nerve root repair in a beagle model

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Introduction: Nerve root repair is a major challenge in clinical practice. Nerve grafting is required to treat severe nerve root defects caused by spinal iatrogenic injury or trauma. Available nerve sources for autologous transplantation are limited. Stem cells offer promise for nerve root repair and regeneration. However, the current lack of Schwann cell phenotype, high costs, and major trauma limit the production of Schwann cells from stem cell differentiation. Thus, the purpose of this study is to investigate the ability of adipose-derived stem cells (ADSCs) to differentiate into the Schwann cell phenotype, after treatment with Schwann cell-derived neurotrophic factor (SDF) in vitro.

Methods: ADSCs were isolated and cultured for use in two types of nerve grafts: acellular allogeneic nerves (ACEN), and acellular allogeneic nerves treated with SDF (ACEN+SDF). Chemically extracted, untreated acellular allogeneic nerves (CEN), acellular allogeneic nerves with isolated and cultured autologous SCs (CEN+SCs), and fresh autografts (AG) served as controls. Hematoxylin and eosin (HE) and S100 immunohistochemical staining were performed to observe the cytokine levels in the nerve grafts; enzyme-linked immunosorbent assay (ELISA) and real-time PCR were performed to evaluate the S100 and glial fibrillary acidic protein (GFAP) expression.

Results: The number and biological morphology of the cells in the ACEN+SDF group were close to the level of those of autologous Schwann cells, and were significantly better than those for the cells in the ACEN group without SDF treatment. HE staining and S100 immunohistochemical staining showed that the number, distribution, and morphology of positive cells in the ACEN+SDF group were better than those in the ACEN group, and similar to the cocultured autologous Schwann cells. The acellular nerve allografts seeded with ADSCs and SDF showed significant S100 and GFAP expressions. No significant statistical differences were observed between the ACEN+SDF, ACEN+SCs, and AG groups.

Discussion: SDF showed good compatibility with ADSCs and acellular nerve scaffolds in vitro, and SDF could promote the differentiation of ADSCs into Schwann-like cells. These data suggest that such acellular nerve allografts should be evaluated as therapeutic strategies for treating severe iatrogenic or traumatic nerve root defects.

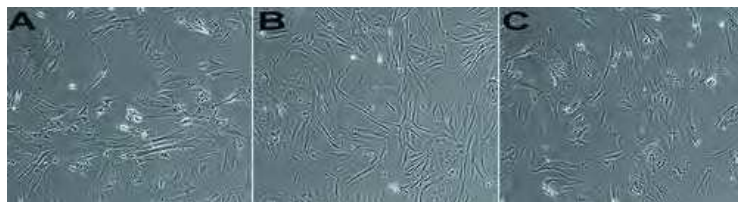


Fig. 1 Culture supernatants were analyzed using an optical microscope (×100). The number and biological morphology of the cells in the ACEN group are shown in Fig. 1A, those of cells in the ACEN+SDF group are shown in Fig. 1B, and those of cells in the CEN+SCs group are shown in Fig. 1C.

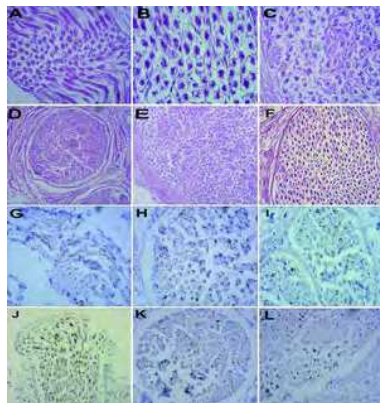


Fig. 2 HE and S100 immunohistochemical staining of various nerve grafts (Fig. 2A, ACEN group, HE, ×200; Fig. 2B, ACEN+SDF group, HE, ×200; Fig. 2C, CEN+SCs group, HE, ×200; Fig. 2D, ACEN group, HE, ×100; Fig. 2E, ACEN+SDF group, HE, ×100; Fig. 2F, CEN+SCs group, HE, ×100; Fig. 2G, ACEN group, S100, ×200; Fig. 2H, ACEN+SDF group, S100, ×200; Fig. 2I, CEN+SCs group, S100, ×200; Fig. 2J, ACEN group, S100, ×100; Fig. 2K, ACEN+SDF group, S100, ×100; Fig. 2L, CEN+SCs group, S100, ×100).

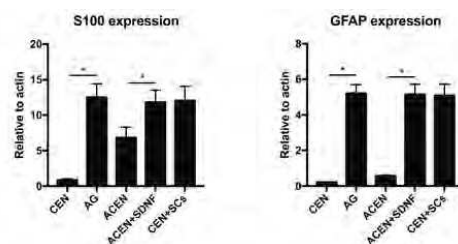
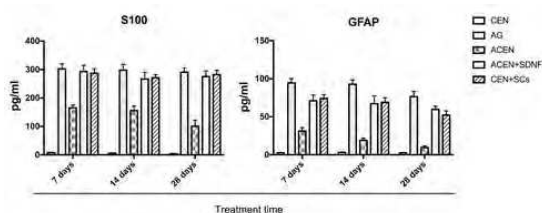


Fig. 3 Quantitative expression of S100 and GFAP in supernatants. **Fig. 4** mRNA expressions of S100 and GFAP.

Extensive spinal fusion surgery to correct severe deformities in patients with Parkinson's disease or Parkinson's syndrome: clinical outcomes over a five-year follow up

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Introduction: Postural disorders associated with Parkinson's disease or Parkinson's syndrome (PD) lead to spinal imbalance and deformity and can result in significant disability. Spinal surgery in PD patients has a high incidence of complications, and revision surgeries have been reported. We performed extensive fusion surgery to correct severe spinal deformities in patients with PD. Clinical outcomes of surgical treatment in PD patients over a medium or long-term follow-up period are currently unknown. The objective of this study was to clarify the mid-term results of extensive spinal fusion surgery in PD patients.

Methods: We investigated PD patients who had undergone extensive fusion surgery more than 5 years prior. Data on patients' backgrounds, surgical parameters, peri-operative and mechanical complications, revision surgeries, and time course of indoor activities of daily living (ADL) were assessed. Indoor ADLs were classified into four stages: independent, T-cane, walker, and wheel chair use.

Results: A total of 18 consecutive patients (4 male and 14 female, average age 71.2 years and average follow-up duration 59.7 months) with a minimum of 5 years progress reporting were included. These included 14 patients diagnosed with Parkinson's disease and 3 patients diagnosed with Parkinson's syndrome. Average blood loss, duration of surgery and fusion levels were 1922 g, 422 minutes and 11.7 levels, respectively. Peri-operative complications were observed in 13 cases (72.2 %), including delirium (hallucination) (11 cases), massive bleeding (over 3000 g) (3 cases), deterioration of PD (4 cases), deep wound infection (1 case), and fracture of the sacrum (1 case). Before surgery, 1 case was independent in ADL, 1 case relied on a T-cane, 12 cases relied on a walker, and 4 cases used a wheelchair. Improvements in ADL were observed 1 year after surgery: 5 cases were independent, 3 cases relied on a T-cane, 5 cases relied on a walker, and 4 cases used a wheelchair; however, 4 cases did not improve, because of death, skin perforation by rods followed by subsequent surgical revision, deterioration of knee osteoarthritis, and deterioration of PD. Revision surgeries were performed in 6 patients (33.3 %) within 3 years of surgery, because of rod fractures, proximal junctional failure, and skin penetration of the instrumentation. In the 3 to 5 years after surgery, the ADL of 9 patients worsened because of deterioration of PD. A total of 11 cases were followed up over 5 years. At this time point, no cases were independent, 2 cases relied on a T-cane, 3 cases relied on a walker, and 6 cases used a wheelchair.

Discussion: Surgical intervention in PD patients with spinal disorders leads to good outcomes in the short term; however, the condition of the patients deteriorated because of complications 2 years after surgery, and worsening of PD occurred 3–5 years after surgery.

Geographic differences in intraoperative neuromonitoring during minimally invasive lateral spine surgery

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Introduction: Intraoperative neuromonitoring with modalities including electromyography (EMG), motor evoked potentials (MEP), and somatosensory evoked potentials (SSEP) are used during spinal surgery to detect and prevent possible neurological injuries. Little is known about regional variations in intraoperative neuromonitoring during minimally invasive lateral spine surgery, and there is no current standard for what modalities should be used during these procedures. The purpose of this study was to see if the rate of usage of each modality was the same between geographic regions.

Methods: A retrospective review was performed using the Accurate Neuromonitoring and US Monitoring (USMON) databases to identify patients who received intraoperative neuromonitoring during minimally invasive lateral lumbar interbody fusion from 2008 to 2018. Demographic information (age, gender, and region within the United States) as well as clinical information (type of intraoperative neuromonitoring and rates of alerts) were assessed. 841 patients with an average age of 61 years (range 12 to 88 years) had intraoperative neuromonitoring during MIS LLIF/XLIF procedures. 314 were from the Southeast (including Alabama, Georgia, North and South Carolina, Florida, and Mississippi) and 527 from the Northeast (New York and New Jersey).

Results: Each modality was used at a different frequency between regions ($p < 0.0001$): in the Southeast, EMG was used in 98.7% of cases, SSEP was in 77.4%, and MEP in 10.5% while in the Northeast, EMG was used in 92.9% of cases, SSEP in 99.6%, and MEP in 36.1%. When SSEP was used (91.3% of all cases), an alert was seen in 6.8% of cases. When EMG was used (95.1% of all cases), an alert was seen in 4.6% of cases, and when MEP was used (26.5% of all cases), an alert was seen in 3.2% of cases. Overall, alerts for each modality occurred at different rates ($p < .05$). Between regions, there was no difference in MEP alerts ($p = .83$) but EMG and SSEP alerts occurred at different rates, with both alerts seen more frequently in the Northeast, ($p < .05$). Four cases had an alert occur in two modalities, two cases had SSEP and EMG alerts, and two other cases had SSEP and MEP alerts. No common cause was found to trigger any of the alerts.

Discussion: The rate of usage for all three monitoring modalities was different between regions as MEP and SSEP were used more often in the Northeast and EMG was used more often in the Southeast. This regional variation indicates potential opportunity for standardization of monitoring indications. Although the alerts for each modality were seen at different rates, an alert from one modality was rarely seen in the same case as an alert from a different modality. In the few instances with alerts from more than one modality within the same case, the alerts did not seem to have the same cause. Because of this, utilizing different intraoperative neuromonitoring modalities has the potential to increase detection of potential neurologic injury.

Asymptomatic construct failure after metastatic spine tumour surgery: a new entity or a continuum with symptomatic failure?

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Introduction: Reported incidence of implant and/or construct failures after instrumentation in metastatic spine tumour surgery (MSTS) is low (1.9-16%). These incidence rates are based on clinical presentations or revisions required for symptomatic failures. The phenomenon of asymptomatic construct failure (AsCF) after MSTS has not been described. Hence, we aim to study the incidence, onset, underlying mechanism, natural history, and the associated factors leading to AsCF after MSTS.

Methods: Ours is a retrospective review of the prospectively collected data of 288 patients who underwent MSTS at a single tertiary care institute from 2005–2015. Data collected were patient demographics, oncological, operative and postoperative variables. Operative details collected were the number of spinal levels instrumented and/or decompressed and types of fixation used. Radiological evidence of construct failures was identified using the available serial radiographs. Patients with AsCF were analysed for risk factors and survival duration. Competing risk regression analyses were done where AsCF was the event of interest, with symptomatic failure (SF) and death as competing events. Kaplan-Meier survival curves were obtained for patients with AsCF, SF and no failures.

Results: AsCF was observed in 41/246 patients (16.7%). Average onset of AsCF after MSTS was 2 months (1-9 months). Early AsCF (<3months from index surgery) accounted for 80.5%, while late AsCF (>3months) were observed in 19.5%. In our study, early AsCF occurred due to: 1) reduction of body height of the vertebra within the construct in patients who had only posterior instrumentation (n=22) and 2) cage subsidence/tilting in patients who had undergone anterior column reconstruction (n=11). Increasing age ($p<0.02$) and primary breast (13/41=31.7%) ($p<0.01$) tumours were associated with higher rates of AsCF. The frequencies of the various radiological failure mechanisms were: Screw ploughing-15; Screw loosening-15; Screw pull-out-3; Screw cut-out-8; Screw breakage-2; Cage subsidence-6; Cage displacement-1; Cage breakage-0; Rod breakage-1; and Angular deformity (Increase in kyphosis-25; Decrease lordosis-4). Most common radiologically detectable AsCF mechanism was angular deformity (increase in kyphosis) in 29 patients, followed by screw ploughing and screw loosening in 15 patients each. There was a trend towards AsCF in patients with SINS \geq 7, instrumentation across junctional regions and construct length of 6-9 levels, although the associations were not significant. Median survival of AsCF patients was 20 months (3-95 months) in patients with early failure and 41 months (11-92 months) in patients with late failure. Average follow-up duration was 20 months. None of the AsCF patients underwent revision surgery during the study period.

Discussion: Majority of early AsCF were clinically inconsequential and did not require any intervention. Late failure was seen in patients who survived longer and maintained ambulation for a longer period. This may be due to the failure of fusion and/or late recurrence of tumours. AsCF is not necessarily an indication for aggressive or urgent intervention. However, we recommend frequent follow-up with periodic investigations to detect progressive construct failure. Increasing age and patients with primary breast tumour have a higher possibility of AsCF after MSTS.

Are double-level TLIFs preferable to single-level TLIF for contiguous double-level spondylolytic spondylolisthesis?

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Introduction: Lumbosacral contiguous double-level spondylolytic spondylolisthesis is an extremely rare condition, characterized by severe lumbosacral malalignment and sagittal spino-pelvic imbalance. To date, the effect of double-level or single-level TLIF on sagittal reconstruction and the clinical outcomes of these patients still remain largely unknown. This study is to investigate the sagittal realignment and clinical outcomes of contiguous double-level spondylolytic spondylolisthesis after posterior instrumented double-level or single-level transforaminal lumbar interbody fusion (TLIF).

Methods: From January 2010 to September 2018, the records of patients with contiguous L4-S1 double-level spondylolysis were retrospectively reviewed. Patients who had undergone double-level or single-level TLIF and a minimum of 2 years' follow-up were included. The slippage parameters and spino-pelvic parameters were measured preoperatively, postoperatively and at the latest follow-up.

Results: A total of 38 patients (23 females and 15 males, mean age of 57.1±6.9 years) were enrolled. Eighteen patients were treated with double-level TLIF and the remaining 20 with single-level TLIF at the levels with the dominant slippage (L4/5 in 14; L5/S1 in 6). After surgery, the spondylolisthesis was significantly reduced at both levels. There was a significant reduction in PT and a significant increase in SS. Significant increase in L4-S1 height and L4-S1 lordosis and decrease in L5 slope and L5 incidence were also observed. Compared to single-level TLIF, double-level TLIF increased L4-S1 height and L4-S1 lordosis and reduced L4-SVA and L5 incidence more obviously, and the sagittal balance was better corrected in double-level TLIF group. Double-level TLIF group showed larger increase in ODI scores and VAS scores for low-back pain. The incidence of implant-related complications was lower in double-level group.

Discussion: Posterior short-segment instrumented TLIF can bring favorable radiographic and clinical outcomes in patients with lumbosacral contiguous double-level spondylolytic spondylolisthesis. Double-level TLIF is more efficient to improve L4-S1 height, regional lumbar lordosis, global sagittal balance.

Intra-operative neuromonitoring (IONM): is there a role in metastatic spine tumour surgery?

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Introduction: Multimodal Intraoperative neuromonitoring (IONM) is considered as a standard of care in spinal deformity surgeries. However, limited data exist about its role in Metastatic Spine Tumour Surgery (MSTS). Therefore, we aim to report our experience with IONM in MSTS.

Methods: A total of 135 patients from 2010 to 2017, who underwent MSTS with IONM at our institute were studied retrospectively. After excluding 7 with no baseline signals, 128 patients were analysed. The data collected comprised of demographics, details of tumour involvement, i.e., primary tumour type, area of spinal column involved, tumour burden, and pre-operative neurological status (ASIA Grading); surgical details such as the type of surgery (MIS/Open), surgical approach, levels instrumented and levels decompressed. Postoperative neurological status (ASIA) was assessed and patients with neurological deficit were followed up for a period of 12 months or until their demise, whichever was earlier. All patients had 20-32 channel multimodal intraoperative neuromonitoring in the form of somatosensory-evoked potentials (SSEP), transcranial electric motor evoked potentials (tcMEP) and free running electromyography (EMG).

Results: The 128 patients included 61 males and 67 females with a mean age of 61 years. 116 underwent posterior procedures; 9 anterior and 3 both. The frequency of preoperative ASIA Grades were A=0, B=0, C=10, D=44 and E=74 patients. In total, 54 underwent MSTS for neurological deficit, 66 for instability pain and 8 for intractable pain. The most common site of metastasis for which surgery was performed was thoracic, followed by lumbar. Out of the 128 patients, 116 underwent posterior procedure; 9 had anterior, and 3 a combination of both. Of 128 patients, 13 (10.2%) had significant IONM alerts, representing true positives; 114 true negatives, 1 false negative and no false positives. Among the 13 true positives, 4 (30%) underwent minimally invasive and 9 (70%) open procedures. 8 (69.2%) patients had posterior approach. 7 (53.84%) true positive alerts were during decompression, which resolved to baseline upon completion of decompression; while 5 (38.46%) were during instrumentation, which recovered to baseline after adjusting/downsizing the instrumentation; and 1 (8.3%) during lateral approach which reversed after changing the plane of dissection. Among the 13 true positives, 1 alert was of all three modalities, 5 were of MEP and SSEP, 2 were of MEP and EMG and 5 alerts were of MEP alone. Of the 7 patients without baseline, 5 were ASIA-A, 2 were ASIA-C. The sensitivity, specificity, positive and negative predictive values were 99.1%, 100%, 100% and 92.9% respectively.

Discussion: Multimodal IONM in MSTS helped in preventing post-operative neurological deficit in 9.4% of patients. It's high sensitivity and specificity to detect intraoperative neurological events envisages its use in ASIA-grade D/E patients requiring instrumented decompression.

Viability cellular allograft for spine fusion - clinical success comparing two surgical techniques

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Introduction: The current gold standard in lumbar fusion consists of transpedicular fixation in combination with an interbody placement of autologous bone from iliac crest. Due to the limited availability of autologous bone as well donor site morbidity after iliac crest grafting, alternative grafts have been developed to supplement tissue without adversely affecting therapeutic value. Level I randomized trials comparing efficacy of a DBM preparation (*Grafton DBM*) compared with iliac crest autograft demonstrated 86% for the DBM group and 92% for the autograft group.^[1] Less positive results have been reported comparing DBM gel coupled with autograft vs. autograft composite on the contralateral side in patients undergoing instrumented posterolateral fusion.^[2] After two years follow-up, fusion rates of 52% on the DBM side and 54% on the autograft were reported. Defining comparable clinical outcomes in these two studies leaves room for alternative grafts to evolve as more efficacious. This data represents the use of a cellular bone matrix (*VIA Graft*) for spine fusion in two surgical practices using different grafting techniques.

Methods: Surgeon #1 blended four components; VIA Graft, local autograft, BMAC, and collagen hydroxyapatite sponge, and placed in the posterolateral gutters for patients receiving posterolateral instrumented fusions, and in the posterolateral gutters, interbody spacers, and intradiscal spaces, for patients receiving posterolateral fusions and transforaminal interbody fusions.

Surgeon #2 obtained iliac crest bone marrow and mixed Via Form moldable material in a ratio of approximately 5 mL of via graft to 1 mL of bone marrow aspirate; packing approximately 2-3ml of the Via Form/bone marrow mixture into each disk space. Additional Via Form is packed into the interbody space, adequate to fill the available bone graft void/window.

Results: Surgeon #1 treated 51 patients and 79 levels, while Surgeon #2 treated 133 patients and 202 levels. Patient demographics were similar in age, diabetes, and tobacco use. Fusion were 96% and 98%, respectively, irrespective of surgical technique. Preoperative VAS for the patients in Surgeon #2's practice was 61.9 (13-100), while VAS 12 months following was 24.8 (0-71). Two of the patients in Surgeon #2's practice required fusion extensions because of falls, but the initial sites remained fixed and solid.

Discussion: Evidence of successful fusion using viable bone/matrix combinations demonstrated efficacy exceeding that of commonly used graft extenders. Based on these outcomes, both surgical procedures were deemed safe, effective, and therapeutically successful. In patients requiring vertebral body fusion, the techniques described effectively resulted in 96 and 98% fusion in respective cohorts of 51 and 133 patients.

[1] Kang J, An H, Hilibrand A, Yoon ST, Kavanagh E, Boden S. Grafton and local bone have comparable outcomes to iliac crest bone in instrumented single-level lumbar fusions. *Spine*. 2012 May 20;37(12):1083-91

[2] Frank P. Cammisa; Gary Lowery; Steven R. Garfin; Fred H. Geisler; Peter M. Klara; Robert A. McGuire; Walter R. Sassard; Harrison Stubbs; Jon E. Block. Two-Year Fusion Rate Equivalency Between Grafton® DBM Gel and Autograft in Posterolateral Spine Fusion: A Prospective Controlled Trial Employing a Side-by-Side Comparison in the Same Patient. *Spine*. 2004 29(6):660-666

Factors influencing extended hospital stay in patients undergoing metastatic spine tumour surgery and its impact on survival

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Introduction: Metastatic spine tumour surgeries (MSTS) are indicated for preservation or restoration of neurological function, in order to provide mechanical stability and pain alleviation. The goal of MSTS is to improve the quality of life of the patients with spinal metastases and rarely for oncological control which is usually achieved by adjuvant therapies. Hence, outcome measures such as length of stay (LOS) and rate of complications after MSTS are important indicators of quality of the medical/surgical management and healthcare provided, but there is limited literature evidence for the same. We carried out a retrospective analysis on prospectively collected data to determine the incidence and the factors influencing normal (nLOS) and extended length of stay (eLOS) after MSTS.

Methods: Data of 220 consecutive patients who had undergone MSTS between 2005 and 2015 at a single tertiary care institute, were retrieved from hospital electronic records. The preoperative, intraoperative and postoperative variables, discharge destinations as well as socioeconomic factors were analysed. The key outcome indicator was eLOS, which was defined as positive when the LOS exceeded the 75th percentile for this cohort. Univariate and multivariate logistic regression analyses were performed to determine the predictive factors of eLOS.

Results: The overall median LOS was 7 days (1–30 days) and 55 patients had eLOS (LOS \geq 11 days). Multivariate analysis revealed that significant variables independently associated with eLOS were instrumentation >9 spinal segmental levels (OR 2.89, 95% CI 1.1–7.5, $p = 0.032$) and presence of postoperative complications (OR 3.68, 95% CI 1.85–7.30, $p < 0.001$). Metastatic tumours other than breast, prostate and lung were found to have a lesser risk of eLOS (OR 0.31, 95% CI 0.14–0.70, $p = 0.004$). Survival estimates showed that patients with eLOS have a shorter survival than patients with nLOS (Crude HR 1.81, 95% CI 1.13–2.89, $p = 0.003$).

Discussion: Our study demonstrates that instrumentation levels >9 , metastases from lung, breast and prostate, and the presence of major postoperative complications were the factors influencing eLOS; hence these factors should be carefully addressed whenever possible. Reduction of LOS will assist the health care providers in better resource allocation as well as enable metastatic spine patients to spend a larger proportion of their limited life span in their home or preferred environment.

Association of global sagittal alignment with the adjacent segment disease after posterior lumbar interbody fusion in spondylolytic spondylolisthesis

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Purpose: Adjacent segment disease (ASD) is one of the most common complications associated with posterior lumbar interbody fusion (PLIF). We investigated the association of the pre- and post-operative global sagittal alignment of ASD after one level PLIF in spondylolytic spondylolisthesis.

Methods: The study design was multi-center retrospective study. The approval of Institutional Review Board (IRB) was obtained before the study. Consecutive 101 consecutive patients (mean age was 57.8±13.8-years, mean follow-up 24.0±16.8 months) who underwent one level PLIF for L5-S1 spondylolytic spondylolisthesis between 2008 and 2017 were retrospectively reviewed. Definition of ASD was "disc height loss >3 mm, posterior angulation >5°, or progression of slippage >3 mm between the pre- and post-operative radiographs" by Nakashima and Okuda. We both included symptomatic and non-symptomatic ASD. MRI was used to evaluate the pre-operative disc degeneration in the adjacent segment of the PLIF according to Pfirrmann's classification between ASD and non-ASD group. The pre- and post-operative spinopelvic alignment (% slip, sacral slope (SS), lumbar lordosis (LL), pelvic tilt (PT), pelvic incidence (PI), Spinal Deformity Study Group lumbosacral angle (SDSG-LSA)), global sagittal alignment (sagittal vertical axis (SVA) and thoracic kyphosis (TK)) were evaluated.

Results: Incidence of ASD was 11.9% (12 out of 101 patients). The pre-operative disc degeneration in the adjacent segment by Pfirrmann's classification was not significantly different between ASD and non-ASD group ($p=0.42$). Regarding the pre-operative spinopelvic alignment, the mean LL in ASD group ($37\pm 10^\circ$) tended to be smaller than that in non-ASD group ($45\pm 13^\circ$) and the mean PT in ASD group ($24\pm 7^\circ$) was significantly larger than that in non-ASD group ($19\pm 8^\circ$) ($p=0.09, 0.03$). However, the mean SDSG-LSA in ASD group ($-7\pm 7^\circ$) was not significantly different from that in non-ASD group ($-5\pm 7^\circ$) ($p=0.92$). Regarding the post-operative spinopelvic alignment, the mean LL in ASD group ($34\pm 19^\circ$) also tended to be smaller than that in non-ASD group ($44\pm 14^\circ$) and the mean PT in ASD group ($23\pm 6^\circ$) was significantly larger than that in non-ASD group ($19\pm 8^\circ$) ($p=0.07, 0.04$). However, the mean SDSG-LSA in ASD group ($-7\pm 8^\circ$) was not significantly different from that in non-ASD group ($-7\pm 5^\circ$) ($P=0.90$). Regarding the pre- and post-operative global sagittal alignment, neither SVA nor TK were significantly different between ASD and non-ASD group.

Conclusions: This study indicated that patients who developed ASD had hypo-lordosis and retroverted pelvis at both pre- and follow-up. In this study, we could not obtain the local kyphosis at L5-S1 and LL by PLIF. To obtain better local lordosis at L5-S1 is the key to prevent post-operative ASD for spondylolytic spondylolisthesis after one level PLIF.

Carbon-fiber-reinforced PEEK fixation system in the treatment of spine tumours

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Introduction: Combination of surgery and radiotherapy is becoming more frequent for the treatment of bone tumours of the spine [1].

Metallic hardware interfere with postoperative radiotherapy due to the artefacts on imaging and due to the scattering effects. The risk of over-irradiation of neighbouring structures limits the dose delivered making treatment less effective. Composite materials such as carbon-fiber-reinforced (CFR) polyethyl-ether-ether-ketone (PEEK) have been used since many years for interbody and body replacement cages [2,3]. This material is biologically compatible, promoting osteoblastic activity [4]. It is radiolucent at the standard radiograms, barely visible on CT scan and MRI, allowing easy planning CT scan [5], early detection of local recurrence and no scattering effect during radiotherapy. A CFR-PEEK spine fixation system has been recently proposed.

Methods: We retrospective evaluate 60 consecutive tumor patients, treated in a single institution who underwent spinal surgery including a composite CFR-PEEK fixation system (Carboclear™, produced by CarboFix Orthopedics® Ltd., Herzliya, IL).

Results: There were 33 male and 27 female, mean age 58 years (range 18– 78). 37 cases were primary tumour (24 recurrence) and 23 were metastases (13 recurrence). A separation surgery has been performed in 41 cases, a gross total excision in 11 cases and en-bloc resection in 8 cases.

Only one intraoperative complication related to the implant occurred (screw breakage). No rod breakage, neither any screw/rod disconnection was found during FU. One case of loosening of sacral screws at 12 months FU in one patient submitted to previous surgery (multi recurrent malignant tumour, loosening found at the time of the local recurrence). One case of pull out of distal screws at 6 months FU. After the surgery in 41 patients a postoperative radiotherapy has been performed (23 cases with particle and 18 with photons) (see a case in Figure 1).

Discussion: Thanks to radiolucency CFR-PEEK stabilization devices are more suitable in patients eligible for radiotherapy: the absence of image artefacts together with significantly less dose perturbation improve the treatment accuracy. Moreover, the radiolucency is useful in the follow-up of patients allowing early detection of local recurrence.

The advantage of using CFR-PEEK composite implants in terms of overall results and patients' outcome needs to be prospectively defined with larger patient series and longer follow-up. In this perspective, even the final prognosis could be positively affected by combination of less aggressive surgery and appropriate courses of radiotherapy.

References:

- [1] Sharan AD, et al. Am Acad Orthop Surg 22(7):447–454.
- [2] Brantigan JW, et al. Spine (Phila Pa 1976) 19(13):1436–1444.
- [3] Boriani S, et al. Orthopedics 25(1):37–42.
- [4] Morelli C, et al. J Biomed Mater Res A 83(1):178–183.
- [5] Jackson JB 3rd, et al. Spine (Phila Pa 1976) 42(1):E1–E7.

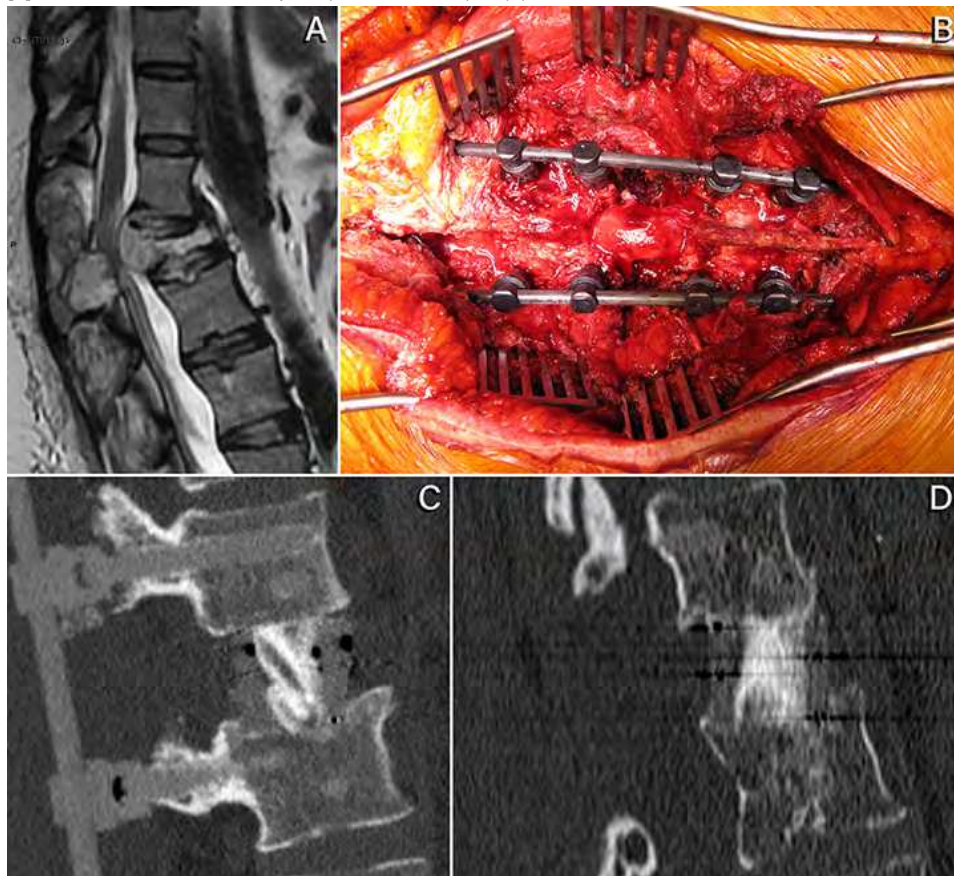


Figure 1. A: L1 hemangioendothelioma submitted to palliative decompression elsewhere. B: Gross-total double approach excision with posterior fixation by CFR-PEEK composite implant. C: Posterior fixation by CFR-PEEK and anterior reconstruction by CFR-PEEK cage filled with autogenous bone chips. Radiotherapy (44Gy). D: 2D CT reconstruction at 10 months follow up. No tumour recurrence. Full implants stability. Fusion of the graft.

Update on custom made 3D printed titanium implants for anterior column reconstruction following en bloc resection for spinal tumours

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Introduction: Reconstruction of the segmental defect after en bloc resection for spinal tumours aims at immediate stability and secondary solid fusion. The present communication provides an update on the results of an ongoing study concerning the use of 3D printed custom made implants for anterior column reconstruction.

Methods: In 17 patients submitted to en bloc resection for spinal tumour between November 2015 and June 2018 at the same Institution, anterior column reconstruction was performed using 3D printed custom made implants. Resection was planned according to Enneking and Weinstein-Boriani-Biagini staging systems. Implants were designed according to the preoperative planning of the resection on CT-scan.

Results: At an average 18 months follow-up (range 1-28), one major mechanical complication occurred requiring the implant removal and one implant was replaced due to recurrence of the disease. Mechanical complication consisted in a massive subsidence of the prosthesis into the adjacent vertebral body and occurred with development of progressive distal junctional kyphosis (Figure 1). Critical analysis of the construct revealed insufficient posterior instrumentation, but custom made implants itself did not show post-operative mechanical complications (breakage or migration of the implant). However, because of the necessity of a surgical revision of the construct, it was considered a major mechanical complication. The removed implant was processed and sectioned for histological analysis that revealed the presence of new bone formation into the implant.

Discussion: Custom made 3D printed titanium implants seems to be a viable option for restoration of the anterior column after en bloc resection for spinal tumor. Longer follow-up will be needed for fusion rates and long-term complication rates.

References: [1]Glennie RA, Rampersaud YR, Boriani S, Reynolds JJ, Williams R, Gokaslan ZL, Schmidt MH, Varga PP, Fisher CG. A Systematic Review With Consensus Expert Opinion of Best Reconstructive Techniques After Osseous En Bloc Spinal Column Tumor Resection. *Spine (Phila Pa 1976)* 2016 Oct 15;41 Suppl 20:S205-S211.

[2] Boriani S, Gasbarrini A, Bandiera S, Ghermandi R, Lador R. En Bloc Resections in the Spine: The Experience of 220 Patients During 25 Years. *World Neurosurg.* 2017 Feb;98:217-229.

[3] Choy WJ, Mobbs RJ, Wilcox B, Phan S, Phan K, Sutterlin CE 3rd. Reconstruction of Thoracic Spine Using a Personalized 3D-Printed Vertebral Body in Adolescent with T9 Primary Bone Tumor. *World Neurosurg.* 2017 Sep;105:1032.e13-1032.e17.

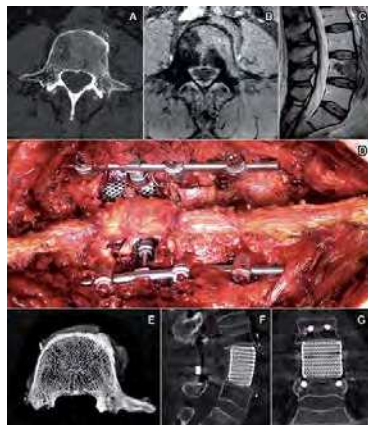


Figure 1: 55-years old non-intact patient affected by L4 solitary metastasis (A-C). Surgery was performed as single-stage double approach procedure (D). Resection was performed at the level of disc spaces L3-L4 and L4-L5 (E). Coronal (F) and sagittal (G) CT scan showing reconstruction of the anterior column using BiomimeticTiC prosthesis.

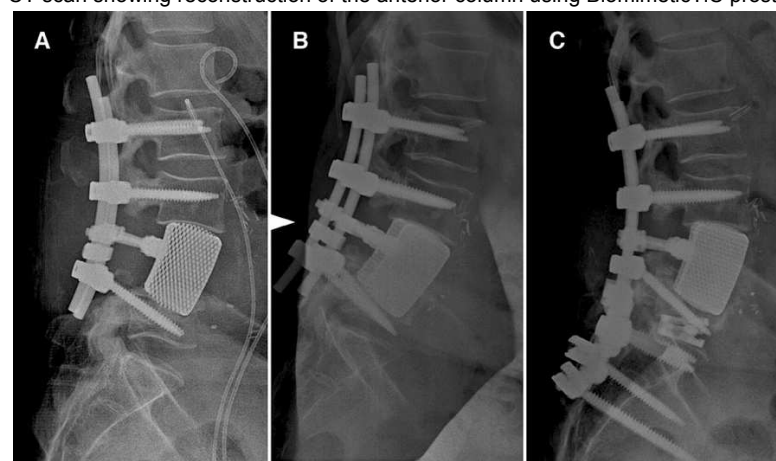


Figure 2: At 3 months follow up subsidence was evident (A), which progressed at 6 months FU with global sagittal imbalance (B). The revision was performed extending instrumentation down to ilium and providing additional support to the anterior column with L5-S1 expandable TLIF (C). No evidence of disease at 14 months FU.

Cortical bone trajectory screws for lumbar interbody fusion: Influence on proximal adjacent segment degeneration.

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Introduction: Lumbar interbody fusion with cortical bone trajectory (CBT) screw constructs provides an alternative method of pedicle screw fixation in minimally invasive spine surgery. Recently, possible risk of superior facet joint violation by the screw during CBT technique has been reported. However, further influence on progression of adjacent segment degeneration is not well understood. In this study, we explored efficacy of the CBT technique and potential risk of adjacent segment degeneration.

Methods: We retrospectively analyzed 60 patients who underwent 1-level lumbar interbody fusion from 2011 to 2015. Patients were divided into 2 groups; 30 patients with traditional pedicle screws (PS group; operated between 2011 and 2012) and 30 patients with CBT screws (CBT group; from 2013 to 2015). Outcomes following the surgery including numeric rating scale (NRS) for back pain, Japanese Orthopaedic Association (JOA) score, and bony fusion rate were evaluated 1 year after the surgery. Superior facet joint violation by the screw was evaluated by postoperative CT scans. Proximal adjacent segment degeneration was evaluated by plane x-ray according to decrease of disc height, and progression of slip and motion angle three years after the surgery.

Results: Postoperative pain was significantly less in CBT group postoperatively. Recovery rate of JOA score was 69.1% in PS group and 72.0% in CBT group 6 months after the surgery, respectively (not significant difference). Bony fusion was obtained in 27 cases in PS (90.0%) and 26 cases in CBT (86.6%) one year after the surgery, with no significant difference between the groups. While screw in contact with inferior articular process of superior vertebral level was observed in 15/60 screws (25.0%) in CBT group, none of the screws directly penetrated the joint space. Facet joint violation was seen in 5/60 screws (8.3%) in PS group. Radiological adjacent segment disease was observed in 2 cases (6.7%) in PS group and 1 case (3.3%) in CBT group. No correlation was seen between violation of facet joint and adjacent segment degeneration. Transient unilateral leg pain due to adjacent level disc herniation was seen in one case in PS group.

Discussion: The incidence of facet joint contact was higher in CBT group, but facet joint violation of the screw did not directly correlate with further induction of adjacent segment degeneration in three years follow-up. Potential limitation of this study is that postoperative follow-up period is short, and patient's population is small. Further long term follow-up is needed to evaluate accurate impact on adjacent segment following CBT screw fixation.

COI: The authors declare no conflicts of interest associated with this paper.

Acute readmission and reoperation after lumbar decompression surgery: an analysis of 81,365 patients

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Introduction: While lumbar spine decompression is a common surgical procedure, acute readmission or reoperation for exacerbation of symptoms after lumbar decompression surgery is a rare occurrence. Previous studies have lacked adequate sample size to measure and analyze predictors of this rare complication. The purpose of this study was to determine pre-operative patient factors and surgical variables associated with readmissions or reoperations for exacerbation of symptoms following lumbar decompression surgery.

Methods: A retrospective review was conducted of a national cohort of patients undergoing lumbar spine decompression surgery between 2013 and 2016. Readmission within 30 days postoperatively due to exacerbation of back pain, leg pain, or neurological deficits was measured. Reoperations within 30 days postoperatively for revision spinal decompression or fusion were also measured. Multivariate logistic regression was used to determine preoperative patient and surgical factors associated with 30-day readmissions or reoperations. As a secondary outcome measure, preoperative predictors of increased operative time were also identified.

Results: A total of 81,365 patients undergoing lumbar decompression surgery between 2013 and 2016 were identified in a national cohort. Of those patients, 40% of patient underwent a laminectomy or bilateral decompression and 62% underwent a foraminotomy or unilateral decompression. A total of 3,188 patients (3.9%) were readmitted within 30-days postoperatively due to exacerbation of back pain, leg pain, or neurological deficits. A total of 1,967 patients (2.4%) underwent reoperation for revision spinal decompression or fusion were also measured within 30-days postoperatively. Revision decompression (OR: 2.0, P < 0.01), additional levels of foraminotomy/unilateral decompression levels (OR: 1.3, 1.5, and 2.5 for 1, 2, and 3+ levels, P < 0.05), microscopic laminectomy (OR: 1.5, P = 0.04), and female sex (Odds ratios [OR]: 1.2, P < 0.01) were associated with increased readmissions. Revision decompression surgery (OR: 2.0) and additional foraminotomy/unilateral decompression levels (OR: 1.9, 1.8, and 2.3 for 1, 2, and 3+ levels, P < 0.05) were associated with increased reoperations.

Discussion: While acute readmission or reoperation for symptom exacerbation after lumbar decompression is a rare occurrence, incidence of exacerbation increases with revision decompression surgery and multilevel foraminotomies/unilateral decompression. As these acute readmissions and reoperations result in high costs to patients and the healthcare system, alternative treatment options, open bilateral decompression or spinal fusion surgery, should also be presented to patients when considering these procedures.

Table 1: Multivariate analysis of risk factors associated for readmission due to exacerbation of back pain, leg pain, or neurological symptoms

	(Overall: 3.9%)	Multivariate Odds Ratio (95% C.I.)	P-value
Age (years)			
18-29	2.50%	Reference	
30-39	2.8%	1.27 (0.83 - 1.94)	0.270
40-49	3.3%	1.16 (0.76 - 1.76)	0.492
50-59	3.5%	1.30 (0.86 - 1.95)	0.210
60-69	3.7%	1.27 (0.84 - 1.91)	0.257
70 +	5.8%	1.59 (1.06 - 2.39)	0.025
Sex			
Female	4.3%	1.24 (1.06 - 1.45)	0.006 *
Male	3.6%	Reference	
Obesity			
Not Obese	3.7%	Reference	
Obesity Class I	3.9%	1.04 (0.86 - 1.25)	0.688
Obesity Class II or III	4.6%	1.11 (0.91 - 1.36)	0.300
Levels of Decompression			
1	3.4%	Reference	
2	4.8%	0.84 (0.66 - 1.07)	0.164
3	5.9%	1.11 (0.78 - 1.58)	0.559
4	5.0%	0.73 (0.34 - 1.57)	0.421
5+	5.2%	1.48 (0.64 - 3.46)	0.362
Levels of Foraminotomy/Laminotomy			
0	4.7%	Reference	
1	3.1%	1.33 (1.08 - 1.64)	0.007 *
2	4.4%	1.51 (1.02 - 2.23)	0.037 *
3+	6.4%	2.48 (1.32 - 4.66)	0.005 *
Far Lateral Decompression/Disectomy	3.3%	1.04 (0.63 - 1.73)	0.879
Revision Decompression	4.0%	2.05 (1.53 - 2.76)	< 0.001 *
Microscopic Laminectomy	4.8%	1.51 (1.01 - 2.24)	0.043 *
Microscopic Foraminotomy/Laminotomy	3.2%	1.09 (0.81 - 1.47)	0.563

*Indicates statistically significant result (α < 0.05)

Table 2: Multivariate analysis of risk factors associated for reoperation due to exacerbation of back pain, leg pain, or neurological symptoms

	(Overall: 2.4%)	Odds Ratio (95% C.I.)	P-value
Age (years)			
18-29	2.5%	Reference	
30-39	2.0%	0.82 (0.57 - 1.16)	0.255
40-49	2.4%	0.91 (0.65 - 1.27)	0.584
50-59	2.4%	0.75 (0.54 - 1.06)	0.104
60-69	2.3%	0.73 (0.52 - 1.03)	0.070
70 +	2.7%	0.72 (0.51 - 1.03)	0.072
Sex			
Female	2.8%	1.27 (1.08 - 1.49)	0.003 *
Male	2.2%	Reference	
Obesity			
Not Obese	2.3%	Reference	
Obesity Class I	2.4%	1.09 (0.90 - 1.31)	0.375
Obesity Class II or III	2.7%	0.71 (0.56 - 0.89)	0.003 *
Levels of Decompression			
1	2.2%	Reference	
2	2.8%	1.04 (0.80 - 1.35)	0.784
3	3.4%	0.89 (0.57 - 1.40)	0.610
4	2.2%	0.46 (0.14 - 1.46)	0.186
5+	3.2%	2.26 (0.96 - 5.35)	0.063
Levels of Foraminotomy/Laminotomy			
0	2.7%	Reference	
1	2.2%	1.93 (1.54 - 2.41)	< 0.001 *
2	2.7%	1.78 (1.19 - 2.65)	0.005 *
3+	3.0%	2.34 (1.00 - 5.47)	0.049 *
Far Lateral Decompression/Disectomy	1.5%	0.91 (0.49 - 1.67)	0.754
Revision Decompression	3.0%	1.96 (1.40 - 2.74)	< 0.001 *
Microscopic Laminectomy	2.2%	1.54 (0.98 - 2.41)	0.059
Microscopic Foraminotomy/Laminotomy	2.3%	1.03 (0.77 - 1.38)	0.835

*Indicates statistically significant result (α < 0.05)

Benefits of medical optimization before thoracolumbar three-column osteotomies: an analysis of 618 patients

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Introduction: Thoracolumbar three-column osteotomies are associated with high postoperative morbidity. However, modifiable risk factors for postoperative complications have not previously been identified due to previously limited cohort sizes. The purpose of this study is to identify modifiable risk factors for postoperative complications following Thoracolumbar Three-Column Osteotomy, and thus determine the benefits of pre-operative medical optimization in these patients

Methods: A retrospective review was conducted of a national cohort of patients undergoing thoracolumbar three-column osteotomy between 2013 and 2016. Post-operative complications, readmissions, and reoperations were observed for 30 days postoperatively. Preoperative risk factors including preoperative laboratory values were assessed and correlated with postoperative outcomes. This includes serum sodium < 135 mEq/L, hematocrit < 30%, creatinine ≥ 1.2 mg/dL, INR ≥ 1.2, or albumin < 3.5 g/dL.

Results: A total of 618 patients undergoing thoracolumbar three-column osteotomies between 2013 and 2016 were identified in a national cohort. Of these 27.3% of patients did not have adequate medical "optimization", with normal preoperative levels of serum sodium, creatinine, hematocrit, international normalized ratio (INR), and albumin (Table 3). The overall rate of serious medical complications over 30-days postoperatively was 8.4% (Table 4). Minor complications occurred in 19.4% of patients. Fifty-five (8.9%) patients had an unplanned reoperation or readmission due to surgical complications. Among patient with adequate preoperative optimization, 6.2% had serious medical complications (P < 0.01), 16.3% had minor complications (P < 0.01), and 8.6% had reoperation or readmission related to surgical complication (P = 0.67). Preoperative renal insufficiency (odds ratio[OR]: 32.6, P = 0.003), preoperative anemia (OR: 249.9, P = 0.02 [Hct < 25]; OR: 38.3, P < 0.01 [Hct 25-30]), and chronic obstructive pulmonary disorder (COPD; OR: 5.7, P = 0.01) were associated with serious medical complications. Extended operative time over 8 hours (OR: 4.1, P = 0.05), diabetes mellitus (OR: 3.3, P = 0.02), COPD (OR: 5.7, P = 0.01), and preoperative hypoalbuminemia < 3.5 (OR: 4.1, P = 0.01) were associated with minor complications. Preoperative anemia (Hct < 25, OR: 40.8, P = 0.03) was associated with surgical complications resulting in readmission or reoperation.

Discussion: Over 25% of patient's undergoing thoracolumbar three-column osteotomies lacked preoperative optimization of correctible medical laboratory values. This includes serum sodium < 135 mEq/L, hematocrit < 30%, creatinine ≥ 1.2 mg/dL, INR ≥ 1.2, or albumin < 3.5 g/dL. Patients with optimized preoperative medical factors have significantly lower rates of serious medical complications.

Table 1: Effect of medical preoptimization on postoperative complications

	Frequency	%	Serious Medical Complications			Minor Complications			Readmission or Reoperation due to Surgical Complications		
			Rate	Rate for rest of cohort	P-value	Rate	Rate for rest of cohort	P-value	Rate	Rate for rest of cohort	P-value
Medical optimization of preoperative laboratory values: (Na ≥ 135, Hct ≥ 30, Cr < 1.2, INR < 1.2, Albumin ≥ 3.5)	453	73.3%	6.2%	14.6%	P<0.01	16.3%	27.9%	P<0.01	8.6%	9.7%	P = 0.67
Medical optimization of preoperative laboratory values AND absence of chronic obesity, diabetes mellitus, or chronic obstructive pulmonary disease:	219	36.7%	3.0%	11.7%	P<0.01	11.6%	24.2%	P<0.01	6.0%	10.6%	P = 0.05

Table 2: Multivariate analysis of risk factors for serious medical complications

Risk Factor	(Overall: 8.4%)	Odds Ratio (95% C.I.)	P-value
Age (years)			
18-49	3.7%	Reference	-
50-59	9.7%	2.03 (0.06 - 70.40)	0.696
60-69	8.0%	1.48 (0.07 - 32.29)	0.802
70+	10.9%	5.72 (0.12 - 271.38)	0.376
Body mass index			
0 - 29	6.6%	Reference	-
30 - 39	11.7%	1.22 (0.05 - 26.92)	0.902
40 +	3.3%	27.99 (0.70 - 1119.01)	0.077
Diabetes mellitus	12.4%	3.73 (0.24 - 58.63)	0.348
Chronic obstructive pulmonary disorder	16.7%	24.13 (1.99 - 293.08)	0.012 *
Operative time (hours)			
0:00 - 3:59	4.3%	Reference	-
4:00 - 5:59	5.3%	0.02 (0.00 - 5.01)	0.158
6:00 - 7:59	9.1%	1.85 (0.15 - 23.00)	0.632
8:00 +	12.8%	5.62 (0.27 - 117.24)	0.265
Preoperative Hematocrit			
< 25	28.6%	249.88 (2.53 - 24726.51)	0.019 *
25-29	24.0%	38.31 (3.04 - 483.17)	0.005 *
30 +	7.8%	Reference	-
Preoperative Hyponatremia (<135)	18.2%	5.37 (0.27 - 106.85)	0.271
Preoperative Renal Insufficiency (Cr ≥ 1.2)	18.6%	32.65 (3.39 - 314.08)	0.003 *
Preoperative INR 1.2 +	17.9%	1.54 (0.11 - 21.44)	0.750
Preop Albumin < 3.5	17.5%	7.49 (0.87 - 64.32)	0.067

Correlation between ODI and PROMIS in minimally invasive lumbar microdiscectomy

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Introduction: As the focus in spine surgery shifts from radiographic to patient-centric outcomes, patient-reported outcomes measures (PROMs) are becoming increasingly important. They are linked to patient satisfaction, and are thus being used to assess healthcare expenditure, determine compensation and evaluate cost-effectiveness. It is evident that PROMs are important to various stakeholders, including patients, physicians, payers and healthcare institutions. Thus, it is vital to establish methods to interpret and evaluate these outcomes. The purpose of this study is to evaluate the correlation between ODI and PROMIS Physical Function (PROMIS-PF) in patients undergoing minimally invasive lumbar microdiscectomy.

Methods: PROMs collected pre-operatively and 6 weeks, 3 months, 6 months and 1 year post-operatively were analyzed using Pearson product-moment correlation. Paired samples t-test was used to assess change in PROMs and an MCID threshold of >12.8 on the ODI was used to evaluate clinically significant improvement.

Results: A total of 182 patients, with 171 one-level and 11 two-level procedures were included. The most common operative levels were L4-L5 or L5-S1, with about 90% of discectomies being performed at these levels, with an equal number at L4-L5 and L5-S1. The mean change in ODI and PROMIS from the pre-operative visit to each follow-up was statistically significant. In addition, 62.7% of patients had an improvement greater than or equal to the MCID on the ODI by 6 weeks, 67% by 12 weeks, 67.2% by 6 months and 69.6% by 1 year. The results of the correlation showed a statistically significant negative correlation at all time-points, which was moderate preoperatively ($r=-0.58, n=182, p<0.0001$), strong at 6-weeks ($r=-0.72, n=111, p<0.0001$), and very strong at 3-months ($r=-0.82, n=69, p<0.0001$), 6-months ($r=-0.80, n=54, p<0.0001$), and 1-year ($r=-0.85, n=41, p<0.0001$).

Discussion: While ODI has been used to evaluate outcomes in lumbar spine patients for several years, PROMIS is a relatively new outcome measure that is increasingly being implemented. PROMIS-PF has been shown to decrease patient burden and be more efficient, flexible and precise than other PROMs. The results of our study show a very strong negative correlation between ODI and PROMIS in the post-operative period, especially at 3 months or greater follow-up. Thus, PROMIS-PF is a good surrogate for ODI in assessing post-operative outcomes. Larger studies are warranted to evaluate the true utility and value of this outcome measure, and methods to interpret its clinical significance need to be established. Further research on the use of PROMIS to track outcomes will contribute to guiding patient-centered care and thus enhance the value of spine care.

Table 1: Mean ODI and PROMIS

	ODI	PROMIS
Pre-operatively	45.03 ± 17.16	35.58 ± 6.40
6 weeks	25.26 ± 17.71	42.07 ± 7.83
3 months	22.34 ± 20.07	44.94 ± 10.17
6 months	23.99 ± 21.60	44.49 ± 10.12
1 year	20.87 ± 21.50	47.23 ± 10.43

Table 2: Correlation between ODI and PROMIS

	Number of observations (n)	Pearson Correlation Co-efficient (r)	Strength of Correlation	p - value
Pre-operatively	182	-0.58	Moderate	<0.0001
6 weeks	111	-0.72	Strong	<0.0001
3 months	69	-0.82	Very Strong	<0.0001
6 months	54	-0.80	Very Strong	<0.0001
1 year	41	-0.85	Very Strong	<0.0001

Neurological recovery in surgically treated traumatic conus medullaris syndrome combined with thoracolumbar fracture

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Introduction: The thoracolumbar junction is the most frequently injured region of the spine. Conus medullaris is placed at the region of thoracolumbar junction and can be combined with thoracolumbar fractures. However, there is a still debate regarding the clear definition of traumatic conus medullaris syndrome and there has been a few literatures regarding the prognosis of traumatic conus medullaris syndrome. We analyzed clinical features and prognosis of traumatic conus medullaris syndrome combined with acute traumatic thoracolumbar fracture.

Methods: Between 2011 and 2018, we retrospectively reviewed 32 consecutive patients who diagnosed with traumatic conus medullaris syndrome combined with acute thoracolumbar fracture. Traumatic conus medullaris syndrome was defined with both clinical (lower leg weakness or bowel urinary dysfunction) and radiological features (compression on conus medullaris with or without the signal change on T2-weight magnetic resonance image). All patients underwent decompression and fusion surgery in less than 72 hours after injury (except 3 patients). Baseline ASIA grade and bowel and urinary dysfunction were evaluated at the time of injury. At final follow-up, ASIA grade, ambulatory capacity and bowel and urinary function were evaluated.

Results: Mean age was 47.0 ± 13.5 years and male was dominant ($n=23$). Most common cause of injury was fall-down ($n=20$). Twenty-five cases were burst fracture, 1 case was flexion distraction injury, and 6 cases were fracture-dislocation. The levels of conus medullaris injury were T12 in 7 patients, L1 in 18 patients and L2 in 7 patients. ASIA grades at baseline were A in 7 patients (21.9%), B in one patient (3.1%), C in 13 patients (40.6%), D in 6 patients (18.8%), and E in 5 patients (15.6%), respectively. Bowel or urinary dysfunction at baseline were found in 26 patients (81.3%).

At final follow-up (mean 40.0 ± 28.7 months), ASIA grades were A in 6 patients (18.75%), C in 4 patients (12.5%), D in 17 patients (53.1%), and E in 5 patients (15.6%). 14 patients (43.8%) could walk independently and 11 patients (34.4%) with walker or cane. Among patients with bowel and urinary dysfunction, 13 patients (40.6%) recovered completely and 8 patients (30.8%) incompletely.

Discussion: In traumatic conus medullaris syndrome with thoracolumbar fracture, complete paralysis (21.8%) was relatively low incidence at the time of injury. With the immediate decompression and fusion surgery after injury, most patient can eventually walk independently (43.8%) and with walker-aid (34.4%). Bowel and urinary function were common after injury (81.3%) and the rate of complete recovery is relatively low (40.6%). The immediate surgery can improve function of patients with traumatic conus medullaris syndrome with thoracolumbar fracture.

Correlation between ODI and PROMIS in minimally invasive lumbar decompression surgery

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Introduction: As the focus in spine surgery shifts from radiographic to patient-centric outcomes, patient-reported outcomes measures (PROMs) are becoming increasingly important. They are linked to patient satisfaction, and are thus being used to assess healthcare expenditure, determine compensation and evaluate cost-effectiveness. It is evident that PROMs are important to various stakeholders, including patients, physicians, payers and healthcare institutions. Therefore, it is vital to evaluate these outcomes. The purpose of this study is to assess the correlation between Oswestry Disability Index (ODI) and Patient-Reported Outcome Measurement Information System Physical Function (PROMIS-PF) in patients undergoing minimally invasive lumbar decompression.

Methods: A retrospective review of prospectively collected data on 243 patients who underwent minimally invasive lumbar decompression surgery was performed. PROMs collected pre-operatively and 6 weeks, 3 months, 6 months and 1 year post-operatively were analyzed; a sub-group analysis by number of levels was performed. Paired Samples t-test was used to analyze the change in ODI and PROMIS. Minimal Clinically Important Difference (MCID) of 12.8 for ODI, as determined by Copay et al was used to assess the number of patients experiencing a clinically significant improvement. Pearson product-moment correlation was used to determine the correlation between ODI and PROMIS-PF.

Results: The improvement in ODI and PROMIS-PF from pre-operatively to each follow-up was statistically significant in 1 and 2-level cases, but not in 3-level cases. 59.1% of patients had an improvement >MCID for ODI by 6 weeks, 62% by 3 months, 58.3% by 6 months and 64.9% by 1 year. Overall, there was a statistically significant negative correlation at all time-points, which was moderate preoperatively ($r=-0.59, n=243, p<0.0001$), strong at 6-weeks ($r=-0.70, n=150, p<0.0001$), very strong at 3-months ($r=-0.80, n=95, p<0.0001$), strong at 6-months ($r=-0.75, n=78, p<0.0001$), and very strong 1-year ($r=-0.83, n=50, p<0.0001$). Similarly, in 1- and 2-level surgery, there was a statistically significant negative correlation at all time-points, which was moderate preoperatively and ranged from strong to very strong the post-operatively. In contrast, in 3-level surgery the correlation was not statistically significant at any time-point.

Discussion: The results of our study show a statistically significant moderate to very strong, negative correlation between ODI and PROMIS-PF, except in 3-level lumbar decompression. Thus, PROMIS-PF is a good surrogate for ODI. Larger studies are warranted to evaluate the utility and value of this outcome measure, and methods to interpret its clinical significance need to be established.

Table 1: Mean ODI and PROMIS Scores

	ODI	PROMIS
All Decompressions		
Pre-operatively	44.02 ± 17.71	35.41 ± 6.18
6 weeks	26.20 ± 18.12	41.45 ± 7.45
3 months	23.81 ± 19.63	43.63 ± 9.58
6 months	26.32 ± 20.11	42.92 ± 9.49
1 year	21.88 ± 20.80	46.05 ± 10.07
1-level Procedures		
Pre-operatively	45.17 ± 17.58	35.62 ± 6.12
6 weeks	26.01 ± 18.42	41.93 ± 7.61
3 months	23.43 ± 20.23	44.14 ± 9.96
6 months	24.32 ± 19.96	44.38 ± 9.37
1 year	21.35 ± 21.92	46.89 ± 10.04
2-level Procedures		
Pre-operatively	42.94 ± 17.88	34.77 ± 6.50
6 weeks	27.18 ± 18.27	40.87 ± 7.11
3 months	24.59 ± 20.32	43.14 ± 8.89
6 months	30.65 ± 21.04	39.16 ± 9.16
1 year	24.18 ± 19.11	45.32 ± 10.13
3-level Procedures		
Pre-operatively	29.02 ± 14.11	35.40 ± 6.19
6 weeks	24.58 ± 13.73	36.41 ± 4.46
3 months	21.27 ± 10.16	39.35 ± 7.05
6 months	28.93 ± 17.16	42.95 ± 9.68
1 year	21.11 ± 12.69	34.77 ± 4.72

Table 2: Correlation between ODI and PROMIS

	Number of observations (n)	Pearson Correlation Co-efficient (r)	Strength of Correlation	p - value
All Lumbar Decompressions				
Pre-operatively	243	-0.59	Moderate	<0.0001
6 weeks	150	-0.70	Strong	<0.0001
3 months	95	-0.80	Very Strong	<0.0001
6 months	78	-0.75	Strong	<0.0001
1 year	50	-0.83	Very Strong	<0.0001
1 Level Lumbar Decompression				
Pre-operatively	180	-0.59	Moderate	<0.0001
6 weeks	108	-0.68	Strong	<0.0001
3 months	69	-0.81	Very Strong	<0.0001
6 months	53	-0.74	Strong	<0.0001
1 year	38	-0.87	Very Strong	<0.0001
2 Level Lumbar Decompression				
Pre-operatively	52	-0.63	Strong	<0.0001
6 weeks	35	-0.80	Very Strong	<0.0001
3 months	20	-0.90	Very Strong	<0.0001
6 months	20	-0.81	Very Strong	<0.0001
1 year	10	-0.69	Strong	0.028
3 Level Lumbar Decompression				
Pre-operatively	10	-0.62	Strong	0.059
6 weeks	7	-0.15	Very Weak	0.744
3 months	6	-0.38	Weak	0.454
6 months	5	-0.48	Moderate	0.411
1 year	2	-1.00	Very Strong	

Reinfarction rates in patients undergoing lumbar spine procedures

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Introduction: Myocardial reinfarction is a serious complication for patients with a history of MI undergoing non-cardiac surgeries. With cardiac function directly related to the amount of infarcted myocardial tissue, it logically follows that patients experiencing a myocardial reinfarction are associated with a higher overall mortality and morbidity than patients experiencing their first myocardial infarction. Patients with no history of previous myocardial infarction have documented perioperative myocardial infarction rates of 0.1%-0.7%, while patients with a history of myocardial infarction have postoperative reinfarction rates of around 7%. The aim of this study was to analyze the overall 30-day postoperative reinfarction rate in patients undergoing lumbar spinal surgeries. An emphasis was placed on initial-MI-to-surgery time interval, corresponding reinfarction rates, and associated costs.

Methods: Within the PearlDiver database, both the Medicare database and the Humana database were analyzed from 2005 - 2017. Patients with a history of myocardial infarction who underwent subsequent lumbar spine surgery were identified and stratified based on the time interval between their initial MI and the date of their lumbar surgery. Based on this time interval, patients were placed into one of five different groups: 0-3 month, 4-6 month, 7-12 month, 13-24 month, and 25+ month. Each chronological group was analyzed to determine incidence of reinfarction and the associated risk ratio. Chi Square analysis was used to determine significance. Postoperative costs associated with each patient (60 day follow-up) were obtained from the Medicare database and analyzed using ANOVA statistical analysis. Patient gender, age and type of procedure were independently analyzed.

Results: A total of 7,246 patients in the Medicare database experienced a myocardial infarction and underwent subsequent lumbar surgery, while 2,457 patients met these inclusion criteria in the Humana database. In the Medicare database, a total of 444 patients (6.12%) experienced a reinfarction within 30 days of surgery. In the Humana database, a total of 132 patients (5.37%) experienced a reinfarction within 30 days of surgery. However, these incidences of reinfarction were unequally distributed among the five temporal groups (initial-MI-to-surgery time). Patients in the 0-3 month group exhibited reinfarction incidences of 53.44% and 20.17% in the Medicare and Humana databases, respectively. All other groups yielded incidences in the range 1.8%-4.3%. Cost analysis reflected this higher incidence as it revealed increased costs associated with the 0-3 month group. Fusion procedures corresponded to higher rates of postoperative reinfarction than non-fusion procedures.

Discussion: The time interval between a patient's initial MI and lumbar surgery has a significant effect on the incidence of postoperative myocardial reinfarction. The 0-3 month group demonstrated a noteworthy increase in risk of reinfarction while all other groups exhibited comparably low reinfarction rates. With procedural and initial-MI-to-surgery time interval stratification, this study may serve as a template for physicians to use in their consideration of surgical timing and technique in conjunction with patient demographics.

Hidden blood loss in extreme lateral interbody fusion for adult spinal deformity

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Study Design: A single-center retrospective case series.

Objective: To determine the total perioperative blood loss in extreme lateral interbody fusion (XLIF) for adult spinal deformity (ASD).

Summary of Background Data: XLIF, a minimally invasive method using an intervertebral cage that enhances bone fusion and corrects rigid spinal deformity, is often used with posterior spinal fixation (PSF) to treat ASD. However, the amount of intraoperative blood loss (IBL) reported for XLIF may underestimate the actual perioperative blood loss.

Methods: We assessed 32 consecutive ASD patients with Schwab-SRS type L (mean age: 68.7±8.2 years; mean follow-up 2.0±1.3 years) who were treated by multilevel XLIF (mean, 2.5±0.6 levels) followed by PSF after 3–5 days. We didn't leave a drainage tube after XLIF. We calculated the actual blood loss (ABL) after XLIF by the Gross equation, by hemoglobin (Hb) balance, and by the Orthopedic Surgery Transfusion Hemoglobin European Overview (OSTHEO) formula, and compared the results of the three methods. We defined hidden blood loss (HBL) as the difference between the ABL and IBL.

Results: Post-XLIF tests showed a significant decrease in the Hb (from 11.8±1.1 mg/dl to 10.6±1.1 mg/dl) and hematocrit (from 36.0±3.2% to 32.5±3.2%) compared to preoperative values. Although the mean IBL was relatively small (33±52 mL; mean per level 14±24 mL), we calculated the mean ABL as 291±171 mL (Gross equation), 304±144 mL (Hb balance), and 332±196 mL (OSTHEO). The mean HBL (Gross equation) was 258±168 mL, which was 8 times greater than the IBL on average. There was no difference in the results obtained using the three methods.

Discussion: The HBL in XLIF was 8 times greater than the IBL, which is much higher than those reported for other spinal surgery procedures. XLIF uses a smaller skin incision, which makes it difficult to confirm bleed sites and the amount of blood collected inside the retroperitoneal space. During surgery, the large dead space of the retroperitoneum can disturb suctioning, decreasing the amount of blood that is included in the IBL. When planning correction and fusion surgery for ASD, surgeons should not underestimate the ABL during XLIF.

The titanium coated PEEK cage maintains better graft bone contact with the endplate than PEEK cage at six months after PLIF surgery: a multicenter, prospective, randomized study

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Introduction: Posterior lumbar interbody fusion (PLIF) is widely used as safe and effective surgical procedure for the treatment of lumbar canal stenosis due to degenerative unstable lumbar spine. Many surgeons use the PEEK (polyetheretherketone) interbody cage to avoid a cage subsidence because of similar elasticity to the cortical bone. On the other hand, several basic researches reported that titanium also had good bone affinity. Therefore, titanium coated PEEK (Ti/PEEK) cage expected to have both characters has been frequently used in recent years. However, previous reports did not reveal the significant difference of interbody fusion rate when either PEEK or Ti/PEEK cage was used. This study aimed to investigate the interbody fusion rate of PLIF in two groups (PEEK vs. Ti/PEEK) evaluated by CT.

Methods: This study was conducted in multicenter, prospective, randomized fashion at 11 institutions. Patients who underwent one level PLIF for degenerative lumbar disease were enrolled. Patients were randomly allocated for either PEEK or Ti/PEEK group before the surgery. From March 2016 to August 2017, 128 patients were enrolled and randomized into two groups, of whom 112 patients (88%) were completed the treatment and evaluation. Postoperative lumbar computed tomography (CT) were taken within a month, two, four, six and 12 months postoperatively. Interbody fusion was assessed by 4 independent, blinded certified physicians by using CT images. Interbody fusion was defined when upper and lower endplate bony contact (more than 50% of grafted bone) was observed in both the sagittal and coronal center plane of the cage in CT. In early period bony contact dose not mean true bony fusion. We could not discriminate bone contact or true bony fusion. The rates of bony contact were compared between PEEK and Ti/PEEK groups. Statistical analysis was performed by chi-square test.

Results: In 112 patients, mean age was 68. Fifty-four patients underwent PLIF with Ti/PEEK (TP) cage, and 58 patients with PEEK (P). The rates of interbody fusion were as follows; 62% in Group TP and 50% in Group P ($p=0.194$) within a month, 36% in Group TP and 26% in Group P ($p=0.254$) at second months, 36% in Group TP and 35% in Group P ($p=0.218$) at fourth months, 39% in Group TP and 19% in Group P ($p=0.023$) at sixth months, and 41% in Group TP and 36% in Group P ($p=0.562$) at 12 months after the surgery.

Discussion: Previous studies have reported high bony fusion rate over 90% short term after PLIF with PEEK cage, and similar fusion rates were also reported even using Ti/PEEK cage. However, our study using more strict evaluation system in thin slice CT images showed the lower rate of bony contact rate between endplate and graft bone. Our findings also showed graft bone was temporarily absorbed from second months in both groups and further absorbed to sixth month in the PEEK group. On the other hand, in the Ti/PEEK group, graft bone was absorbed in the same manner, but relatively maintain bone graft contact even at sixth month after the surgery.

A person-centered prehabilitation program based on cognitive-behavioral physical therapy for patients scheduled for lumbar fusion surgery – a one year follow-up of a randomized controlled trial

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Introduction: Prehabilitation programs have led to improved postoperative outcomes in several surgical contexts, but there are presently no guidelines for the prehabilitation phase before lumbar fusion surgery. This study investigated whether a person-centered physiotherapeutic prehabilitation program based on a cognitive-behavioral approach reduces disability and improves functioning after lumbar fusion surgery more than does conventional care in a sub-group of patients with chronic low back pain.

Methods: Patients scheduled for lumbar fusion surgery were recruited from two private spine clinics and one university hospital in Gothenburg, Sweden. The patients were a subgroup of individuals with CLBP, characterized by the combination of motion elicited (often called mechanical), localized, clinically provokable pain, with corresponding (i.e. the same region) radiologically demonstrated degenerative changes (i.e. disc height reduction and facet arthrosis in varying combination) in one or a few of the lumbar intervertebral segments. The patients were randomized into either an active intervention group or to a control group. The active intervention utilized a person-centered approach over 5 sessions (4.5 hours in total) and focused on promoting physical activity and targeting pain-related fear factors before surgery. The control group received conventional preoperative care.

The primary outcome was the Oswestry Disability Index score. Secondary outcomes were back and leg pain intensity, catastrophizing, kinesiophobia, self-efficacy, anxiety, depression, health-related quality of life, and patient-specific functioning, physical activity, and physical capacity. Data were collected on seven occasions up to 1 year postoperatively. A linear mixed model was used to analyze the change scores of each outcome.

Results: No statistically significant difference between groups was found on the primary outcome (disability) over time (baseline to 1 year). Among secondary outcome measures, a statistically-significant interaction effect ("Group x Time") was seen for EQ-5D. Minimally important changes over time were found in almost all outcomes in each group separately. Both groups reached a stable plateau of change in primary and secondary outcomes by 8 weeks post-operatively. The ODI change from baseline to 6 months was statistically significant in each group separately. Moreover, at 8 weeks post-operatively, ODI had already decreased ≥ 8 (= MIC value for ODI), in both groups. In the patient specific functioning scale (PSFS) the improvement continued to 1 year. The intervention group reached the MIC value for PSFS (decrease of 2 points) at three months; the conventional care group at six months.

Discussion: A prehabilitation program leads to clinically important changes, and does not lead to any negative side effects. It is not clear what kind of prehabilitation program is the most effective.

The active intervention could show that the patients improved sooner in their own selected functioning goals as opposed the control. The patient specific outcomes seem to better reflect the change over time, than does other PROMs. Future studies should further look into how to best prepare patients for a successful outcome of surgery.

Trial registration: Current Controlled Trials ISRCTN17115599.

Immediate restoration of lordosis in single-level Minimally Invasive Transforaminal Lumbar Interbody Fusion (MI-TLIF): a comparison of expandable and static interbody cages

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Introduction: Sagittal alignment is becoming an increasingly important consideration in spine surgery. The current literature is conflicted regarding the effect of Minimally Invasive Transforaminal Lumbar Interbody Fusion (MI-TLIF) on sagittal parameters and the role of expandable cage technology. The purpose of this study is to compare the lordosis generated by static and expandable cages in order to determine if there is a benefit of expandable cages MI-TLIF; and determine what factors affect segmental lordosis and foraminal decompression.

Methods: Upright lateral radiographs of patients undergoing single-level MIS-TLIF with non-articulating expandable or static interbody cages were reviewed. Segmental lordosis(SL), regional lordosis(RL) and Posterior Disc Height(PDH) were measured pre- and post-operatively. Distance from anterior edge of vertebral body to the front of the cage was measured. Based on pre-operative SL, patients were stratified into: low-lordosis(<15o), moderate-lordosis(15-25o) and high-lordosis(>25o).

Mann Whitney u-test and Mixed ANOVA were used to compare radiographic parameters between static and expandable cages. Wilcoxon Sign-Ranked Test was used to compare the change in radiographic parameters from pre-operatively to post-operatively. Linear regressions were conducted to assess the effect of pre-operative radiographic parameters, cage-type and cage-position on post-operative SL and PDH.

Results: Of the 171 patients included; 111 were in the static and 60 in the expandable cohort. Patients with low pre-operative lordosis experienced an increase in SL and maintained RL regardless of cage-type. Those with moderate to high pre-operative lordosis experienced a decrease in SL and RL with the static cage but maintained SL and RL with the expandable cage. Although both cohorts showed an increase in PDH, the increase in the expandable cohort was significantly greater. Pre-operative SL was predictive of post-operative SL; and pre-operative SL, pre-operative PDH and cage-type were predictive of post-operative PDH. Cage position was not related to post-operative SL or PDH.

Discussion: Expandable cages showed favorable results in restoring posterior disc height and maintaining lordosis in the immediate post-operative period. Cage position did not impact the restoration of lordosis or posterior disc height. Pre-operative segmental lordosis was the most significant predictor of post-operative segmental lordosis. Thus, pre-operative radiographic parameters and goals of the surgery should be important considerations in surgical planning.

Table 1: Segmental Lordosis

	Static	Expandable	P-value [#]
Low Lordosis	n = 27	n = 21	
• Pre-Operative	10.35 ± 3.33	9.39 ± 3.55	0.350
• Post-Operative	13.76 ± 6.16	14.91 ± 6.65	0.406
• p-value*	p = 0.001	p = 0.001	
Moderate Lordosis	n = 48	n = 24	
• Pre-Operative	19.05 ± 2.68	18.59 ± 2.54	0.444
• Post-Operative	17.33 ± 5.40	20.36 ± 5.50	0.036
• p-value*	p = 0.026	p = 0.247	
High Lordosis	n = 36	n = 15	
• Pre-Operative	29.44 ± 3.07	28.62 ± 2.79	0.457
• Post-Operative	25.32 ± 6.98	25.91 ± 5.87	0.901
• p-value*	p = 0.001	p = 0.078	

Results are reported as Mean ± SD

p-value for difference between static and expandable cages

* p-value for change from pre-operatively to post-operatively

Table 2: Lumbar Lordosis

	Static	Expandable	P-value
Low Lordosis	n = 27	n = 21	
• Pre-Operative	46.86 ± 12.64	49.27 ± 13.27	0.442
• Post-Operative	48.25 ± 11.50	48.20 ± 12.02	0.876
• p-value*	p = 0.773	p = 0.543	
Moderate Lordosis	n = 48	n = 24	
• Pre-Operative	56.69 ± 9.85	56.63 ± 10.02	0.783
• Post-Operative	54.70 ± 10.74	52.33 ± 9.48	0.239
• p-value*	p = 0.037	p = 0.004	
High Lordosis	n = 36	n = 15	
• Pre-Operative	62.11 ± 12.82	59.20 ± 10.25	0.450
• Post-Operative	57.94 ± 13.68	56.86 ± 10.28	0.634
• p-value*	p = 0.003	p = 0.334	

Results are reported as Mean ± SD

p-value for difference between static and expandable cages

* p-value for change from pre-operatively to post-operatively

Table 3: Posterior Disc Height

	Static	Expandable	P-value
Low Lordosis	n = 27	n = 21	
• Pre-Operative	6.66 ± 1.48	3.69 ± 1.89	<0.0001
• Post-Operative	8.36 ± 1.91	6.78 ± 2.35	0.022
• p-value*	p = 0.001	p < 0.0001	
Moderate Lordosis	n = 48	n = 24	
• Pre-Operative	5.62 ± 2.07	3.42 ± 1.82	<0.0001
• Post-Operative	8.07 ± 2.26	7.73 ± 2.02	0.671
• p-value*	p < 0.0001	p < 0.0001	
High Lordosis	n = 36	n = 15	
• Pre-Operative	5.76 ± 1.80	3.77 ± 1.68	0.001
• Post-Operative	8.52 ± 2.47	7.95 ± 2.09	0.463
• p-value*	p < 0.0001	p = 0.001	

Results are reported as Mean ± SD

p-value for difference between static and expandable cages

* p-value for change from pre-operatively to post-operatively

Is the surgical invasiveness index valid in minimally invasive spine surgery

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Introduction: The Surgical Invasiveness Index(SII) is often used to determine the magnitude of a surgical procedure i.e. the 'invasiveness', and thus assess the risks associated with the procedure and predict patient recovery. It has been shown that SII is a predictor of the risk of surgical site infection. However, in the cohort used to create and validate this index, only 6.7% of patients had undergone minimally invasive procedures. Thus, it is not known whether this index is valid and applicable in minimally invasive spine surgery (MISS). The purpose of this study is to assess the validity of the Surgical Invasiveness Index in minimally invasive spine surgery.

Method: Patients who underwent minimally invasive spine surgery by a single surgeon between April 2017 and September 2018 were included in this study. The SII was calculated for each patient; and individual linear regressions were run with procedure time(in minutes) and estimated blood loss(EBL, in ml) as the dependent variables.

Results: For the 386 patients included in this study, the SII ranged from 1 to 29, with a median of 5 [IQR: 2-8]. The procedure time ranged from 17 to 418 minutes, with a median of 65 [IQR: 48.75-95]. Although EBL ranged from 10 ml to 600 ml (median:25, IQR: 25-25), 81.6% of patients had EBL <25ml and 97.7% had EBL<100ml.

The regression analysis for procedure time showed a strong statistically significant association, with $r^2=0.695$ ($p<0.0001$), thus indicating that the SII explains 69.5% of the variability in the duration of the surgical procedure (Figure 1). In contrast, the regression analysis for EBL showed a weak association, with $r^2=0.161$ ($p<0.0001$), thus indicating that the SII explains only 16.1% of the variability in EBL (Figure 2).

Discussion: The results of our study show that the SII explains almost 70% of the variability in the duration of the surgical procedure for MIS procedures. However, it does not adequately explain the variability in EBL. Given the low blood loss in MIS surgery with over 80% of procedures having EBL<25ml, the SII does not appropriately reflect surgical stress in these patients. Larger studies are warranted to assess the validity of the SII in MIS procedures and potentially develop a MIS-specific Invasiveness Index. A more refined and comprehensive index, which accounts for the minimally invasive approach may more accurately reflect the magnitude of surgery in these patients and thus better predict surgical outcomes in terms blood loss, risk of complications, post-operative recovery and functional outcomes.

Figure 1

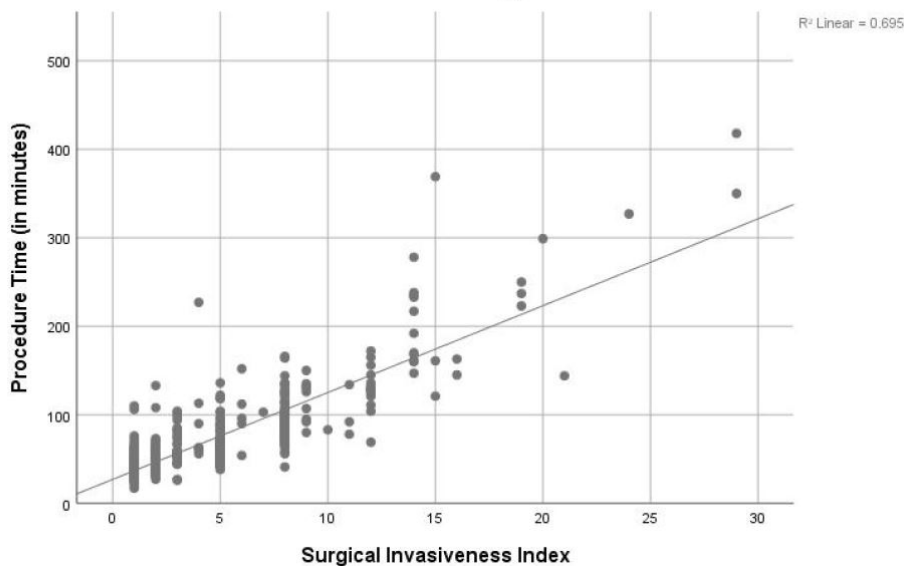
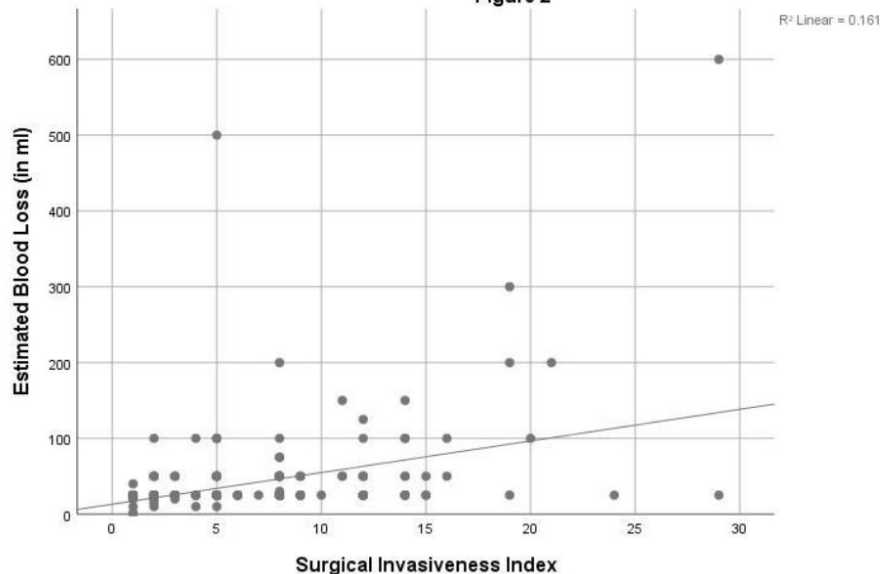


Figure 2



Analysis of the factors associated with having an indication for surgery in lumbar spinal stenosis

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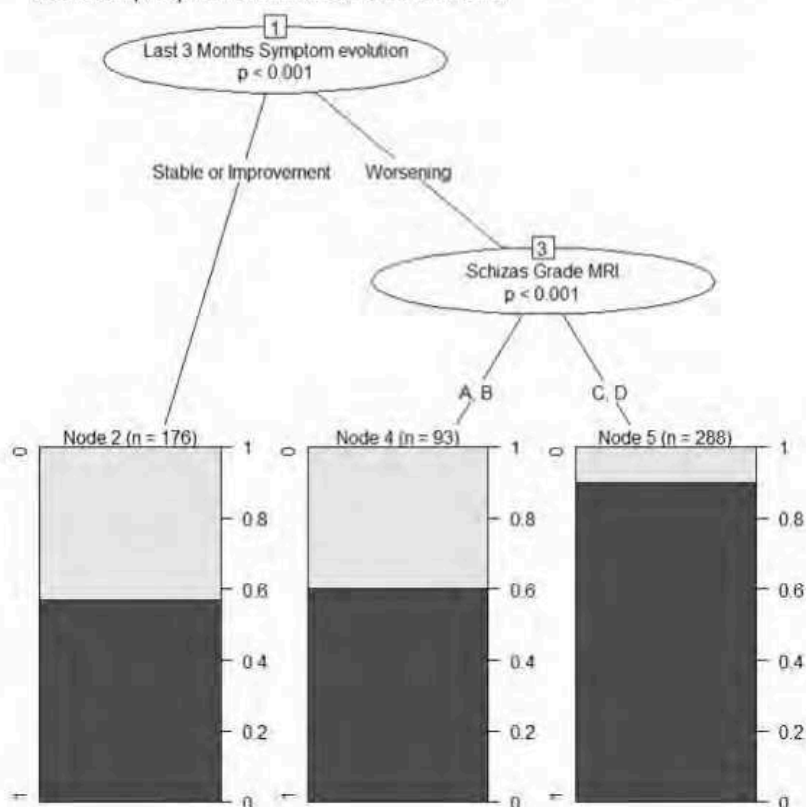
Introduction: The outcome of surgery for spinal stenosis can be very variable, suggesting that patient selection could be improved. Studies have compared groups of stenosis patients undergoing either surgery or non-operative care^{1,2} but only in relation to treatment received and not whether there was actually an indication for surgery or not. This means that patients declining/unable to undergo surgery were grouped with those for whom no surgical indication ever existed (as the "non-op group"), potentially biasing the results. The aim of this study was to evaluate, in a comprehensive multivariable model, the baseline characteristics that distinguish patients considered to have an indication for surgery from those with no such indication.

Methods: Data were extracted for patients with sufficiently complete data for all variables of interest registered in the database of the Lumbar Spinal Stenosis Outcomes Study (LSOS), a multicentre, prospective observational study of patients with spinal stenosis and neurogenic claudication being treated surgically or conservatively.³ A total of 556 full observations were identified for inclusion; 280 (50.4%) females, mean age 72.8 (8.5) y. A logistic forward stepwise regression model was built with this sample to predict "having an indication of surgery", as documented by the referring clinician, using a range of baseline variables (demographic, clinical history, neurological, radiological, patient self-ratings for pain, disability, HRQL, psychological status) and controlling for study site fixed-effects.

Results: A total of 415 (73%) patients had an indication for surgery and 142 (27%) did not. The predictors of "indication for surgery" in the multivariable model with the lowest p values ($p < 0.01$) included: worse score on the "back trouble thermometer", lower psychological distress (SCL-K-9), higher Roland Morris score, grade C or D morphological spinal stenosis grade (rootlet to cerebrospinal fluid ratio on axial MRI; Schizas grade), and less disc degeneration (Pfirrmann grade). Other significant predictors ($p < 0.05$) included non-Swiss nationality, symptoms getting worse in the last 3 months, no PT in the last 3 mo, and numbness of the foot. Model discrimination was good (AUC 87.2%, 95% CI 84.1-90.3%) and the model was well calibrated. A classification tree for surgical indication (with variable-based sample splits that minimise classification error) is shown in Fig 1.

Discussion: The most important variables shown to be associated with having an indication for surgery were a combination of severe/worsening symptoms and disability, less psychological distress, and radiological evidence of severe stenosis without accompanying disc degeneration. We suggest that these should be combined into an algorithm for further investigation as potential "appropriate use criteria" to assist with decision-making in lumbar spinal stenosis. Our further studies will examine whether patients with a higher probability of having a surgical indication based on these criteria actually go on to have a significantly better outcome after surgery.

Figure 1. Classification tree of surgical indication, nodes [1,3] represent variable-based sample splits that minimize classification error



References

1. Azimi P et al J Neurosurg Sci. 2017;61(4).
2. Kim H-J et al Eur Spine J. 2015;24(2):339-347.
3. Steurer J et al. BMC Musculoskelet Disord. 2010;11(2008):254.

Assessing the true cost of minimally invasive TLIF in patients with workers' compensation using TDABC

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Introduction: As the percent growth in workers' compensation medical costs outpaces growth in US health expenditures, new policies now decrease the number of cases approved, thus burdening low-wage, vulnerable workers who are disproportionately covered by it. Since the majority of workers' medical compensation is underwritten for back injuries, our study uses time-driven activity-based costing (TDABC) to determine the cost drivers of transforaminal lumbar interbody fusions (TLIF) over the total cycle of care. This study aims to determine the true cost of an MIS-TLIF for workers' compensation patients across the full cycle of care. It also identifies cost-drivers, and assess whether reductions can meaningfully decrease cost or increase value in the episode of the care.

Methods: This is a prospective cohort study using time-driven activity-based costing. The patient sample consisted of 174 total patients at a tertiary medical center (14 patients followed directly to characterize the care pathway; 160 consecutive patient records used to assess the average utilization of resources). The primary outcome measure is the full cost of episode of an MIS-TLIF, covering initial clinic evaluation through post-operative visit at 6-months and the secondary outcome measures is identification and reduction of cost-drivers along the cycle of care.

For our time-driven activity-based costing model, we defined a full care cycle as initial patient visit through the post-operative 6-month follow-up (including 3 phases: preoperative, day of operation, and post-operative). Time-capture data was acquired for 14 separate iterations of the cycle by directly following patients through each step of the cycle. These data were combined with the average utilization rates and time stamps extracted from the EMRs of 160 consecutive patients broken down into 17 unique process maps for 150 total points. Each point was then assigned cost per unit time as a function of 4 factors—personnel, space, durable equipment, consumables. These capacity cost rates were combined with time data to generate total cost data.

Results: Of the total TDABC derived cost (>\$25,590), implants were the greatest cost overall (28%). The most expensive individual step over the course of the total care cycle was the surgical procedure (70%). In terms of individual capacity cost rates, personnel costs were a major cost-driver (22%), along with non-implant operative supplies (22%), of which drugs and biologics accounted for 43%. Of the different simulated process map improvements, we were able to decrease costs by 6% total (from \$313 through peak utilization smoothing to \$1160 by elimination of unnecessary practice variation through use of implants).

Conclusions: TDABC allows us to determine both the true cost of a TLIF and the cost-drivers across the care-delivery value-chain. This cost model also revealed bottle necks within the care cycle, and specific places where resources were underutilized. However, this model found that the largest costs in transforaminal lumbar interbody fusions were from consumables such as implant and biologics, neither of which responds directly to pressures from the decrease in approvals for workers' compensation spine cases, thus shifting costs to the workers themselves.

Is the outcome of surgery for lumbar degenerative spondylolisthesis related to the appropriateness of surgery?

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Introduction: In spine surgery, many treatment failures are attributable to poor patient selection and the application of inappropriate treatment. "Appropriate use criteria" (AUC) serve to help clarify the indications for a procedure. This study aimed to use recently published AUC₁ to evaluate the appropriateness of surgery for lumbar degenerative spondylolisthesis (LDS) in a large group of patients and to examine the association between adherence to the criteria and postoperative outcome.

Methods: This was a retrospective analysis of prospectively collected data recorded in our Spine Outcomes database (linked to EUROSPINE's Spine Tango Registry) from patients who had undergone LDS surgery in our clinic, between 2005 and 2012. Appropriateness of the use of surgery in each patient was judged using the published criteria¹. Patients completed the Core Outcome Measures Index (COMI) before surgery and at 3, 12 and 24 months follow-up (FU).

Results: In total, 537 patients (age 69±10 y; 384 (72%) women) were eligible for inclusion. 98% completed a COMI form preoperatively, 96% at 3 mo FU, 92% at 12 mo FU, 90% at 24 mo FU. We were able to apply the appropriateness criteria in 475/537 (88 %) patients with the necessary baseline data. Some type of surgery (either decompression or fusion±stabilisation) was considered appropriate in 224 (47%) of the operated patients, inappropriate in 95 (20%), and uncertain in 156 (33%). There was a significant difference between the groups in the pattern of change in COMI score from preoperatively to follow-up ($p < 0.001$) whereby patients who were considered appropriate (A) or uncertain (U) candidates had greater improvements in COMI than those who were considered inappropriate (I) candidates. The minimal clinically important change (MCIC) score of 2.2 points for COMI was reached by 78% A, 83% U and 55% I cases ($p < 0.001$, I vs A and U). The odds of achieving the MCIC were 3-times greater in patients considered appropriate/uncertain for surgery than in those considered inappropriate (OR 3.4 95%CI 1.99-5.63).

Discussion: The results suggest a relationship between adherence to the AUC and outcome. The findings provide support for the use of AUCs in clinical practice, to guide indications for surgery, but the findings should be confirmed in prospective studies that also include a control group of non-operated patients.

(1) Mannion AF et al (2014) Eur Spine J. 2014 Sep;23(9):1903-17.

Surgical training in spine surgery: safety and patient-rated outcome

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Background: The surgical education of spine surgery residents (RES) in the operation theatre is a fundamental part of their training. However, patient safety and clinical outcome have the greatest priority and must not be sacrificed in favor of education. This can present a dilemma and inappropriate judgement may result in increased morbidity and less satisfied patients. The aim of this study was to investigate the difference in surgical complication rates and patient reported outcomes between lumbar procedures carried out either by experienced spine surgeons or by supervised spine surgery residents in a large Swiss teaching hospital.

Methods: This was a single-center retrospective analysis of prospectively collected data within the EUROSPINE Spine Tango Registry, using data from our institution between the years 2004-2015. The study included a total of 1415 patients. Patients operated on by board certified spine surgeons (BCS) served as a control group. Patients were divided into three groups based on the surgical procedure: lumbar single level fusion (SLF): RES n=60, BCS n=261, single level decompression for lumbar spinal stenosis (SLD): RES n=72, BCS n=246 and surgery addressing disc hernia, such as microdiscectomy or sequestrectomy (DH): RES n=247, BCS n=529. Patients completed the multidimensional Core Outcome Measures Index (COMI; 0-10 scale) preoperatively and 3 and 12 months postoperatively plus single items concerning satisfaction and global treatment outcome (GTO) at 3 and 12 months. The outcomes of interest were operation time, blood loss, complications, length of hospitalization as well as the patient reported outcome measures. Multiple linear regression models were used to investigate the influence of resident performance on the outcomes of interest.

Results: There were no differences between RES and BCS in the surgical or medical complication rates ($p>0.05$). Blood loss was found to be significantly higher in RES' surgeries for SLD only ($p<0.05$) and operation time was significantly longer only in DH cases ($p<0.05$). Length of hospitalization was slightly but not significantly higher in the RES group in SLF cases ($p=0.178$). Baseline status as given by COMI scores was similar preoperatively in patients of RES and BCS. COMI scores significantly improved after all three types of procedure ($p<0.0001$) without difference between the patients of RES and BCS ($p>0.05$). There was no difference between RES and BCS patients with regard to satisfaction and GTO.

Conclusion: In the given setting, surgical training of spine surgery residents under guided supervision by board certified spine surgeons was shown to be safe as it was not associated with increased morbidity and mortality. Furthermore, it had no detrimental influence on patient reported outcome.

The association between early post-operative leg pain intensity and disability at one-year and two-years follow-up after first time lumbar discectomy

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Introduction: In a clinical low back pain population the prevalence of sciatica is 11-12%, and lumbar disc herniation is the causing pathology in estimated 90% of cases. The prevalence of sciatica peaks in the working age group. Thus, poor treatment outcomes are associated with great costs for the individual and the society. Therefore, there is a need to identify patients at risk of poor recovery after discectomy. The objective of this study was to examine the association between leg pain intensity measured pre-operatively and early post-operatively, and disability as measured by the Oswestry Disability Index (ODI) at one-year and two-years follow-up after lumbar discectomy.

Methods: The study is a longitudinal cohort single-center study of patients identified from a clinical database DaneSpine. The patients were included when undergoing first-time, single level limited discectomy. Follow-up time-points were at five weeks, one year and two years post-operatively. Associations were examined using Generalized Estimating Equations adjusted for covariates identified in a lost to follow-up analysis.

Results: Leg pain intensity pre-operatively and at early follow-up was associated with the ODI at one year ($n = 643$) and two years ($n = 577$) after surgery, with early follow-up showing the strongest association, $p = .000$. A statistically significant higher degree of disability at one-year and two-years follow-up was seen when leg pain intensity exceeded 30 (0-100 scale) at early follow-up, $p = .000$.

Discussion: Leg pain intensity greater than 30 at early follow-up, is associated with worse disability at one and two-years after primary, single-level lumbar discectomy. This finding may guide the clinician in adjusting the post-operative regimen in these patients that are at greater risk of long-term disability.

Preoperative depression identified by the SF-12 mental component score affects outcomes following lumbar fusion

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Introduction: The impact of pre-existing depression on outcomes following lumbar spine surgery is not well established. Many patients may not be previously diagnosed and depression is not routinely screened for by surgeons. The aim of this study was to retrospectively identify patients with symptoms of depression using the mental component score (MCS-12) of the Short Form-12 (SF-12) survey and determine its impact on outcomes following lumbar fusion.

Methods: Patients who underwent lumbar fusion between one to three levels for degenerative lumbar pathology were retrospectively identified at single center, academic institution. Exclusion criteria consisted of patients under the age of 18, less than at 10 months of follow-up, history of previous infection, tumor, trauma, or revision. Patients were divided into two groups based on a preoperative MCS-12 cut-off of 45.6. Other outcome measures that were collected included SF-12 Physical Component Score (PCS-12), Oswestry Disability Index (ODI), Visual Analogue Scale back pain (VAS Back) and leg pain (VAS Leg) scores. Continuous variables between groups were compared using an independent samples t-test. Multivariate analysis with multiple linear regression – controlling for age, sex, body mass index, smoking status, preoperative diagnosis, number of levels decompressed, number of levels fused, follow-up, duration of preoperative symptoms – was used to determine if depression was a predictor for change in each patient reported outcome scores.

Results: 352 patients met the criteria for the study, with 20 (34.1%) patients in the depression group (MCS-12 \leq 45.6), and 232 (65.9%) in the non-depression group (MCS-12 $>$ 45.6). There was a significant difference between groups in all preoperative outcome measures except for PCS-12 scores (Table 1), with the depression group reporting higher disability and pain. Postoperative scores were all significantly different, with the depression group still reporting higher disability and pain in all domains. Multiple regression analysis revealed that depression was an independent predictor of change in both PCS-12 (β -coefficient -0.142, $p = 0.003$) and VAS Leg (β -coefficient 0.119, $p = 0.008$) scores.

Discussion: In this retrospective study, patients with depression tended to have more disability and pain preoperatively that continued to persist postoperatively. Multivariate analysis showed that patients with depression experience less improvement in PCS-12 scores postoperatively, and while they experienced a greater reduction in leg pain, the overall leg pain scores remained higher. Our findings suggest it may be beneficial to identify patients with depression at preoperative screenings to optimize outcomes after lumbar surgery.

Table 1: Patient Reported Outcome Measurement (PROMs) Comparisons between Depression and Non-Depression Groups

	Overall (n = 352)	Depression MCS \leq 45.6 (n = 120)	Non-Depression MCS $>$ 45.6 (n = 232)	p-value
ODI Pre	41.7 [39.9, 43.4]	51.0 [48.2, 53.9]	36.7 [34.7, 38.7]	$p < 0.001^*$
ODI Post	21.6 [19.8, 23.4]	27.1 [23.5, 30.7]	18.1 [16.0, 20.2]	$p < 0.001^*$
PCS-12 Pre	31.1 [30.2, 32.0]	30.3 [29.0, 31.6]	31.4 [30.3, 32.6]	$p = 0.216$
PCS-12 Post	40.0 [39.0, 41.0]	37.9 [36.2, 39.5]	41.5 [40.0, 42.9]	$p = 0.001^*$
VAS Back Pre	5.9 [5.5, 6.2]	6.6 [6.1, 7.2]	5.4 [5.0, 5.8]	$p < 0.001^*$
VAS Back Post	2.9 [2.7, 3.2]	3.4 [2.9, 3.9]	2.5 [2.2, 2.8]	$p = 0.002^*$
VAS Leg Pre	6.1 [5.8, 6.4]	7.1 [6.5, 7.6]	5.6 [5.2, 6.0]	$p < 0.001^*$
VAS Leg Post	2.4 [2.2, 2.7]	3.1 [2.5, 3.7]	2.1 [1.7, 2.4]	$p = 0.002^*$
ODI Delta	-20.1 [-22.3, -17.8]	-23.3 [-27.6, -19.0]	-18.5 [-21.1, -15.9]	$p = 0.073$
PCS-12 Delta	9.1 [7.9, 10.2]	7.4 [5.7, 9.2]	10.1 [8.6, 11.5]	$p = 0.003^*$
VAS Back Delta	-3.0 [-3.4, -2.7]	-3.1 [-3.7, -2.5]	-2.9 [-3.4, -2.5]	$p = 0.747$
VAS Leg Delta	-3.7 [-4.0, -3.3]	-3.8 [-4.5, -3.1]	-3.5 [-4.0, -3.0]	$p = 0.008^*$

Cost prediction modeling of single level lumbar decompression and fusion by machine learning

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Introduction: Costs of lumbar decompression and fusion continue to rise, however complex cost variability has made identification of factors associated with higher costs challenging. Prior studies have been limited by methodologic issues and limited power. Machine learning may improve predictive power versus conventional analysis and identify more relevant risk factors of high costs. Therefore, we sought to 1) model inpatient costs with machine learning algorithms, 2) assess and compare the models' predictive power, and 3) identify predictors of increased costs.

Methods: Costs and perioperative data of skeletally mature patients undergoing lumbar decompression with single-level fusion for lumbar degenerative disease from January 2011 through June 2017 were retrospectively reviewed. Patients with a primary diagnosis of deformity, tumor or fracture or patients undergoing staged or revision procedures were excluded. The data was then divided into training and testing groups with 10-fold cross validation using 10 unique supervised machine learning algorithms (additive regression, decision table, gaussian processes, linear regression, IBk, random committee, random forest, random tree, regression by discretization and SMOreg). The models were assessed and compared. Common patient and procedure-specific variables were assessed for association with cost in univariate and multivariable analysis.

Results: A total of 781 patients were included in the analysis (mean age 60.5±12.9, 56.1% female). Mean inpatient costs were \$26,823.33±8,428.59. Predictive models were made using the 10 machine learning algorithms. These were assessed for performance, with correlation coefficients ranging from $r = 0.159$ - 0.688 (Table 1). Among all the algorithms, SMOreg demonstrated the best predictive performance ($r = 0.688$; Table 1).

Univariate analysis found that ASA ($p < 0.001$) and presence of durotomy ($p = 0.023$) were associated with higher costs, while increasing length of stay (LOS; $r = 0.63$), operative time (OT; $r = 0.38$), estimated blood loss (EBL; $r = 0.23$), body mass index (BMI; $r = 0.13$) and age ($r = 0.108$) were associated with increasing costs. Sex, smoking status, surgeon and assistant training levels, and comorbidities including diabetes, cardiovascular, pulmonary or renal disease were not associated with increased costs. In the multivariable analysis, LOS, OT, EBL, ASA, BMI, and age remained associated with cost (r 's= 0.63 , 0.38 , 0.15 , 0.14 , 0.13 , and 0.11 , respectively).

Discussion: Inpatient costs associated with single-level lumbar decompression and fusion were modeled by machine learning. The SMOreg algorithm provided the best performance. In multivariable analysis, ASA, BMI and age were preoperative variables associated with increased costs. EBL, LOS and OT were also associated with increased costs. Addressing predictive factors preoperatively may decrease care variability and cost. Furthermore, modeling cost may enable more effective unitization and reimbursement models with improved allocation of cost-effective care.

Table 1. Comparison of machine learning and conventional algorithms for prediction of costs.

Algorithm	Correlation Coefficient
SMOreg	0.688
Linear Regression	0.679
Gaussian Processes	0.679
Random Forest	0.631
Random Committee	0.583
Additive Regression	0.578
Regression by Discretization	0.471
Decision Table	0.470
Random Tree	0.451
IBk	0.159

Five-year results of lumbar spinal stenosis with degenerative spondylolisthesis treated with decompression alone

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Introduction: In the field of spine surgery, it is still controversial whether the fusion is necessary in surgical treatment for lumbar spinal stenosis (LSS) with degenerative spondylolisthesis. In our institution, LSS patients with neurological intermittent claudication always received decompression alone even if they have degenerative spondylolisthesis. The purpose of this study was to clarify the surgical results of degenerative spondylolisthesis with decompression alone.

Methods: This study was a prospective cohort study. Eighty-two patients with LSS were included (male 44, female 38, most age group 70s). All patients received decompression surgery for symptomatic levels without fusion. The patients with cervical and thoracic spinal disease, rheumatoid arthritis, or destructive spondyloarthropathy were excluded. Primary outcome was numerical rating scale (NRS) of satisfaction with surgery (0: not satisfied, 10: completely satisfied). NRS of 8 or more was defined as satisfied group in this study. Secondary outcomes were NRS for low back pain, leg pain, and leg numbness and Roland Morris Disability questionnaire (RDQ). Subjects were divided into two groups according to preoperative X-ray finding with or without spondylolisthesis (grade I or more). Statistical analysis was performed by Chi-square test and Wilcoxon test. A p-value less than 0.05 was considered significant.

Results: Preoperatively, 47 patients had degenerative spondylolisthesis and 35 patients had only spondylosis on X-ray examination. There were no significant differences in preoperative NRS of low back pain, leg pain, and leg numbness, and RDQ between two groups. Five years after surgery, 68% of the patients with spondylolisthesis and 63% of the patients without spondylolisthesis were classified into the satisfied group. There was no significant difference in satisfaction with surgery between the patients with or without spondylolisthesis. There were also no significant differences in NRS of low back pain, leg pain, and leg numbness, and RDQ between the patients with or without preoperative spondylolisthesis at 5-year follow up.

Discussion: The results of this study showed that preoperative spondylolisthesis had no influence on 5-year outcomes of decompression surgery for LSS patients. Decompression surgery was considered suitable enough to treat LSS patients even if the degenerative spondylolisthesis was found in preoperative imaging study.

Who will do better; predicting better surgical outcomes in lumbar spinal stenosis – a prospective 10-year follow-up study

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Introduction: Lumbar spinal stenosis (LSS) is a leading cause for low back surgery in the elderly. The prevalence of LSS is increasing due to aging of the general population [1,2]. Psychological variables as preoperative depression, life dissatisfaction and weak sense of coherence showed an association with poorer surgical outcomes even at 10-year period [3-5]. However, limited data is available about other than psychological predictors for long-term surgical outcome in patients with LSS. In this prospective study, we aim to evaluate preoperative predictors for better surgical outcomes in LSS in 10-year follow-up.

Methods: This is a prospective observational study, where 102 study patients with LSS underwent a decompressive surgery between 2001-2004, and 72 of the original participants participated at 10-year follow-up. Study patients fulfilled detailed questionnaires preoperatively and follow-up data were collected at 3 and 6 months, 1 year, 2, 5 and 10 years postoperatively. The surgical outcomes were Oswestry Disability Index (ODI) and Visual analogue scale (VAS). Predictors in the models were: absence of previous lumbar surgery, better self-rated health, non-smoking status and regular use of painkillers less than 3 months, BMI and comorbidities. Longitudinal associations were analyzed using a linear mixed model.

Results: On multivariate analysis, the predictors for better ODI scores at 10-year follow-up were: *absence of previous lumbar operation* (estimate -7.23 (SD 3.3); $p < 0.005$; 95%CI -13.8;-0.69), *better self-rated health* (-7.53 (2.5); $p < 0.005$; 95%CI -12.5;-2.5), *non-smoking status* (-9.2 (2.5); $p < 0.005$; 95%CI -15.4;-3.0) and *regular use of painkillers less than 3 months* (-10.5 (3.0); $p < 0.001$; 95% CI -16.6;-4.5). The predictors for lower VAS scores were *absence of previous lumbar operation* (-14.67 (4.2); $p < 0.001$; 95%CI -23.0;-6.4), *better self-rated health* (-6.61 (3.2); $p < 0.05$, 95%CI -13.0;-0.2), *non-smoking status* (-9.55 (3.9); $p < 0.05$; 95%CI -17.3;1.8) and *regular use of painkillers less than 3 months* (-8.9 (3.8); $p < 0.05$; 95%CI -16.5;-1.4). *Body Mass Index* nor the *number of comorbidities* were not associated with the better ODI- and VAS-scores.

Conclusion: The duration of patient's intensive painful symptoms is a relevant variable that can help deciding optimal time of surgery, while smoking cessation should be strongly considered in order to improve the surgical outcomes. In addition, patients assessing positively their health status and undergoing their first lumbar surgery are more likely to express better surgical outcomes even at 10 years follow-up time. The current study results can enhance the codification of informed decision making processes for consideration of surgical treatment in patients with LSS.

1. 1. Ciol MA, Deyo RA, Howell E, Kreif S (1996) An assessment of surgery for spinal stenosis: time trends, geographic variations, complications, and reoperations. J Am Geriatr Soc (3)
2. 2. Kalichman L, Cole R, Kim DH, Li L, Suri P, Guermazi A, Hunter DJ (2009) Spinal stenosis prevalence and association with symptoms: the Framingham Study. Spine J 9(7):545-550 3. Katz JN, Harris MB (2008) Clinical practice. Lumbar spinal stenosis. N Engl J Med 358(8):818-825
3. 3. Pakarinen M, Tuomainen I, Koivumaa-Honkanen H, Sinikallio S, Lehto SM, Airaksinen O, Viinamäki H, Aalto T (2016) Life dissatisfaction is associated with depression and poorer surgical outcomes among lumbar spinal stenosis patients: a 10-year follow-up study. Int J Rehabil Res (4). doi: 10.1097/MRR.000000000000182
4. 4. Sinikallio S, Pakarinen M, Tuomainen I, Airaksinen O, Viinamäki H, Aalto TJ (2017) Preoperative sense of coherence associated with the 10-year outcomes of lumbar spinal stenosis surgery. J Health Psychol . doi: 10.1177/1359105316687633
5. 5. Tuomainen I, Pakarinen M, Aalto T, Sinikallio S, Kröger H, Viinamäki H, Airaksinen O (2018) Depression is associated with the long-term outcome of lumbar spinal stenosis surgery: a 10-year follow-up study. Spine J (3). doi: 10.1016/j.spinee.2017.08.228

The Association between surgical level and postoperative thigh symptoms among patients undergoing standalone Lateral Lumbar Interbody Fusion (LLIF)

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Introduction: It has been reported that LLIF is often associated with postoperative lumbar plexus symptoms, including pain, paresthesia, and motor deficits in the lower extremities, especially in the anterior thigh regions. Previous studies demonstrated that LLIF procedures at L4/5 were associated with a higher motor deficit rate than other levels, but it remains to be clarified which level is at the highest risk for pain and paresthesia. LLIF is often performed along with a posterior procedure, which might lead to a bias in assessing the true incidence of thigh symptoms solely associated with LLIF. In this study, we investigated the difference in incidence of postoperative thigh symptoms (pain and paresthesia) by procedure level among patients who underwent a standalone LLIF procedure.

Materials and Methods: Institutional ethics board approval was obtained for this study. We reviewed the data of 1290 consecutive patients undergoing LLIF between 2006-2016 in a single academic institution and 285 standalone LLIF cases without preoperative motor deficits were identified. Postoperative anterior thigh symptoms were defined as newly onset anterior thigh pain or paresthesia. The incidences of postoperative thigh pain and paresthesia were assessed in all levels between T12/L1 and L4/5. Statistical analyses were conducted utilizing the Fisher exact test, Chi-squared test for categorical comparison, Student t test for continuous variables, and logistic regression test for univariate/multivariate analysis. The statistical significance level was set at $p < 0.05$.

Results: Mean age (\pm SD (range)) was 62.8 ± 13.1 . 58.2% of the patients were female. The numbers of patients undergoing LLIF by levels fused were: single level $n=115$, two levels $n=111$, three levels or more $n=59$. 121 (42.5%) patients demonstrated postoperative thigh symptoms. Among them, 81 patients (28.4%) had anterior thigh pain and 62 patients (21.8%) had anterior thigh paresthesia. Three or more levels fused (OR 2.96, $p=0.004$) and surgery at L2/3 (OR 2.59, $p=0.001$) were significant risk factors for postoperative anterior thigh paresthesia in univariate analysis, but no association with anterior thigh pain. Multivariate analyses demonstrated that only L2/3 was an independent risk factor for anterior thigh paresthesia (OR 2.09, $p=0.049$). In subgroup analysis of 114 patients with a single level L1/2-L4/5 procedure, anterior thigh pain was not associated with any surgical levels, but paresthesia was significantly associated with a L2/3 procedure ($p=0.003$, pairwise comparisons (Holm-Bonferroni) L2/3 vs L1/2, $p=0.058$; vs L3/4, $p=0.018$; vs L4/5, $p=0.024$).

Discussion: Our results demonstrated that a standalone LLIF procedure at L2/3 was significantly associated with a higher incidence of postoperative anterior thigh paresthesia, and postoperative thigh pain showed no significant association with any specific operative levels. These results suggest that this higher risk of anterior paresthesia might be related to the proximity of surgical level and specific peripheral nerves, such as the genitofemoral nerve and lateral femoral cutaneous nerve. On the other hand, anterior thigh pain might have a different pathological entity such as direct psoas muscle injury. The surgeons should be aware of the potential risk for anterior thigh paresthesia when performing L2/3 LLIF procedures.

How reliable are measures of treatment success after surgery for central spinal canal stenosis?

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Introduction: The test-retest reliability of patient-reported outcome measures (PROMs) is typically evaluated in patients with chronic, stable symptoms, prior to treatment. Whether the same PROMs deliver reliable results *after* treatment, when symptoms may be less extreme and less variable within a group of patients, has rarely been investigated, despite the fact that the "success" of treatment is governed by post-treatment scores or change-scores (pre to post-treatment). Moreover, few studies have examined the reliability of retrospective "global treatment outcome" items used as external criteria when determining minimal clinically important change (MCIC) scores for PROMs.

Methods: Data were extracted for patients with lumbar spinal stenosis registered in our in-house outcomes database who had completed our standardised PROM as part of their routine follow-up (FU) (ROUTINE) and had also completed the same PROM a second time, as part of a separate prospective study (LSOS). To be included, the two PROMs had to have been completed within 3 mo of each other for 1y FU, within 4 mo for 2y FU, and within 5 mo for 5 y FU. The PROM contained the multidimensional Core Outcome Measures Index (COMI) and a global treatment outcome (GTO) item ("how much did the operation help your back problem"; 5-point scale, dichotomised as "good" and "poor" outcome). Repeated measures ANOVA, intraclass correlation coefficients (ICC; 2-way mixed, absolute agreement), and Kappa values were calculated.

Results: 64 patients (72.9 ± 6.9 y; 48% female) had PROMs from the two sources (ROUTINE and LSOS) that could be compared for test-retest reliability. There were no significant differences between test and retest scores for any of the COMI domains or for the COMI summary score (all $p > 0.05$). The corresponding ICCs showed good agreement between the repeated measures (0.74-0.79). In the LSOS and ROUTINE datasets, 81% and 83% patients, respectively, reported a "good global outcome"; the corresponding Kappa for agreement between the ratings on an individual basis was 0.73 ("good agreement").

Conclusion: Despite the more stringent nature of the evaluation given by this "real-life" test-retest design, the FU COMI scores showed good reliability, with ICCs comparable to those previously reported in the original COMI validation studies^{1,2} with assessments made 1-2 weeks apart in patients with chronic stable symptoms. The GTO was also confirmed as a reliable variable and thus suitable for use as the "external criterion of success" when establishing minimal clinically important change scores for PROMs.

- 1) Mannion AF et al. *Eur Spine J* 14: 1014-1026, 2005.
- 2) Ferrer M et al *Spine* 31: 1372-1379

Improvement effect of microendoscopic decompression surgery on low back pain of lumbar spinal stenosis and risk factors of poor outcome

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Introduction: Decompression surgery can be effective in relieving pain due to lumbar spinal stenosis (LSS). However, predicting the improvement of low back pain is difficult. We investigated the effect of microendoscopic laminotomy (MEL) on improving low back pain and determined the risk factors of poor results in LSS.

Methods: This retrospective cohort study included 132 continuous patients who had LSS with back pain (defined as preoperative low back pain VAS value of 40 mm or more) for whom MEL was performed between July 2014 and June 2017. The JOA score and VAS value were assessed during clinical evaluation, and modic changes of endplates, intervertebral disc degeneration, vacuum phenomenon (interbody, intervertebral joint), facet joint edema, presence of old vertebral fracture, spinal instability (sliding increase of 2 mm or more at bending or posterior enlargement of 10 degrees or more), sagittal spinopelvic parameters (SVA, PI, LL, PI - LL, SS, PT) of the vertebral column were assessed by imaging studies. We classified patients with a VAS value for low back pain of 25 mm or more postoperatively into the residual low back pain group and those with less than 25 mm into the back-pain improvement group. Univariate analysis of factors may related to residual low back pain including sex, age, and BMI was performed. Then, multiple logistic regression analysis was performed by using variables those P values were less than 0.1 as an explanatory variable.

Results: One year after surgery, 108 cases were assessed and the follow-up rate was 81.8%. The average value of the JOA score improved from the preoperative mean of 14.2 to postoperative average of 19.2, and the mean VAS value of back pain, lower limb pain, and numbness improved from 64.4, 63.4, and 58.9 preoperatively to 32.1, 34.5, and 33.8 postoperatively, respectively. If the improvement of the VAS value of 20 mm or more is defined as the minimum clinically significant difference (MCID), the achievement rate of the MCID for low back pain improvement was 71.3%. Using the univariate analysis, BMI, preoperative VAS value, and Modic type 1 changes were isolated. Using the multiple logistic regression analysis, BMI (unit odds ratio 1.13) and Modic type 1 changes (odds ratio 3.87) were statistically significant risk factors for residual low back pain.

Conclusion: Around 70% of patients with LSS achieved an improved MCID of low back pain after MEL. Risk factors for residual low back pain were high BMI and Modic type 1 changes on MRI. Spinal instability did not affect the outcome in the present series. This study could be useful to patients and physicians because the results may be applicable to other types of decompression surgery for LSS.

Lumbar pedicle morphology and vertebral dimensions in isthmic and degenerative spondylolisthesis – a comparative study

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Introduction: Pedicle screws are the most common device used to achieve fixation in fusion of spondylolistheses. The safe and accurate placement with this technique relies on a thorough understanding of the bony anatomy. There is a paucity of literature comparing the surgically relevant osseous anatomy in patients with a DS and an IS.

Methods: A retrospective comparative study was conducted on patients with a single level, symptomatic L4-L5 Degenerative Spondylolisthesis (DS) or a single level, symptomatic L5-S1 Isthmic Spondylolisthesis (IS) to determine the differences in the osseous anatomy in patients with DS vs those with IS. Magnetic resonance imaging (MRI) for these patients was reviewed and morphometry of the pedicle and vertebral body were analyzed by two independent observers for the levels from L3 to S1 and radiographic parameters were compared between groups.

Results: A total of 572 levels in 143 patients were studied including 103 patients with a DS and 40 with an IS. After accounting for confounders, IS and DS had an independent effect on transverse vertebral body width, pedicle height, width and sagittal pedicle angle. Patients with an IS had a smaller pedicle height ($p<0.001$) and pedicle width ($p=0.001$) than patients with DS. Additionally, the angulation of the pedicles varied based on the diagnosis.

Discussion: The osseous anatomy is significantly different in patients with a DS compared to an IS. Patients with an IS have smaller pedicles in the lumbar spine. Also, the L4 and L5 pedicles are more caudally angulated and the S1 pedicle is less medialized. Understanding the differences in pedicle anatomy is important for the safe placement of pedicle screws.

Table 1. Comparison of radiographic parameters between patients with an isthmic and a degenerative spondylolisthesis.

	Degenerative Spondylolisthesis (n=103)		Isthmic Spondylolisthesis (n=40)		p-value
	Mean (SD)	Percent of DS	Mean (SD)	Percent of IS	
Age	62.5 (11.9)		48.8 (13.9)		<0.001*
BMI	31.3 (6.1)		31.0 (5.7)		0.769
Gender (%)					
Female		66.0%		45.0%	0.021*
Male		34.0%		55.0%	
Ethnicity					0.362
Caucasian		87.4%		92.5%	
African American		7.8%		7.5%	
Hispanic		4.9%		0.0%	

The association between sacroiliac joint-related pain following lumbar spine surgery and spinopelvic parameters: A prospective multicenter study

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Introduction: Some reports have demonstrated an association between spinopelvic parameters and postoperative SIJP after lumbar fixation surgeries. However, these studies were retrospective and did not include non-fixation surgeries. The purpose of the study was to prospectively calculate the incidence of postoperative sacroiliac joint related pain (SIJP), and investigate the association between spinopelvic parameters and postoperative SIJP.

Methods: We prospectively registered consecutive patients who underwent lumbar spine surgery. In the analyses, we excluded those in whom the sacroiliac joint (SIJ) score was more than 4/9 preoperatively, and those with hip osteoarthritis and an operated hip. We defined postoperative SIJP as unilateral buttock pain of the following criteria that occurred within three months of the surgery: > 4/9 SIJ score; positive response to analgesic periarticular SIJ injection with fluoroscopy; no residual nerve compression findings; and no misplacement of implants. The patients were divided into the SIJP group and the non-SIJP group. We compared the background information and analyzed the differences in spinopelvic parameters in both groups. Additionally, receiver-operating characteristic (ROC) curve analyses were performed to evaluate the cut-off values of spinopelvic parameters.

Results: Of the 281 patients enrolled, 265 were included and eight developed postoperative SIJP (3.0%). There were no significant differences in the background information between the groups. Preoperative and postoperative radiological evaluations revealed that the pelvic incidence (PI) in the SIJP group was significantly higher than that in the non-SIJP group, and there were no significant differences in both preoperative and postoperative lumbar lordosis (LL), pelvic tilt, sacral slope, and the PI minus LL. For preoperative PI, the area under the curve, cut-off value, sensitivity, and specificity were 0.73739, 59, 62.5%, and 81.9%, respectively.

Discussion: The incidence of SIJP following lumbar operations was 3.0%, which was lower than that previously reported. The difference could be attributed to the strict definition of SIJP and prospective evaluation in the current study. Preoperative evaluation of SIJ scores in all patients was a strength in this study. While the PI value of the non-SIJP group in our study was similar to the normative value, that of the SIJP group was higher. PI is a sum of PT and SS; therefore, both PT and SS tended to be higher in the SIJP group than in the non-SIJP group. However, there were not significant. Of the eight SIJP cases, only one included fixation surgery; the fixation was performed at L3/4/5 levels, without including L5/S1. Although there have been some reports that postoperative SIJP could result in adjacent segment degeneration of lumbosacral fixation, there could be other mechanisms of postoperative SIJP. The postoperative SIJP following decompression surgery without fixation might be a change in the sagittal alignment; however, the postoperative spinopelvic parameters were not much changed compared to the preoperative one. A possibility is that the true change of the posture was not detectable in the static evaluation based on standing radiographs. In conclusion, the incidence was 3.0%, and it was recommended to take care the SIJP following lumbar operations when PI was >59.

Low back pain after lumbar discectomy for disc herniation: what can you tell your patient?

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Introduction: Lumbar discectomy is frequently performed to alleviate radicular pain resulting from disc herniation. While this goal is achieved in most patients, improvement in low back pain (LBP) has been reported inconsistently. The goal of this study was to characterize how LBP evolves following discectomy.

Methods: We performed a retrospective analysis of the Canadian Spine Outcomes Research Network (CSORN) registry. Patients who underwent surgery for lumbar disc herniation were eligible for inclusion. The primary outcome was a clinically significant reduction in the back pain numerical rating scale (BPNRS) assessed at 12 months. A binary logistic regression was used to model the relationship between the primary outcome and potential predictors.

Results: There were 751 patients included in the analysis. The chief complaint was radiculopathy in 79%; 47% underwent a minimally invasive procedure and 26% underwent fusion. BPNRS improved at 3 months by 43% and this improvement was sustained at all follow-ups. LBP and leg pain improvement were correlated. Clinically significant improvement in BPNRS at 12 months was reported by 57% of patients. Six factors predicted a lack of LBP improvement: the number of operated level, low education, marriage, not working, low expectations with regards to LBP improvement and a low BPNRS preoperatively.

Discussion: Clinically significant improvement in LBP is observed in 57% of patients after lumbar discectomy. These data should be used to better counsel patients.

Factors associated with bony fusion after lateral interbody fusion for adult spinal deformity

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Purpose: In the surgery for adult spinal deformity (ASD), multi-level lateral interbody fusion (LIF) is conducted to correct 3-dimensional spinal deformity. Because larger LIF cage requires a larger amount of graft bone, we use porous hydroxyapatite/type 1 collagen composite to substitute for autologous iliac crest bone graft (IBG). The purpose of this study was to evaluate factors associated with intervertebral fusion after placement of LIF cages for ASD.

Methods: This is a single center retrospective study. Consecutive 31 ASD patients, 83 segments, (2 males, 29 females, mean age 68.2-years, mean follow-up 27.7 months) who underwent LIF and posterior spinal fusion more than 4 segments were enrolled into this study. The concave slot of the LIF cage was filled with autologous IBG, and the convex slot with porous hydroxyapatite/type 1 collagen composite, respectively. Fusion status was evaluated by CT-multiplanar reconstruction images after 12 months surgery. Fusion was defined as “a trabecular continuity of more than 1 mm between adjacent vertebrae, passing through the cage space in either coronal or sagittal planes” according to Lee and Kushioka. Factors analyzed regarding association with intervertebral fusion included age, gender, intervertebral level, material of cage (titanium alloy or polyetheretherketone), and perioperative use of teriparatide.

Results: Intervertebral fusions were obtained in 61 segments (73.5%) at 12 months after surgery. Fusion only on the concave side (autologous IBG side) was observed in 28 segments (33.7%), only on the convex side (porous hydroxyapatite/type 1 collagen composite side) was observed in 4 segments (4.8%), and on both concave and convex sides was observed in 29 segments (34.9%). Fusion was observed significantly more in the concave slot ($p=0.002$). Use of teriparatide was significantly associated with fusion ($p=0.046$), however, age ($p=0.208$), gender ($p=0.400$), I intervertebral level ($p=0.348$) or material of cage ($p=0.292$) was not associated with fusion.

Discussion: The fusion rate of ASD surgery using LIF cages was 73.5% after 12-month surgery. The fusion rate was higher on the concave slot filled with autologous IBG than on the convex slot filled with porous hydroxyapatite/type 1 collagen composite. Teriparatide might have accelerated fusion in the LIF cages. Therefore, grafting autologous IBG in LIF cage and use of perioperative teriparatide are recommended in the surgical treatment for ASD to enhance a fusion rate.

The value of selective diagnostic nerve root block in the treatment of multilevel degenerated lumbar spinal stenosis

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Objective: Lumbar spinal stenosis is the most frequent indication for spinal surgery in elderly patients. However, in clinical practice, some patients have undergone multi-level, large-scale decompression and internal fixation surgery due to the unclear location of the responsible segment. This increases the surgical trauma, reduces the stability of the spine, leads to the increase of iatrogenic injuries and surgical complications. Therefore, it is very important to define the responsibility section before surgery. The aim of this study is to investigate the diagnostic value of selective nerve root block in the treatment of multilevel lumbar degenerative diseases.

Methods: Thirty-eight cases of lumbar degenerative diseases with atypical clinical signs and multilevel degeneration, treated from July 2016 to December 2016 with selective nerve root block for confirmation of responsibility segments on the basis of surgical decompression or fusion segment, were retrospectively analyzed. Predicting the orifice root or the traveling root, which one was compressed was necessary before operation through preoperative imaging. Reach the target through precise puncture. The dosage of lidocaine used for diagnosis is enough to avoid blocking both the orifice root and the traveling root at the same time, and to avoid the occurrence of epidural block, so that the location can not be completed. If the symptoms of the patients were relieved by 50%-70% after blocking, the nerve roots of the previous segment were blocked after the local anesthesia disappeared to determine all the responsible segments. If the symptoms are not relieved, the nerve root is excluded. The VAS and JOA scores were compared before and 7 d, 3 months, 12 months after operation, and at the end of the follow-up period.

Results: The accuracy of selective nerve root block in determining responsibility segments was significantly higher than that of MRI examination, the difference was statistically significant ($P < 0.05$). All 38 patients were followed up for (12.6 ± 3.1) months, no residual nerve root symptoms were observed. Seven days, 3 months, 12 months after operation and at last followup, the VAS score and JOA score were significantly improved compared with those before operation, the difference was statistically significant ($P < 0.05$). Seven days, 3 months, 12 months after operation and at last follow-up, there were no statistically significant differences in the VAS score and JOA score ($P > 0.05$). Conclusion: For patients with responsibility segment -undefined multilevel lumbar degenerative diseases, preoperative selective nerve root block can locate the responsibility segment. Then the individual surgical treatment can ensure the postoperative effect and the long-term stability of the spine, and can also avoid the trauma caused by preventive decompression and long segmental fusion and the long term complications as well.

Five-year postoperative good outcomes after facet fusion using a percutaneous pedicle screw system for degenerative lumbar spondylolisthesis

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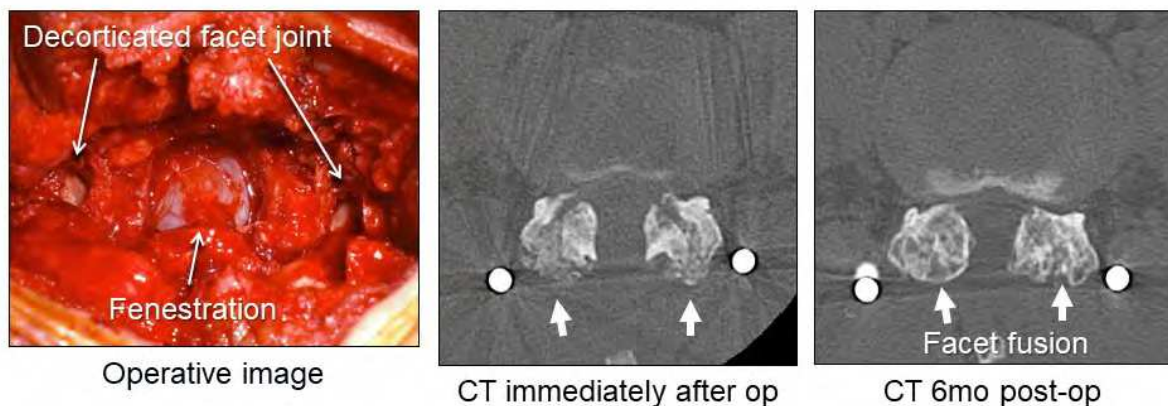
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Introduction: We observed good clinical outcomes after posterolateral fusion (PLF) in terms of *in situ* fusion, a low incidence of adjacent segment disease (ASD), and the lack of need for slippage reduction in a long-term clinical and radiological follow-up study of PLF for degenerative lumbar spondylolisthesis (DLS). Furthermore, we previously found that facet fusion (FF) using a percutaneous pedicle screw (PPS) system as a minimally invasive evolution of PLF also resulted in good clinical outcomes. Here, we assessed clinical outcomes 5 years after FF.

Methods: The indications for lumbar fusion were: 1) sagittal translation $\geq 8\%$ on a flexion-extension lateral radiograph or 2) anterior wedging ≥ 5 degrees on a flexion radiograph and a disc range of motion (ROM) ≥ 10 degrees. Seventy-four of 95 consecutive patients (43 women, 31 men; mean age, 68.7 years; follow-up rate, 77.9%) who underwent FF for single-level DLS were retrospectively reviewed after a minimum follow-up of 5 years. The surgical method involved making a 5-cm skin incision, bilateral laminar fenestration, and FF with autologous bone harvested from the spinous process. PPS insertion was performed through the fascia. We evaluated the therapeutic effectiveness of FF using the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), Roland-Morris Disability Questionnaire (RMDQ), and visual analogue scale (VAS) preoperatively and at 1 and 5 years postoperatively. The revision surgery rate was also evaluated.

Results: The therapeutic effectiveness rate, determined using the JOABPEQ, increased in all categories from 1 to 5 years postoperatively, including in the Low Back Pain score, which increased in 75.7% to 82.1% of the patients; however, the Walking Ability score showed a decrease from 95.5% to 83.0% of the patients. The mean RMDQ value and VAS score were significantly decreased at 1 year postoperatively and maintained at 5 years postoperatively. There was no statistically significant difference between the VAS scores for low back pain, buttock and lower limb pain, and numbness in the buttocks and lower limbs at 1 and 5 years postoperatively. There were four patients requiring revision surgery for ASD 1 to 5 years after the first surgery (revision surgery rate, 5.4%). Revision surgery for complications or poor clinical outcomes immediately after surgery was not required in any of the patients.

Discussion: FF maintained good clinical outcomes 5 years postoperatively. The revision surgery rate of 5.4% at 5 years after FF was extremely low compared to previously reported rates of 12.1% (Park et al.) and 12.9% (Greiner-Perth et al.) at 5 years after interbody fusion. Considering that good RMDQ and VAS values were maintained, the decreased 5-year postoperative therapeutic effectiveness in Walking Ability, determined via the JOABPEQ, might have been caused by aging. Low back pain did not worsen 5 years after *in situ* fusion. Thus, FF is useful in the long-term management of DLS.



1. Park Y, Ha JW, Lee YT, Sung NY. Minimally invasive transforaminal lumbar interbody fusion for spondylolisthesis and degenerative spondylosis: 5-year results. Clin Orthop Relat Res. 2014 Jun;472(6):1813-23.
2. Greiner-Perth R, Boehm H, Allam Y, Elsaghir H, Franke J. Reoperation rate after instrumented posterior lumbar interbody fusion: a report on 1680 cases. Spine (Phila Pa 1976). 2004 Nov 15;29(22):2516-20.

Impact of preoperative diagnosis on clinical outcomes of oblique lateral interbody fusion for lumbar degenerative disease in a single-institution prospective cohort.

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Introduction: Oblique lateral interbody fusion is considered a useful surgical option for various lumbar degenerative diseases with favorable clinical results and few complications. However, clinical outcomes following oblique lateral interbody fusion stratified according to the preoperative diagnosis in large size cohort have not been fully evaluated. The purpose of this study was to evaluate the clinical outcomes following oblique lateral interbody fusion for lumbar degenerative disease and to identify differences in outcomes when stratified according to preoperative diagnosis.

Methods: All patients receiving oblique lateral interbody fusion for lumbar degenerative diseases were included in the current study and were stratified into four diagnostic groups: 1) degenerative spondylolisthesis (DS group), 2) spondylolytic spondylolisthesis (SS group), 3) spinal stenosis without spondylolisthesis and instability (ST group), and 4) deformity (DF group). Clinical outcomes were assessed using multiple patient-reported questionnaires and radiologic outcomes including cage subsidence and completion of interbody fusion were also evaluated.

Results: Overall, 169 patients with 262 operative levels were included in the study. All clinical scores items showed significant improvement at 1-year postoperatively for all diagnostic groups. Net and percent improvement, a proportion of patients reaching a threshold for substantial clinical benefit were not significantly different between the diagnostic groups in all scoring items, except for lower extremity radiating pain of the deformity group. Although the DF group had the highest overall complication rate, neurologic complications were more frequent in the SS group. Additional direct decompression at the immediate postoperative period following the oblique lateral interbody fusion was required only in 3 of 169 cases (1.8%) in the current study. The rate of complete fusion and cage subsidence for individual levels at postoperative 1 year was 62.7% and 32.6% respectively, which showed no significant difference between the diagnostic groups.

Discussion: Despite the favorable clinical outcomes following indirect decompression in various lumbar degenerative diseases, the effectiveness of indirect decompression has not been clarified for specific conditions. In particular, there is little evidence regarding the clinical outcomes of OLIF in spinal stenosis without spondylolisthesis and dynamic segmental instability. The large prospective cohort of the present study included 22 cases of spinal stenosis without spondylolisthesis and instability designated as the ST group. Regarding the final raw score, net, and percent improvement of clinical scores, the ST group showed no significant differences when compared to the DS and SS groups, which are considered typical indications for OLIF. These results suggest that OLIF can be a useful surgical method even in cases of spinal stenosis without spondylolisthesis and instability.

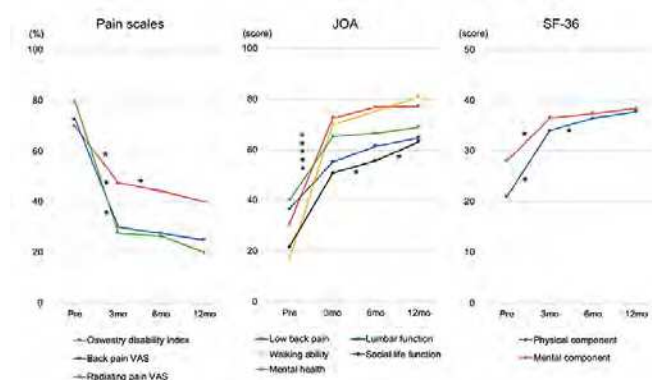


Figure 1. Serial change of clinical scores following OLIF. (Abbreviations: JOA; Japanese Orthopedic Association Back Pain Questionnaire, SF-36; Short Form-36 Health Survey, VAS; visual analogue scale, Pre; preoperative, mo; months) *An interval with statistically significant change (by paired t-test).

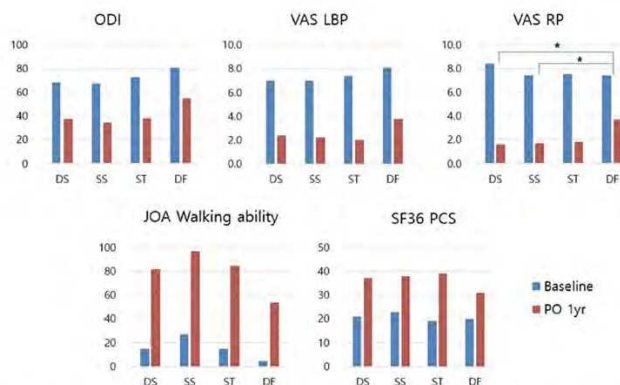


Figure 2. Comparison of baseline and postoperative 1-year clinical scores after stratification into preoperative diagnosis. (Abbreviation: DS; degenerative spondylolisthesis group, SS; spondylolytic spondylolisthesis group, ST; spinal stenosis group, DF; deformity group)

Predictors of surgical outcomes in adult spinal deformity

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Introduction: With the aging of society and the development of minimally invasive surgical procedures, surgical opportunities for treating adult spinal deformity (ASD) are increasing. However, since this treatment is based on a relatively new concept of spinal imbalance, there are many unclear points about the preoperative factors affecting surgical outcome. In this report, we have elucidated the predictors of surgical outcomes in ASD.

Methods: In this retrospective study, we included 58 patients (4 men and 54 women), in the age range of 52 to 81 years (mean age, 71±6) who were diagnosed with adult spinal deformity (Degenerative Lumbar Kyphoscoliosis) and had undergone spinal fusion, between January 2011 and August 2017. We used the satisfaction level (0-10) at 1-year after surgery and the change in the Oswestry disability index (ODI; 1-year postoperative % - preoperative %) as the indications for surgical outcome (objective variable). The preoperative factors (explanatory variable) included sex, age, body mass index (BMI), preoperative C7 Sagittal Vertical Axis (SVA), Pelvic Incidence-Lumbar Lordosis (PI-LL), ODI(%), Japanese Orthopedic Association (JOA) score, the score of 5 domains in the JOA Back Pain Evaluation Questionnaire (JOABPEQ), lumbar Visual Analog Scale (VAS)(low back pain, leg pain, numbness), presence or absence of Kitchen Elbow Sign (KES; changes in the skin from elbow to forearm caused by supporting with the elbows during work in the standing position). We performed multiple regression analysis to identify predictors of surgical outcomes (significance level: $p < 0.05$).

Results: Leg VAS (standard partial regression coefficient, $\beta = 0.44$), ODI (-0.55), and KES (0.4) were the preoperative factors significantly associated with the satisfaction level. Age (standard partial regression coefficient, $\beta = 0.33$), JOABPEQ social life function (-0.67), ODI (-0.79), and KES (-0.36) were the preoperative factors significantly associated with the changes in the ODI(%).

Discussion: This is the first report to elucidate the predictive factors associated with patient satisfaction as well as patient disability for the surgical outcomes of ASD. Current results suggest that greater involvement in preoperative social activity leads to higher levels of improvement and satisfaction following the treatment.

Types of nerve root anomalies with the high risk for nerve root injury during surgery can be identified with MR Neurography

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Introduction: Nerve root anomalies are the most important factor causing iatrogenic nerve root injury during surgery. In order to avoid nerve root injury during surgery, it is important to diagnose nerve root anomalies before surgery, but it was not easy to identify nerve root morphological abnormality by conventional imaging method. In recent years the development of a new imaging method has made it possible to clearly show nerve root morphology. Our objectives are to describe 2 cases of nerve root anomalies deeply related to nerve root injury during surgery, to discuss an unclassified variant of the Neider and Macnab classification.

Subject and methods: High resolution MR Neurography has been adopted, and the sequence has been taken with 3D-SHINKEI (Phyllips). The morphological appearance of nerve root anomalies was classified using the system developed by Neider and Macnab. The subjects were 8 cases 9 roots (5 males, 3 females, average age 65 years) diagnosed with MR Neurography as a nerve root anomaly.

Results: Nerve root anomalies were unilateral in 8 cases and bilateral in only one case with hemi vertebrae of L5. Of the nerve root anomalies, the conjoined type was 7 roots (L4-L5; 3 roots, L5-S1; 4 roots), the accompanied type was 1 root, and an unclassified anomaly type in Neider and Macnab classification was 1 root (Case 1). This type was a confluent nerve root anomaly consists of 2 nerve roots (L5-S1) that arise separately from the dural sac with caudal origin of L5 root and join together distally at the left L5-S level. Surgery was performed in 5 of 8 cases. Nerve root injury occurred during surgery in Case 1. In L4-L5 conjoined roots with cranial origin of L5 root at L4-5 level (Case 2), we found that the L5 root which was located on the most lateral side of the spinal canal had the high risk for nerve root injury.

Discussion: Neider and Macnab classification is the most frequently used for lumbosacral nerve root anomalies. It is classified into three types, conjoined (Type 1), redundant (Type 2), and anastomotic (Type 3). However, the anomaly observed in Case 1 is not described by the classification. The confluent nerve root has been proposed by Burke et al. 2013 as Type 4 anomaly in the classification. In this anomaly, because the intervertebral disc is covered with nerve roots in the intervertebral foramen, it is extremely high risk for injury to the exiting nerve root during discectomy. In fact, the anomalous nerve root has been injured during surgery. In Case 2, the positional relationship between the nerve root and the dural sac is different from the usual spinal canal stenosis, so the nerve root is easily injured. These two cases were identified as nerve root anomalies during surgery, but retrospectively it was possible to judge nerve root anomalies in MR Neurography before surgery. Since the nerve root morphology was clearly depicted by MR Neurography, diagnosing the presence of nerve root anomalies before surgery has become important to avoid nerve root injury.

Is PROMIS Physical Function more relevant for lumbar spinal disorders than for cervical spinal disorders?

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Introduction: As the focus in spine surgery shifts from radiographic to patient-centric outcomes, patient-reported outcomes measures (PROMs) are increasingly being used to assess patient satisfaction, and evaluate healthcare expenditure, compensation and cost-effectiveness. While ODI and NDI have been the most commonly used PROMs in spinal disorders, Patient-Reported Outcomes Measurement Information System (PROMIS) is a relatively new outcome measure that is increasingly being implemented. The purpose of this study was to evaluate whether PROMIS Physical Function (PROMIS-PF) is a good surrogate for disease-specific outcome measures in common spinal conditions.

Methods: PROMs collected pre-operatively and 2 weeks, 6 weeks, 3 months and 6 months post-operatively were analyzed. Pearson product-moment correlation was used for correlations between ODI and PROMIS-PF in lumbar surgery, and between NDI and PROMIS-PF in cervical surgery. Fisher Z-transformation was used to compare the strength of correlations at each time-point.

Results: Of the 378 patients included, 292 underwent lumbar and 86 underwent cervical spinal procedures for degenerative conditions of the spine. In lumbar patients, ODI decreased from 40.84±19.23 pre-operatively to 19.66±16.24 at 6 months; and PROMIS-PF improved from 35.51±7.92 to 45.55±9.30. In cervical patients, NDI decreased from 36.32±19.62 pre-operatively to 21.81±16.32 at 6 months; and PROMIS-PF improved from 19.19±8.05 to 46.13±7.12.

A statistically significant negative correlation was seen at all time-points, which was strong between ODI and PROMIS-PF, but moderate between NDI and PROMIS-PF.

A comparison of the strengths of the correlations showed that the correlation between ODI and PROMIS-PF was greater than that between NDI and PROMIS-PF at all time-points, with this difference being statistically significant at 6 weeks, and approaching statistical significance pre-operatively and at 2 weeks. It is likely that these difference would have been statistically significant at other time-points with a larger sample size.

Discussion: These findings indicate that ODI and PROMIS-PF are highly correlated, but NDI and PROMIS-PF are only moderately correlated. Thus, PROMIS-PF appears to adequately capture functional impairment due to lumbar disease, but not that due cervical disease. Prior studies have shown PROMIS to be correlated with legacy measures, and computer adaptive testing allows for faster administration and reduced patient burden. Despite these advantages, it is important to keep in mind that PROMIS was designed to be used across diseases and it may not adequately capture the impact of disease-specific disability in all patient populations. Larger studies are warranted to evaluate the utility of PROMIS in common spinal conditions, and to determine in which patient populations it is truly applicable and relevant.

Table 1: Correlations

	Number of observations (n)	Pearson Correlation Co-efficient (r)	Strength of Correlation	p - value
ODI and PROMIS-PF				
Pre-operatively	256	-0.673	Strong	<0.0001
2 weeks	228	-0.715	Strong	<0.0001
6 weeks	190	-0.779	Strong	<0.0001
3 months	130	-0.732	Strong	<0.0001
6 months	80	-0.685	Strong	<0.0001
NDI and PROMIS-PF				
Pre-operatively	67	-0.530	Moderate	<0.0001
2 weeks	60	-0.598	Moderate	<0.0001
6 weeks	54	-0.559	Moderate	<0.0001
3 months	38	-0.662	Strong	<0.0001
6 months	27	-0.498	Moderate	0.008

Table 2: Comparison of the strength of correlations

	Pearson Correlation Co-efficient (r)		z	p-value
	ODI & PROMIS-PF	NDI & PROMIS-PF		
Pre-operatively	-0.673	-0.530	1.62	0.0526
2 weeks	-0.715	-0.598	1.4	0.0808
6 weeks	-0.779	-0.559	2.6	0.0047
3 months	-0.732	-0.662	0.72	0.2358
6 months	-0.685	-0.498	1.25	0.1056

Changes of ODI item score pattern and spinopelvic parameters after implant removal of posterior instrumented fusion for the unstable thoracolumbar fracture

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Introduction: Implant removal after successful fusion of unstable thoracolumbar fracture may improve clinical and radiological outcome. There are still limited evidences. Therefore, we evaluated clinical and radiological outcome after implant removal of posterior spinal instrumentation for the unstable thoracolumbar fracture.

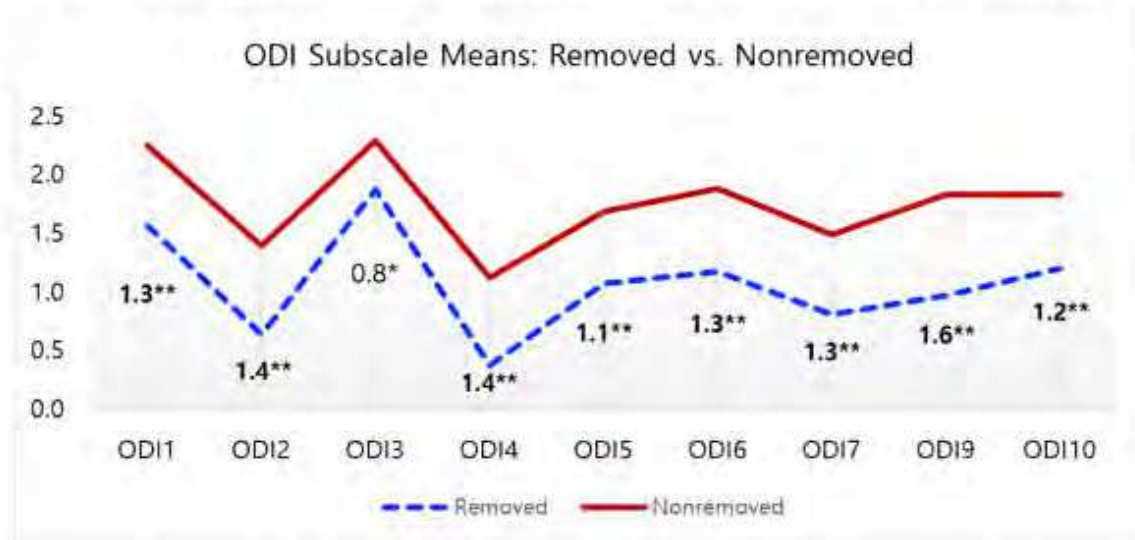
Methods: We analyzed 30 consecutive patients (removal group) who had been treated with posterior instrumentation and bone graft for the unstable thoracolumbar fracture and the control group is the non-removal group (n=41). All patients were evaluated with total score and each item score of Oswestry disability index (ODI), and spinopelvic parameters (bi-segmental Cobb angle of fractured vertebra, sagittal vertical axis, pelvic tilt, sacral slope, pelvic incidence, thoracic kyphosis and lumbar lordosis) before removal surgery and at final follow-up. All parameters before removal surgery and at final follow-up were compared using repeated measured t-test and for the analysis of change of each item of ODI, profile analysis via principal component analysis was used. All parameters of the control group evaluated with same methods at similar follow-up time interval from index surgery.

Results: The average age was 43.0±13.6 years. The mean-time of implant removal after the operation is 36.1±25.5 months. After removal operation, total score of ODI (14.7±9.7 vs. 10.4±6.5, p=0.007) changed significantly. For the changes of each item of ODI, ODI 1 (pain intensity, 2.0±1.2 vs. 1.6±0.8, p=0.017), ODI 2 (personal care, 1.3±1.2 vs. 0.6±0.7, p=0.005), ODI 5 (sitting, 1.6±1.2 vs. 1.1±0.7, p=0.005), ODI 6 (standing, 1.7±1.2 vs. 1.2±0.8, p=0.019) changed significantly. Among radiological parameters, only bi-segmental Cobb angle (10.2±8.0° vs. 13.1±13.0°, p=0.034) changed significantly after removal operation.

Between the removal and the non-removal groups, there were no significant differences in baseline parameter. Total ODI scores (10.4±6.5 in removal group vs. 17.3±10.6 in non-removal group) were significantly different. All of each item of ODI were significantly different (Figure 1.). There were no significant differences of radiologic parameters between groups.

Conclusions: Clinical outcome of patients with posterior instrumented fusion for the unstable thoracolumbar fracture was improved after implant removal. With the results of change of each item of ODI, patients with the implant removal showed better clinical outcome in comparison with non-removal. After implant removal, there was no change in global spinal sagittal balance, even with local kyphosis.

Figure 1. The change of each item of ODI between the removal and the non-removal group.



The numbers included in the figure were effect sizes. According to Cohen (1977), the effect size between 0.3 to 0.5 is small; between 0.5 to 0.8 is medium; and equal to or larger than 0.8 is large.

Facet angle and its importance on joint violation in percutaneous pedicle screw fixation in lumbar vertebrae: a retrospective study

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Introduction: Current percutaneous pedicle screw fixation technique has a high facet violation rate than open surgery, and the relationship of facet joint violation and facet angle has not been studied. This study is aimed to investigate the relationship between the facet angle (FA) at the pedicle level and facet joint violation (FJV) in percutaneous pedicle screw fixation in lumbar vertebrae.

Methods: Prospective imaging analysis was conducted for 115 cases who underwent percutaneous pedicle screw fixation from December 2013 to November 2016 by the same group of surgeons using the same technique, in the spine surgery center of our hospital. The FA at the pedicle level was measured by computed tomography, and diagnosis and evaluation of FJV grade was performed postoperatively. The effect of the variant FA and lumbar segment (L1-L5) on FJV, and the correlation between FA and the FJV and FJV grade in percutaneous pedicle screw fixation were evaluated.

Results: A total of 476 percutaneous pedicle screws were included: 144 L1, 136 L2, 64 L3, 72 L4, and 60 L5 screws, with a total FJV rate of 30.46% (145/476). The FJV rate was 28.78% in upper lumbar group with 344 screws (99/344), and 34.85% in lower lumbar group with 132 screws (46/132). There was no significant difference between groups with regards to FJV rate, and age, gender, or BMI index. Evaluation of variant FA and lumbar segment on FJV rate indicated that FJV rate increased dramatically when FA>35 degree, however, FJV rate was not significantly related to the lumbar segment. There was a positive correlation between FA and FJV rate, as well as FA and FJV grade.

Discussion: There was a positive correlation between the increase of the facet angle at the pedicle level, and the FJV rate and FJV grade. The FJV risk increased remarkably when the FA was over 35 degree.

The improvement of sleep quality after surgery in patients with lumbar spinal stenosis

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Introduction: In our previous work, there were strong associations between symptomatic LSS and poor sleep quality. Sleep quality is a critical factor in determining functional disability and health-related quality of life in symptomatic LSS patients. For the association between lumbar spinal stenosis and sleep disturbance. However, we still don't know whether the surgery for LSS brings the improvement of sleep quality in patients with LSS. Therefore, the purpose of this study was to investigate the change of sleep quality after spine surgery in patients with LSS.

Methods: As a prospective observation study, total of 66 patients were enrolled in this study. All patients were assessed clinical outcomes including visual analog pain scale (VAS) for back and leg pain, Oswestry disability index (ODI), and EuroQol 5-dimension questionnaire (EQ-5D), and sleep quality by the Pittsburgh Sleep Quality Index (PSQI) before and 3 – 6 months after surgery. Continuous and categorical variables were compared between preoperative and postoperative states using paired t-test and McNemar test, respectively.

Results: Mean age \pm standard deviation (SD) was 69.8 ± 8.6 . Fifty-one (77.3%) and 36 (54.5%) patients were classified into poor sleeper preoperatively and 3 – 6 months after surgery, respectively, which changes were statistically significant ($P = 0.001$). Compared to preoperative states, VAS for back pain and leg pain, ODI, EQ-5D, and Global PSQI scores were significantly improved after surgery ($P < 0.001$ for all variables). The change of PSQI was significantly associated with the change of ODI and EQ-5D between preoperative and 3 – 6 months after surgery.

Discussion: After spine surgery for LSS, the rate of poor sleeper were significantly decrease, and this changes were related with the changes of clinical variables. Therefore, successful surgical outcomes for LSS would improve sleep quality in patients with LSS.

Anterior reconstruction surgery for osteoporotic vertebral fractures.

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Introduction: Anterior reconstruction of fractured vertebra is biomechanically ideal to prevent kyphotic deformity or subsequent fractures. However, there are many problems to be solved for applying them to Osteoporotic Vertebral fractures (OVFs) patients. Implant failures, cage sinking and high invasiveness to aged patients are unsolved problems. Recently launched X-core® VBR system (X-core) which has unique rectangular endplates enables rigid mechanical stabilization. Reduction of fixed levels and blood loss may be other advantages of this technique compared to the posterior osteotomy such as pedicle-subtraction osteotomy (PSO) or posterior vertebral column resection (pVCR). In this study, we compared the clinical results of anterior reconstruction using X-core with posterior instrumented reconstruction surgeries for OVFs and will discuss about the usefulness of this surgery.

Methods: Retrospective cohort study using medical records and routinely examined radiographs. From 2015 to 2017, twenty-one X-core surgeries were performed for OVFs in our institution. We compared op. time (min), EBL (ml), performance status (PS) and peri-operative complications with 15 patients who underwent pVCR or PSO (group P) in our institution between 2010 and 2017. Furthermore, we analyzed the clinical data including sagittal alignment of group A.

Results: Average age of patients was 72.6 in group P and 74.8 in group A. Op. time/ EBL were 341 min. and 991 ml in group P and 286 min. and 412 ml in group A. Pre-/ post- PS were 2.7/ 2.1 in group P and 3.4/ 2.0 in group A. Two screw back-out/ two adjacent vertebral fracture and one rod fatigue fracture were observed in group P. One cage sinking, one deep infection and one adjacent VCFs were observed in group A. Preoperative local kyphotic angle in group A was 25.4 degrees and it improved 1.5 degrees after surgery. Postoperative sagittal vertical axis (SVA) was 89.7 mm which was 110 mm before operation. Clinical improving such as JOA score, VAS or PS were not statistically correlated with alignment changes.

Discussion: Anterior reconstruction surgery of fractured vertebra are well known. However, there are many problems to adapt it for OVFs. One big problem is the cage sinking and subsequent alignment loss. another problem is the invasiveness of anterior surgery for elderly patients. Regarding cage sinking and alignment, our results showed that cage sinking was less than 5 % and subsequent alignment changes did not affect the clinical results in OVFs. Also, op. time and EBL were less in X-core group. So it is indicated that anterior reconstruction surgery for OVFs using newly launched implants brought less invasive and better clinical outcomes compared with posterior osteotomy.

Preoperative risk factor of adjacent segment degeneration after two-levels floating posterior fusion at L2-L4 or L3-L5 levels

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Introduction: Many study has reported that multilevel fusion is one of the risk factors for predicting adjacent segment degeneration (ASD) in patients after posterior lumbar fusion. In particular, it has been said that ASD has occurred most frequently in two-level fusion. But there are few reports of the risk factor for predicting ASD in patients after two-level fusion. Our study was done to identify preoperative factor which may be important in the development of ASD in two-levels floating fusion at L2-L4 or L3-L5 levels.

Methods: A retrospective study was conducted on a consecutive series of 72 patients who underwent two-level posterior lumbar fusion (postero-lateral fusion or posterior lumbar interbody fusion, transforaminal lumbar interbody fusion) for degenerative lumbar disease between July 2012 and July 2015. Radiographic ASD (R-ASD) was defined as development of spondylolisthesis > 3mm, decrease in disc height >3 mm, or intervertebral angle at flexion lesser than -5° or 5°. We collected preoperative information regarding body mass index (BMI), segmental lordosis, lumbar lordosis, adjacent disc height, segmental cobb angle, upper instrumented vertebra (UIV) tilt, disc degeneration (Pfirrmann Classification), apical vertebrae rotation (Nash & Moe Classification). Statistical analyses were performed to identify correlates of upper segment of R-ASD.

Results: A total of 46 patients who underwent two-level fusion at L2-L4 or L3-L5 and were followed up for more than one year after surgery. R-ASDs were occurred in 17 patients, 16 were occurred at upper segment and 2 were at lower segment. Symptomatic ASD which required reoperation was not observed. Statistically significant factor affecting R-ASD which occurred at upper segment was only absolute value of preoperative UIV tilt. ROC analysis demonstrated that 10.9 degrees of absolute value of UIV tilt was the most contributing angle (sensitivity 83.3%, specificity 73.3%). Other factors such as BMI, segmental lordosis, lumbar lordosis, adjacent disc height, cobb angle, disc degeneration, apical vertebrae rotation did not contribute to R-ASD.

Discussion: As previously reported, R-ASD occurred mostly at the upper segment. And our results indicate that UIV tilt $\geq 10^\circ$ or UIV tilt $\leq 10^\circ$ is the preoperative risk factor for R-ASD in patients who underwent two-levels floating fusion. This is probably because the greater the UIV tilt, the greater the moment force from the body weight on the upper segment increases. We can easily measure preoperative UIV tilt on a lumbar X - ray image taken in the standing or sitting position, without the data of global alignment, so UIV tilt may be a convenient indicator.

How does the preoperative HR-QOL affect the postoperative satisfaction of patients with degenerative lumbar spondylolisthesis who underwent surgery ?

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Introduction: Surgical treatment of degenerative lumbar spondylolisthesis (DLS) may involve a decompression alone or decompression in combination with a fusion procedure. Good results have been reported for both types of surgery. However, it is also true that there are patients who are not satisfied postoperatively. The purpose of this study was to examine the preoperative factors affecting satisfaction following surgery by investigating cases in which the operation was performed.

Method: 72 patients who underwent surgery for one level mild DLS and followed for more than 5 years were included. We performed posterior lumbar interbody fusion (PLIF) for 48 patients and micro endoscopic muscle-preserving interlaminar decompression (ME-MILD) for 24 patients. The postoperative satisfaction was considered to be poor when subgroup of Zurich Claudication Questionnaire (ZCQ), satisfaction, was under 2 point. Clinical characteristics studied included sex, age, pathology and preoperative health-related QOL such as JOA Back Pain Evaluation Questionnaire (JOABPEQ), Short-Form 36 (SF-36), and visual analogue scales (VAS) were investigated to determine endogenous factors. We performed univariate analysis to determine the factors significantly affecting postoperative satisfaction.

Result: 12 patients (50%) in ME-MILD group and 27 patients (57.3%) in PLIF group were classified as satisfied group. In ME-MILD group, preoperative lumbar spine dysfunction ($P < 0.001$) of JOABPEQ, and Role Physical ($P = 0.04$) and Role Emotional ($P = 0.03$) of SF-36 was statistically significant between satisfied and unsatisfied groups. And there was a strong correlation between preoperative lumbar spine dysfunction and postoperative satisfaction ($r = 0.59$). No factors were endogenous factors affecting postoperative satisfaction in PLIF group.

Conclusion: In this study, we analysed to examine the preoperative QOL factors affecting satisfaction following PLIF and ME-MILD by investigating cases in which the operation was performed. Preoperative lumbar spine function correlated with postoperative satisfaction in ME-MILD group. For cases in which lumbar spine function has declined before surgery, the effect of function preservation, which is an advantage of this operation, may be limited.

Does pre-operative muscle health impact pre-operative health related quality of life scores for patients with lumbar pathology?

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Introduction: Lumbar muscle health has been implicated in the development of disability for patients suffering from lumbar radiculopathy and low back pain. The purpose of the present study was to evaluate the health of lumbar musculature for patients that would eventually undergo an operation for lumbar pathology including disc herniations, lumbar spinal stenosis, neurogenic claudication and facet cysts.

Methods: We performed a retrospective review of patients that eventually went on to undergo a procedure for lumbar pathology. We analyzed magnetic resonance imaging (MRI) to quantify muscle health using validated measures of cross sectional area using the lumbar indentation value (LIV) and lumbar muscle fatty atrophy using the Goutallier classification. T2 axial slices from the disc space at the operative level were analyzed. We graded fatty atrophy on a 0-4 scale and the LIV was calculated using standard techniques of measuring the distance between the tip of a spinous process and a line tangential to the muscular fascia. Goutallier classifications were performed on both the combined multifidus and erector spinae muscles as well as individually for the multifidus muscle. Health related quality of life (HRQOL) scores were collected on all of these patients in the pre-operative period. These scores included the Visual analog back and leg (VAS leg and VAS back) scores, the Oswestry Disability Index (ODI), Short Form 12 (SF-12) mental health and physical health scores and patient-reported outcome measures (PROMIS). We performed a linear regression analysis to determine the relationship of pre-operative LIV and the HRQOLs listed. We also performed an ANOVA analysis to identify the relationship between Goutallier classification and HRQOLs listed and to identify differences in LIV/Goutallier classifications based upon pre-operative diagnosis.

Results: A total of 95 patients were included within our analysis. The average age was 57.9 +/- 14.4 years old and there were 50 men and 45 women. There were 107 disc spaces operated on within this cohort. The most common pre-operative diagnosis was lumbar spinal stenosis (58 patients). We found that the average LIV was 16.1 +/- 7.5 mm. The most common Goutallier classification for the entire lumbar musculature and the multifidus by itself was 2. There was no statistically significant difference in LIV, Goutallier classifications and the pre-operative diagnosis of patients. The pre-operative Goutallier classification of the entire lumbar musculature was inversely proportional to PROMIS scores (0.007) and inversely proportional to the ODI ($p < 0.001$). The only pre-operative score that had a statistically significant correlation to the Goutallier classification of the multifidus muscle was with PROMIS scores ($p = 0.005$). LIV had a positive correlation with PROMIS scores ($p = 0.01$) and an inverse relationship with the VAS leg score ($p = 0.04$).

Discussion: Muscle health contributes significantly to pre-operative disability as measured by various HRQOL scores. These findings further emphasize the relationship between lumbar degenerative conditions and muscle degeneration. Further research is required to understand how improving pre-operative muscle health might impact long term clinical outcomes after surgery for lumbar radiculopathy.

Prospective multicenter surveillance and risk factor analysis of deep surgical site infection after posterior instrumented fusion surgery of the thoracolumbar spine for degenerative diseases

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Introduction: Surgical site infection (SSI) is a serious and significant complication after spinal surgery, and it is associated with high morbidity rates, high healthcare costs, and poor patient outcomes. The accurate identification of risk factors is essential for developing strategies to prevent devastating infections. The purpose of this study was to identify independent risk factors for SSI in adults undergoing posterior instrumented fusion surgery of the thoracolumbar spine using a prospective, multicenter, surveillance research method.

Methods: From July 2010 to June 2015, we performed a prospective surveillance study in adult patients (> 17 yrs.) who had developed deep SSI following posterior instrumented fusion surgery of the thoracolumbar spine for degenerative diseases at 10 participating hospitals. Detailed preoperative and operative patient characteristics were prospectively recorded using a standardized data collection form. The recorded patient-related characteristics included age at time of surgery, sex, body mass index (BMI), smoking, diabetes mellitus, hemodialysis, American Society of Anesthesiologists (ASA) score and steroid use. The recorded surgery-related characteristics included operating time, estimated blood loss, anatomic location of spinal surgery (thoracic, lumbar, sacroiliac), emergency surgery, iliac crest bone grafting, dural tear and use of intraoperative fluoroscopy. Identification of SSI was based on the Centers for Disease Control and Prevention definition. Data were analyzed using multivariate regression analysis with $P < 0.05$ set as the significance level.

Results: A total of 2,913 consecutive adult patients were enrolled, of whom 35 (1.2%) developed deep SSI. Multivariate regression analysis indicated 3 independent risk factors: male sex ($P = 0.002$) and ASA score > 2 ($P = 0.0003$) were independent patient-related risk factors, whereas fusion surgery of thoracic spine ($P = 0.018$) was an independent surgery-related risk factor against developing SSI.

Discussion: Male sex, ASA score > 2 and Smoking was an independent risk factor, and fusion surgery of thoracic spine were independent risk factors for deep SSI after posterior instrumented fusion surgery of the thoracolumbar spine for degenerative diseases. There is a paucity of past study that identified surgery of thoracic spine as an independent risk factor for SSI. Identification of these risk factors for SSI could be used to develop protocols to decrease the risk of SSI.

Evaluation of the surgical stress in the lumbar interbody fusion using E-PASS Scoring System

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Introduction: Predictive surgical risk scores have been developed for general surgery. Among several risk scores, the usefulness of Estimation Physiologic Ability and Surgical Stress (E-PASS) score in orthopaedic field has been reported. The purpose of this study was to investigate the surgical risk of posterior lumbar interbody fusion (PLIF) and Lateral lumbar interbody fusion (LLIF) for the patients with lumbar spinal canal stenosis using preoperative risk score (PRS) and surgical stress score (SSS) in E-PASS. Furthermore, incidence of complications after each surgery was clarified and compared with E-PASS score.

Materials and Methods: Clinical data were collected on 173 (104 were female and 69 were male) consecutive patients who underwent lumbar interbody fusion for lumbar spinal canal stenosis with degenerative spondylolisthesis or disc degeneration. The surgical procedure included 51 patients treated with single level PLIF (group P1), 21 patients treated with 2 levels PLIF (group P2), 65 patients treated with single level LLIF with percutaneous pedicle screw; PPS (group L1) and 36 patients treated with 2 levels LLIF with PPS (group L2). We calculated PRS and SSS in E-PASS and compared in each group, and investigated the relationship between the E-PASS scores and postoperative complications within 1 week after surgery.

Results: A mean age at the surgery was 66.9 years (range, 36-90 years). A mean PRS (\pm S.D.) were 0.498 ± 0.123 in the group P1, 0.510 ± 0.140 in the group P2, 0.520 ± 0.143 in the group L1, and 0.516 ± 0.104 in the group L2. There is no statistically significant difference in each group. A mean SSS (\pm S.D.) were -0.176 ± 0.044 in the group P1, -0.060 ± 0.081 in the group P2, -0.252 ± 0.026 in the group L1, and -0.208 ± 0.041 in the group L2. SSS in each group showed a significantly higher value in order of the group L1, L2, P1, P2 ($p<0.05$). Postoperative complications developed in 4 patients in group L1, 3 patients in group L2, 5 patients in group P1 and 3 patients in group P2. Although there is no significant difference in each group, the frequency became higher in order of the group L1, L2, P1, P2.

Discussion: Both PLIF and LLIF have been performed for degenerative spondylolisthesis with good result, but no study has directly compared these surgical stresses so far. Although PRS was at the same level between PLIF and LLIF group, SSS was significantly lower in the LLIF group than in the PLIF group even if it was compared 2 level LLIF group with single level PLIF group, and when SSS became higher, it was the tendency for the onset incidence of a postoperative complication to become higher.

Conclusions: Procedure with lower surgical stresses may result in considerably less patient morbidity. Therefore, minimally invasive spinal surgery such as the LLIF with PPS may serve a particularly useful role in the management of elderly patients with several illnesses.

46 cases of spinal surgical site infection (SSI) in 4922 patients and the risk factors analysis

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Introduction: Surgical site infection (SSI) is a serious and costly complication of spinal surgery. Within the literature, the incidence of surgical site infection after spine surgery knows a wide variety from 0.7% to 12.0%. There have been several conflicting reports on the risk factor analysis of SSI in spine surgery, and a number of risk factors have been investigated. Although not uniform, there is fairly consistent evidence that obesity/increased body mass index, advanced age, malnutrition, longer operation times, diabetes, smoking, blood transfusion, cancer, and history of a previous SSI are associated with an increased risk of SSI. The purpose of this study is to analyze the risk factors of these 46 cases from 4922 patients in spine surgery from mainland of China.

Methods: A total of 4922 consecutive patients who underwent spinal surgery at Navy General Hospital from Jan, 1995 to Dec, 2017 were retrospectively reviewed. Forty six cases of surgical site infection after spinal operation were analyzed including 17 males and 29 females and aging 16-88 years (mean age 63.1 yr). The involved segments included 10 cases at cervical region, 3 cases at thoracic, 33 cases at lumbar/sacral. All of these cases were recorded the leukocyte count, erythrocyte sedimentation rate, c-reactive protein and bacterial culture before and after operation. The chi-square test and stepwise multivariate proportional hazards logistic regressions were used to identify factors associated with spinal surgical site infection. Variables with $p < 0.05$ were considered statistically significant.

Results: The rate of surgical site infection was 0.93% in this series. All the patients were followed up for 12- 230 months (mean 39 months). 9 cases were managed by continuous intravenous antibiotics administration alone, 34 cases were managed by wound debridement and implant retention, 11 cases were treated by debridement and vacuum sealing drainage (VSD), 3 cases were treated by implants remove and debridement. All cases were successfully treated. No one recurrence. We found that age, diabetes, obesity, instrumentation, blood transfusion and surgical duration might increase the risk of the spinal surgical site infection.

Discussion: The rate of surgical site infection following spinal operation was relatively low in Navy General Hospital, and the surgical site infection was influenced by many risk factors. Early diagnosis and debridement were critical for the management of patients with surgical site infection. This study identifies that several factors—older age, diabetes, obesity, instrumentation, blood transfusion and surgical duration—were each independently associated with an increased risk of developing spinal surgical site infection. We conclude that large database studies may be better suited for identifying risk factors than for determining absolute numbers of infections.

Microsurgical bilateral decompression via a unilateral approach using tubular retractor can improve lumbar spinal canal stenosis patients with scoliotic disc wedging if they have not foraminal stenosis

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Introduction: Scoliotic disc wedging (SDW) has been reported as one of the risk factor of decompression surgery for lumbar spinal canal stenosis (LSCS). Microsurgical bilateral decompression via a unilateral approach (MBDU) has been performed for LSCS patients including SDW in our hospital. We hypothesized that MBDU can improve lumbar spinal canal stenosis patients with SDW if they have not foraminal stenosis. The aim of this study was to evaluate surgical outcome of LSCS involved with or without SDW more than 3 degrees.

Methods: From 2012 to 2016, a total of 97 patients of single level LSCS without foraminal stenosis (54 males and 43 females, mean age 71.5 year-old) who underwent MBDU using tubular retractor at the author's hospital were included into this retrospective study. The level of surgery was L1-L2 in 3 patients, L2-L3 in 9 patients, L3-L4 in 17 patients, L4-L5 in 68 patients. Based on the anteroposterior radiographs, subjects were divided into two groups: more than 3 degrees SDW (W) group (n=27) and non-SDW (NW) group (n=70). The mean age in the W group was 72.6 years (range 55-82 years), and there were 14 men and 13 women; the mean age in the NW group was 71.1 years (range 44-92 years), and there were 40 men and 30 women. In the W group all patients underwent MBDU from the convex side. The mean follow up duration 34.3 months (range 24-70 months) in the W group and 30.3 months (range 24-73 months) in the NW group. Japanese Orthopaedic Association (JOA) score, recovery rate, and SDW angle were evaluated preoperatively and at the final follow up. All parameters were statistically analyzed by Student's t-test. P values<0.05 were statistically significant.

Results: The mean JOA scores in the W and NW groups were 15.7 (range 6-21) and 16.6 (range 4-23) before surgery and 25.0 (range 9-28) and 25.6 (range 18-29) at the final follow up, respectively. The mean recovery rate was 69.7% in the W group and 71.3% in the NW group. There was no significant difference in recovery rate between both groups. The mean SDW angles in the W groups were 4.3 degrees (range 3-9.5 degrees) before surgery and 3.6 degrees (range 2-6 degrees) at the final follow up; there was no significant difference between them.

Conclusion: The clinical outcomes of MBDU were similar in LSCS patients with and without SDW if they have not foraminal stenosis.

Anatomical importance of the anterior part of segmental artery and vein to prevent vascular injury by anterior retractor at Lateral Lumbar Interbody Fusion (LLIF) or Anterior Column Realignment (ACR) technique

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Introduction: Various minimum invasive spine stabilization (MIS) techniques have been developed in recent years. Lateral Lumbar Interbody Fusion (LLIF) is representative method in those. Anterior Column Realignment (ACR) is also getting popular. However potential complications due to the specificity of those techniques have been arising. Fujibayashi has reported 0.4% segmental artery injury in 2998 LLIF cases. Nojiri and Orita have reported the risk of segmental artery injury at lateral side of vertebral body at LLIF. Anterior retractor insertion at LLIF and cutting ALL at ACR also have risk of segmental artery and vein injury. But there is no report which evaluate the pathway of segmental artery and vein of anterior part of disk. The purpose of this study is to investigate anatomical features of segmental artery and vein at the anterior part of disk to prevent the vascular injury.

Method: Five cadaver bodies were used to detect the pathway of the segmental artery and vein. The L2 to L5 segmental arteries and veins were evaluated. Firstly, we investigated whether segmental artery and vein may across the disk at anterior part. If the segmental artery and vein intersect the disc, the distance from midline of disc to the intersection point of the disk was measured. The distance from segmental artery branching site of aorta to the intersection point of the disk was also measured.

Results: Thirty-two segmental arteries and 19 segmental veins were identified. Eight of 32 segmental arteries (25.0%) have intersected the disk at anterior part. Especially at L3/4, 70.0% of artery intersected disk. Seven of 19 segmental veins (36.8%) have intersected the disk at anterior part, at L2/3 30.0%, at L3/4 40.0% intersected. The distance from midline of the vertebral to the segmental artery intersection point of the disk was 5.85mm on average (1.0 to 10.2). That of segmental vein was 7.9mm on average (4.0 to 11.2). At L2/3 and L3/4, segmental artery and vein highly intersected disk.

Discussion: In this study, we detected highly segmental artery and vein intersected the disk at the anterior part. Especially at upper lumbar level, that becomes 30.0-70.0%. Not only anterior retractor insertion at LLIF, but also ACR has more risk of vascular injury because this technique requires to cut ALL. Therefore, this study gives important information to prevent the segmental artery and vein injury to do such technique.

Surgical outcomes for late neurological deficits after long lumbar instrumented fusion for degenerative lumbar diseases

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Introduction: Following spine fusion surgery, adjacent mobile segments encounter compensatory stress concentration. Resultant adjacent segment pathology (ASP) can develop neural symptoms. ASP in patients who underwent long lumbar fusion results in cord compression. We describe 13 patients who experienced neurological deficits after long instrumented lumbar fusion.

Methods: The inclusion criteria were (1) previous long lumbar instrumented fusion, (2) thoracic myelopathy caused by adjacent segment pathologies, and (3) no previous history of myelopathy before lumbar fusion surgery. Thirteen patients, 4 males and 9 females were identified in our institute. All previous surgery was posterior spine fusion without 3-column osteotomy for degenerative lumbar diseases. Radiographic examinations and clinical assessments were performed in all patients prior to revision surgery. Except one patient who underwent anterior surgery only, 12 patients underwent posterior decompression and instrumented fusion was extended. The minimum follow-up period after revision surgery was 1 year (mean 4.5 years, 1-7).

Results: At the time of revision surgery, the mean age of all patients was 71.5±6.6 years (58-82). Before revision surgery, UIV was L2 in 2 patients, L1 in 6 patients, D12 in 2 patients, D11 in 1 patient, and D10 in 2 patients. All patients presented paraparesis due to cord compression at the supra-adjacent levels. Neurological deficits developed on average at 4.9±5.0 years (0.5-15) after previous lumbar instrumented fusion. Interestingly, 3 patients showing neurological deficits within postoperative 1-year underwent iliac screw fixation. The mean duration of neurological deficits was 4.5±3.7 weeks (1-12). All patients showed solid fusion. However, 11 patients except 2 patients with acceptable PI-LL (0.1° and -7.1°) had severe PI-LL mismatch (31.1°±15.6°; range, 14.8°-62.2°).

The most common pathology compressing spinal cord was severe adjacent disc degeneration and subsequent canal stenosis (7 patients). Supra-adjacent segmental fractures occurred in 3 elderly patients (76, 77, and 79 years old). These three patients had additional pathologies at the fractured level, including ossification of yellow ligament, disc herniation, and junctional spondylolisthesis. In 3 patients, huge herniated disc at the adjacent level compressed spinal cord. Neurological status improved in seven patients (ASIA C to D) and was stationary in six patients (ASIA C). Two patients underwent 2nd revision surgery for repeated late neurological deficits from supra-adjacent pathologies.

Nine patients underwent perioperative major complications. The most common medical complication was lung problems such as pneumonia, pleural effusion, and pulmonary thromboembolism. Surgical site infection was identified in 3 patients and managed by antibiotics treatment without surgical debridement. The mean days of hospitalization were 49.1±21.8 (17-85). All complications resolved at the time of discharge.

Discussion: Late neurological deficits can develop with various pathologies at the supra-adjacent levels. Sagittal parameters and iliac screw fixation might be associated with supra-adjacent segment pathology. Surgical outcomes were not favorable and perioperative complications were quite frequent. Surgeons must be aware of the surgical outcomes and notify patients preoperatively.

A retrospective review of transforaminal lumbar interbody fusion patients treated with expandable and static spacers

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Introduction: Utilization of interbody spacers for transforaminal lumbar interbody fusion (TLIF) offers favorable clinical results. Expandable devices allow for *in situ* expansion to optimize fit and mitigate iatrogenic endplate damage that occurs during trialing and impaction as seen in static devices. This study compared the clinical and radiographic outcomes between static and expandable spacers following TLIF.

Methods: A retrospective chart review of patients from a single site was performed on 99 patients who underwent TLIF using one of two interbody spacers. Forty-eight patients received a static peek interbody spacer, and the remaining 51 patients received an expandable titanium interbody spacer. Surgical data, Oswestry Disability Index (ODI), and Visual Analog Scale (VAS) pain scores were collected and analyzed. Radiographs were collected and measured when available. Complication rates were compared using Fisher's exact test.

Results: Patients treated with expandable interbody spacers had significantly ($p < 0.05$) less blood loss (81.7cc vs. 36.2cc) and shorter hospital stays (2.2 vs. 1.4 days). Operating room time was lower for patients treated with expandable interbody spacers than static spacers (130.6 vs. 149.5 minutes), although this difference was not significant ($p = 0.07$). At 3-month and final follow-up, patients treated with expandable implants had significantly lower ODI scores than patients with static implants ($p < 0.05$, 14.4 and 22.6, respectively). Disc height and neuroforaminal height increased significantly ($p < 0.05$) from baseline at the 3-month follow-up time point for both interbody spacers, although the expandable group had significantly greater neuroforaminal height (22.3 vs. 20.1 mm). There was a significant ($p < 0.05$) difference in complication rates between static and 2% for expandable group. By standard of care, only patients that reported a recurrence of low back pain were required to follow-up with their surgeon past 3 months post operatively. Only 3 of 51 (6%) patients from the expandable group had to follow-up at >24 months, compared to 12 of 48 (25%) patients in the static group.

Discussion: Patients treated with expandable interbody fusion spacers used in a transforaminal approach demonstrated significantly less blood loss, shorter length of stay, lower ODI scores, and significantly fewer complications at final follow-up than patients treated with static spacers.

Minimally invasive sacroiliac joint fusion using a novel hydroxyapatite-coated screw: two-year clinical and radiographic outcomes

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Introduction: The proper diagnosis and treatment of sacroiliac joint (SIJ) pain remains a clinical challenge. Dysfunction of SIJ can produce pain in the lower back, buttocks, and extremities. Triangular titanium implants for minimally invasive SIJ fusion have achieved visual analog scale (VAS) and Oswestry Disability Index (ODI) improvements in 83% of patients compared to non-surgical management in a randomized clinical trial. This study reports on a novel hydroxyapatite-coated titanium screw for surgical treatment of SIJ dysfunction.

Methods: Data were prospectively collected on 43 consecutive patients who underwent minimally invasive SIJ fusion with a novel hydroxyapatite-coated screw. Clinical assessments and radiographs were collected and evaluated at 12 and 24 months postoperatively.

Results: Mean patient age was 54.2 ± 10.4 years, and 65.1% of patients were female. Mean operative time was 39.2 ± 18.9 minutes, and estimated blood loss did not exceed 50cc. Overnight hospital stays were required for 88.4% of patients, while remaining patients needed a 2-day stay. Mean preoperative VAS back, left, and right leg pain scores decreased significantly by 26.3, 25.1, and 25.5 points respectively at 12 months postoperatively ($p < 0.01$) and by 30.1, 27.0, and 26.3 points respectively at 24 months postoperatively ($p < 0.01$). ODI scores significantly decreased by a mean of 21.9 points at 12 months and 28.3 points at 24 months ($p < 0.01$). All patients who were preoperatively employed returned to work within 3 months. Two patients who required revision surgery reported symptom improvement within 3 weeks and did not require subsequent surgery.

Discussion: SIJ fusion using a hydroxyapatite-coated screw to treat SIJ dysfunction significantly decreased VAS back and leg pain and ODI scores at 1 year and remained durable at 2-year follow-up.

Incidence and characteristics of postoperative vertebral fractures after fusion surgery in elderly patients

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Background: Osteoporosis is one of important factors to success long fusion surgery in patients with higher age. In addition to implant failure, postoperative vertebral fracture is sometimes noted at the fusion level. Several papers reported osteoporosis, longer fusion levels, fusion to the pelvis and so on, as risk factors of subsequent vertebral fractures after surgery, but surgical indication or methods, or combined osteoporosis treatment are changing gradually moment by moment and update of evaluation is necessary.

Purpose: To evaluate the incidence and characteristics of postoperative vertebral fracture after fusion surgery for 3 levels or more in elderly patients retrospectively.

Patients and Methods: Patients with age of 60 or higher who underwent fusion surgery for more than 3 levels in thoracic and/or lumbar spine were included. The mean follow up period was 32 months, with minimum follow up of 12 months. Total 91 cases (30 male and 61 female) with mean age of 68.4 years old were included. Diagnosis was 45 cases of adult spinal deformity, 31 cases of vertebral fracture or nonunion, 13 cases of lumbar spinal stenosis. The incidence of postoperative vertebral fracture was investigated. Additionally, patients were divided into 2 groups, fracture (+) or (-) group, and age, sex, body mass index (BMI), preoperative T-score, content of osteoporosis treatment, number of fused level and number of existing vertebral fractures were compared using unpaired t-test or χ^2 test. *P* value <0.05 was defined as significant difference. In fracture (+) group, postoperative timing and level of fracture were investigated.

Results: The incidence of postoperative vertebral fracture was 26.4% (24/81 cases). Ratio of female was significantly higher in fracture (+) group. Age, BMI, content of osteoporosis treatment, number of fused level and existing fracture were not statistically significant between 2 groups. Preoperative T-score was significantly lower in fracture (+) group (-2.0 vs -1.1). In 24 cases of fracture (+) group, 20.8% was noted within a month and 45.8% was noted within 3 months. In evaluation of fracture level, most frequent level was upper instrumented vertebra (UIV: 50.0%), followed by lower instrumented vertebra (LIV: 20.8%) and one level above UIV (16.7%). The fracture level was 6 cases in T3-5, 13 cases in T9-L1, 5 cases in L2-4.

Discussion: After fusion surgery for 3 levels or more, subsequent vertebral fracture was induced in high percentage of 26.4%, and most of fractures were occurred at UIV or one level above UIV at thoracic spine, in female with severer osteoporosis, suggesting higher mechanical stress in such condition. Strict treatment for osteoporosis might be important to prevent postoperative subsequent fractures.

Large PI is a risk factor for the progression of scoliosis in patients with lumbar spinal canal stenosis and degenerative lumbar scoliosis.

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Introduction: Degenerative lumbar scoliosis(DLS) makes the quality of elderly population worse and that is prevalent in the elderly population. However, it remains unclear why the progression of scoliosis occurs in patients with lumbar spinal canal stenosis(LSCS) and DLS from the spinal sagittal and coronal alignment view point. The purpose of this study was to investigate the relationship between the total spinal sagittal alignment and coronal Cobb angle in patients with LSCS and DLS.

Methods: Retrospective analysis was performed on 145 consecutive patients (66 women and 79 men) who underwent surgery for LSCS at our hospital. The patients with vertebral body fracture or history of spinal surgery were excluded. Patients were classified into four groups according to Cobb angle ; non-scoliosis group (Cobb angle 0°, n = 53), mild scoliosis group (Cobb angle 1 to 19°, n = 67), scoliosis group (Cobb angle 20 to 29°, n = 15), and severe scoliosis group (Cobb angle ≥30°, n = 10). The following parameters were analyzed; sagittal vertical axis(SVA), thoracic kyphosis (TK), lumbar lordosis (LL), pelvic tilt (PT), and pelvic incidence (PI).

Result: In all scoliosis groups, PI and PI-LL were significantly larger (P <0.01) than those in non-scoliosis group. PT in scoliosis group and severe scoliosis group was significantly larger than that in non-scoliosis group(P <0.01).

The coronal Cobb angle showed significant correlation with PI in scoliosis groups.

Discussion: Previous studies, reported that large PI was correlated with the occurrence of degenerative spondylolisthesis and facet joint deformation when judged by sagittal alignment.

In this study, the coronal Cobb angle showed significant correlation with PI in scoliosis groups. Therefore, large PI and/or large PI-LL can be risk factors for the progression of scoliosis in patients with LSCS and DLS.

Effect of HRQOL and radiographic parameters on minimum posterior decompression in patients with lumbar spinal canal stenosis with spinal sagittal imbalance

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Introduction: Recently, many studies have reported that sagittal spinal imbalance affects the deterioration of QOL. However, few studies have examined clinical outcome after decompression surgeries for lumbar spinal canal stenosis (LSCS) cases with sagittal spinal imbalance. Microscopic bilateral decompression via a unilateral approach (MBDU), which is one of the minimum posterior decompression surgeries, can preserve posterior elements of the lumbar spine (e.g., supraspinous ligament, interspinous ligament). MDDU is expected to keep up postoperative sagittal alignment. In this study, we investigated clinical outcome and change of radiographic parameters after MBDU for LSCS patients with sagittal spinal imbalance.

Methods: One hundred ninety-nine LSCS patients who were performed MBDU were enrolled in this study (113 men and 86 women, mean age 71 years). Considering whether the sagittal spinal balance is imbalanced or not, we divided them to two groups, Group A: SVA >50 mm (89 cases, mean SVA 77 mm) and Group B SVA <50 mm (110 cases, mean SVA 22 mm). Clinical outcomes and radiographic data were analyzed preoperatively and two years postoperatively. Clinical outcomes were evaluated using the JOA score, VAS for low back pain, SF36-PCS and SF36-MCS. We also examined clinical outcomes of patients in Group A whose spinal sagittal alignment got worse postoperatively.

Results: Preoperative JOA scores, SF36-PCS and SF36-MCS, were not significantly different in both groups. Preoperative VAS for low back pain (55.6 mm) in Group A was significantly lower than that in Group B (44.5 mm). Two years after the operation, JOA score was 21.2 points, VAS for low back pain was 34 mm, SF36-PCS/ SF36-MCS was 26/49 points in Group A. The improvement rates of the clinical score (JOA scores, VAS for low back pain, SF36-PCS, and SF36-MCS) were not significantly different in both groups. Compared with cases in Group B, SVA of cases in Group A significantly improved from 76.9 mm to 53 mm 2 years postoperatively.

Regarding the analysis of cases in Group A, the SVA of 26 cases (29%) deteriorated postoperatively. The recovery rate of JOA score of these cases was 50.7%. The rate was not significantly different, compared with cases which maintain sagittal spinal alignment postoperatively. However, the VAS for the low back pain of these cases significantly got worse postoperatively. There was no significant difference in preoperative SVA or PI-LL between cases with postoperative sagittal spinal imbalance and cases without that. Radiographic factor for impairment of sagittal spinal alignment was not detected.

Discussion: Clinical outcomes of MBDU for LSCS patients with sagittal spinal imbalance were comparable with those without the imbalance. MBDU could maintain spinal alignment after operation due to less invasiveness for posterior spinal elements. On patients with sagittal spinal imbalance, cases with the postoperative deterioration of sagittal spinal alignment led to impairment of low back pain. In the future, further analyzing factors related to the impairment of sagittal spinal balance is needed.

Changes in Pelvic Incidence after long spinal fusions for adult deformity correction

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Introduction: Pelvic Incidence (PI) is considered an anatomical angle that never changes in adulthood. Its importance in determining spinal balance was first described by Legaye in 1998. Moreover, different studies found a strong correlation between PI values and the spinal shape, particularly regarding the lumbar lordosis and the pelvic position, described by Pelvic Tilt (PT). The aim of this study is to verify any change in PI in adult patients undergoing surgery for spinal deformity.

Methods: Cross-sectional study. Sixty-six adults patients, 87% females (mean \pm SD age: 65.1 \pm 7.6 years), undergoing fusion from the thoracic spine to the sacrum for adult spine deformity were included. Patients were divided in two different groups: Group A: Sacral Fixation alone and Group B: Sacral Fixation plus Pelvic Fixation. Pre and postoperative standardized full-standing x-rays were analyzed with measurement of: Pelvic Incidence (PI), Pelvic Tilt (PT), Lumbar Lordosis (LL) and Sagittal Vertical Axis (SVA).

Results: Statistically significant variations were observed in PT, SS and TK in both groups after surgery (all, $P < 0.001$). After adjustment for patients' age (>65 vs. <65 years), a statistically significant increase of PI was observed in patients >65 years ($p = 0.006$) in Group A between preoperative and postoperative measurements (Fig. 1). All patients in Group B exhibited a decrease in PI from preoperative to postoperative.

Conclusions: Older patients undergoing long fusion to the sacrum without pelvic fixation had an increase in pelvic incidence after surgery. Conversely, pelvic fixation with intraoperatively extended hips has decreased the value of PI from pre- to early postoperative. These changes could be related to degeneration of the sacroiliac joints causing increased rotational mobility and consequently the movement of the sacrum in the pelvis. The magnitude of variations are in the range of clinical significance. These findings may alter our ideas on correction of sagittal alignment and could lead to a reevaluation of specific spinopelvic relationships and of the sacroiliac joint role

Frailty status as a predictor of discharge disposition following posterior decompression surgery in the patient with lumbar spinal stenosis: a multi-center study using prospectively collected data.

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Background: Frailty status has been thought to predict worse postoperative outcome in several surgical fields. However, the impact of preoperative frailty on postoperative outcomes after surgery for elderly patients with lumbar spinal stenosis (LSS) remains unclear. Our purpose was to determine the relationship between preoperative frailty status and discharge disposition, length of stay (LOS) in hospital, and perioperative complications following elective posterior decompression surgery.

Methods: The clinical data of patients aged over 65 years old, who underwent elective posterior decompression surgery for LSS at multiple institutions, were prospectively collected from October 2017 to September 2018. A total of 165 patients (105 males and 60 females; mean age, 75.46 years) were enrolled in this study. The assessment of preoperative frailty was based on Fried's criteria. Clinical outcomes were prolonged LOS, defined as ≥ 20 days, and discharge to non-home facilities. Potential risk factors for these outcomes, such as Charlson comorbidity index, locomotive syndrome and operative information, were also assessed. The logistic regression analysis was performed to identify the predictors of prolonged LOS and discharge to non-home facilities.

Results: Sixty-one patients were evaluated as preoperative frailty status (frailty group). Prolonged LOS were needed in 41 patients. Proportion of patients who needed prolonged LOS was not significantly different between frailty group and non-frailty group (29.5% vs 22.1%, $p=0.35$). Sixteen patients were discharged to non-home facilities. Frailty group had a higher proportion of patients with discharge to non-home facilities compared with non-frailty group (18.0% vs 4.8%, $p=0.02$). The logistic regression analyses revealed that frailty group had increased risk of discharge to non-home facilities (odds ratio, 3.89; 95% confidence interval, 1.24-12.23) but frailty was not a significant independent risk factor of prolonged LOS (odds ratio, 1.65; 95% confidence interval, 0.77-3.50).

Discussion: Preoperative assessment of frailty status for elderly patients can predict discharge disposition following posterior decompression spine surgery.

Recurrent lumbar disc herniation following percutaneous transforaminal endoscopic discectomy preferentially occurred when Modic changes are present

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Introduction : Recurrent lumbar disc herniation has been defined as disc herniation at the same level, which may be associated with Modic changes, so the purpose of the current study was to investigate the effect of Modic changes and the herniated disc component on the recurrent lumbar disc herniation following percutaneous transforaminal endoscopic discectomy (PTED)

Methods: We included 102 (65 males, 37 females, aged 20–66 yr) inpatients who underwent PTED from August 2013 to August 2016. All patients underwent MRI Preoperative. the presence and type of Modic changes were assessed. During surgery the herniated disc component of each patient was classified into two groups: nucleus pulposus group, Hyaline cartilage group. the association of herniated disc component with Modic changes was investigated. MRI of the lumbar spine were obtained every 6 months to assess the incidence of symptomatic and asymptomatic same-level recurrent disc herniation on more than 2-year follow-up.

Results: In total, 11 patients were lost to follow up, the other 91 patients were follow-up for more than two years (24-96 months). Of 91 patients, 99 discs underwent PTED, 28/99(28.3%) had MCs; Type I, II, and III MCs were seen in 8(8.1%), 18(18.2%), and 2 (2.0%) endplates, respectively.

Among 28 endplates with MCs, according to the herniated disc component, 18 (31.3%) showed evidence of hyaline cartilage in the Intraoperative specimens, including: 5/8 endplates (20%) with Type I MCs, 12/18 (26.3%) with Type II, and 1/2 (100%) with Type III. 11 Among 71 endplates without MCs, 14 (8.3%) showed evidence of hyaline cartilage in the Intraoperative specimens.

We found 2 cases symptomatic and 9 cases asymptomatic same-level recurrent disc herniation in the non-Modic changes group (n=71), 3 cases symptomatic and 8 cases asymptomatic same-level recurrent disc herniation were found in the Modic changes group (n=28), including (Type I: 1 cases symptomatic and 2 cases asymptomatic; Type II : 2 cases symptomatic and 5 cases asymptomatic; Type III : 0 case symptomatic and 1 case asymptomatic)

We found 3 cases symptomatic and 7 cases asymptomatic same-level recurrent disc herniation in the hyaline cartilage group (n=32), 2 cases symptomatic and 12 cases asymptomatic same-level recurrent disc herniation were found in nucleus pulposus group (n=67).

Discussion: Modic changes associated with the herniated cartilage disc component. recurrent lumbar disc herniation following PTED easily recurrence when Modic changes or the herniated cartilage are present

Bone Mineral Density Screening in Patients Who Are Lumbar Total Disc Replacement Candidates

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Introduction: Poor bone quality is identified as a contra-indication for total disc replacement (TDR). This is primarily due to the risk of vertebral body fracture or subsidence. However, there has been little investigation into the role of screening candidates for lumbar TDR. The purpose of this study was to determine the role of routine DEXA scanning to screen for osteopenia/osteoporosis in evaluating candidates for lumbar TDR.

Methods: Clinic records from a 5-year period were reviewed to identify the consecutive series of all patients undergoing lumbar TDR or lumbar interbody fusion performed by one of three surgeons to identify patients who were considered lumbar TDR candidates. Charts were reviewed to determine how many of these patients did not undergo lumbar TDR due to poor bone quality as determined by DEXA scan. Data recorded included general demographic information, results of the DEXA scan if performed, and if the DEXA scan results changed the surgical treatment plan.

Results: During the 5-year period, 371 patients received a lumbar TDR and/or underwent DEXA screening during the evaluation for lumbar TDR. Among the 306 of these patients who had a DEXA scan, 13 patients (4.2%) were ruled out of having TDR due to osteoporosis (25 other patients who had a DEXA did not receive TDR for other reasons). Among the 13 patients not receiving TDR due to poor bone quality: 3 were current or former smokers, 2 had vitamin D deficiency (also a former smoker) or insufficiency, 4 were age 55 years or older, 1 had previous gastric bypass surgery and hysterectomy, and the remaining 3 had no obvious risk factors possibly related to osteopenia/osteoporosis. Among the 67 patients who did not undergo DEXA scanning and received a TDR, there were no complications related to poor bone quality such as fracture.

There did appear to be some selection process among the surgeons prescribing DEXA scanning prior to TDR. The mean age of patients receiving a DEXA scan were older than those not scanned (mean age 43.4 vs. 37.6 yrs; $p < 0.01$) and there was a significant difference in the proportion of patients who received a DEXA scan based on the treating surgeon (88.3% vs. 80.8%, vs. 74.1%; $p < 0.05$). There was no difference in the mean body mass index values for patients scanned vs. not (27.2 vs. 26.5) or gender (81.2% of females vs. 82.6% of males were scanned).

Discussion: Avoiding patients with osteopenia/osteoporosis may be important to reduce complication risk associated with lumbar TDR. In the current study, 4.2% of patients who were screened for osteoporosis did not receive a TDR due to poor bone quality. While there were no bone related complications in patients not scanned, there was some selection of patients receiving osteoporosis screening and 10 of 13 patients not receiving TDR due to poor bone quality had risk factors for osteoporosis. Awareness of evaluating bone quality prior to lumbar TDR may be helpful in reducing the risk of bone-related complications.

Correlation analysis of sagittal alignment and skeletal muscle mass in patients with spinal degenerative disease - Comparative study between cervical spine group and lumbar spine group

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Introduction: There has been no report whether the body composition or the spinal sagittal alignment differs for patient with cervical spine disease and lumbar spine disease. The first purpose of this study was to evaluate the body composition and the spinal sagittal alignment in symptomatic spinal patients. The second purpose of this study was to compare whether the body composition and the spinal sagittal alignment is different in patients with cervical spine disease and lumbar spine disease.

Methods: We retrospectively evaluated 313 patients who were hospitalized for surgery to treat spinal degenerative disease, who were divided into cervical and lumbar spine disease groups. All patients underwent full-length standing whole-spine radiography and bioimpedance analysis before surgery. We used standard measurements to assess the sagittal vertical axis (SVA), cervical lordosis (CL; C2–C7), lumbar lordosis (LL; T12–S1), thoracic kyphosis (TK; T5–12), pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS). We also analyzed radiological and body composition parameters, patient characteristics, and the correlation between SMM and each sagittal parameter.

Results: In the overall cohort, the mean age at the time of operation was 66.5 ± 15.3 years. The correlation coefficients (r) between SMM and PT were negative weak correlation ($r = -0.343$, $P < 0.001$). The correlation with SMM for other LL, PI, SS, and SVA was statistically significant, but the correlation was none. In addition, our results also suggested strong correlations ($r > 0.5$) between LL and SS ($r = 0.744$), between LL and SVA ($r = -0.589$), between PT and SS ($r = -0.580$), and LL and PT ($r = -0.506$).

Fifty-seven patients (18.2%, cervical group) had cervical spine disease and 256 patients (81.8%, lumbar group) had lumbar spine disease. No significant differences in age, height, body weight and BMI were observed between the two groups. There were also no significant differences in biochemical and bioimpedance parameters between the two groups.

In the lumbar group, correlations were found between SMM and PT ($r = -0.288$, $P < 0.001$), between SMM and LL ($r = 0.179$, $P < 0.01$), and between SMM and SS ($r = 0.170$, $P < 0.01$), while only PT ($r = -0.480$, $P < 0.001$) was negatively correlated with SMM in the cervical group.

Discussion: These results demonstrated that PT was most negatively correlated with SMM in patients with cervical or lumbar spine disease. Further, SMM and PT were more correlated in patients with cervical spine disease than patients with lumbar spine disease. Therefore, we suggest that the SMM might be one of the important factors that influenced the posterior inclination of the pelvis in symptomatic spinal patients, especially in cervical spine disease.

Comparison of Reoperation Rates after Fusion Surgeries for Spondylosis between Cervical And Lumbar Regions: National Population-Based Administrative Database Study

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Introduction: Reoperation is one of the key factors affecting the postoperative clinical outcomes. There is a relatively low incidence of reoperation after fusion surgeries for the spinal degenerative disease. Therefore, it is difficult to sufficiently power studies to compare the reoperation rates between the cervical and lumbar regions. National population-based administrative databases provide large cohort that may help overcome this challenge and a complete follow-up of reoperations without the follow-up loss, even after the patients were discharged from the hospital. The purpose is to compare reoperation rates after fusion surgeries for degenerative spinal diseases according to cervical and lumbar regions in a national population of patients.

Methods: We used the Korean Health Insurance Review & Assessment Service national database to select our study population. We included patients who underwent first spinal surgeries from January 2012 to December 2012 under the diagnosis of cervical and lumbar spondylosis. Subjects were included if they had any of the primary procedures of fusion (anterior or posterior) combined with the procedure of decompression procedures (laminectomy, discectomy, corpectomy). We identified 42,060 patients. We assigned the patients into two groups based on anatomical regions: cervical and lumbar spine. We compared the reoperation rate between the two groups. The primary endpoint of reoperation was the repeat of any aforementioned fusion procedures. Age, sex, the presence of diabetes, associated comorbidities, hospital types, and surgical approaches were considered potential confounding factors. The entire follow up period was four years. Reoperation rates were analyzed over early (< one year postoperatively) and late (> one year postoperatively) periods. Statistical analysis for comparison between the two groups was performed using Cox proportional hazards regression modeling.

Results: Total reoperation rate was 2.62% during the entire four-year follow-up period. The reoperation rate of cervical spine group was 2.33% and lumbar spine group was 2.74 %. The reoperation rate was higher in the patients underwent lumbar fusion surgery than in the patients underwent cervical fusion surgery during the entire follow up period. A similar pattern was seen during the late period. However, in the early period, there was no difference in reoperation rates between the two groups. Comorbidities and hospital type were noted to be risk factors for reoperation.

Discussion: The incidence of reoperation was higher in the patients underwent lumbar fusion surgery than in the patients underwent cervical fusion surgery for degenerative spinal diseases.

Patient satisfaction with surgery for single-level degenerative lumbar spondylolisthesis: a prospective multicenter study

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Purpose: This prospective multicenter trial investigated patient satisfaction with surgery for degenerative lumbar spondylolisthesis (DLS) and factors associated with patient satisfaction.

Methods: From October 2013 to March 2016, 165 patients (20 institutes) were enrolled. Inclusion criteria were neurogenic claudication and single-level DLS. Exclusion criteria were previous spine operation, osteoporosis, degenerative scoliosis, multilevel lumbar spinal stenosis, or psychological disorder. Age, gender, body mass index, smoking, comorbidity, job and educational level, bone mineral density, and duration of symptoms before surgery were recorded. Patient-reported outcomes (PROs) were assessed using a visual analogue scale (VAS) for low back pain, leg pain, and numbness, Japanese Orthopaedic Association Back Pain Questionnaire (JOABPEQ), Zurich claudication questionnaire (ZCQ), and EuroQoL 5 Dimension (EQ-5D). Surgical methods were classified as decompression (D), posterolateral fusion (PLF), posterior or transforaminal lumbar interbody fusion (IF), or other procedures. Operating time, blood loss, and perioperative complications were recorded. Slippage, lumbar lordosis, lumbar axis sacral distance, range of motion (ROM) at each disc level, bony fusion, and disc degeneration according to the Schneiderman classification were examined radiologically. One year after surgery, patient satisfaction with surgery (S-VAS) was recorded on a VAS (0–100 mm, higher score indicating greater satisfaction), and ZCQ satisfaction score (ZCQ-S). Spearman's rank correlation and multiple regression analyses were used to identify factors associated with patient satisfaction. An alpha level of 0.05 was considered to be significant.

Results: A total of 114 patients were followed up at 1 year. S-VAS and ZCQ-S were 88.3 ± 19.9 mm and 1.6 ± 0.6 point, respectively (score < 2.5, 94%). The numbers of patients who underwent D, PLF, IF, or other procedures were 12, 25, 61, and 16, respectively. In the D group, S-VAS and ZCQ-S were 89.8 ± 5.8 and 1.8 ± 0.7 , respectively. S-VAS was significantly higher in the IF group than in the PLF group (92.5 ± 13.6 vs. 77.9 ± 28.6 , $P < 0.05$), but ZCQ-S did not differ. S-VAS correlated positively with fusion method, EQ-5D score, JOABPEQ subscale points, and VAS for low back pain, leg pain, and leg numbness. S-VAS correlated negatively with ZCQ symptom severity and physical function scores at follow-up ($P < 0.05$). ZCQ-S correlated with age at surgery and ROM at L5–S1 at 1 year. Multiple regression analysis showed significant associations between S-VAS and ZCQ symptom severity score at follow-up, fusion method, improvement in VAS for low back pain, acquired point of gait and social life disturbance on JOABPEQ subscales, slippage at the fused level, and ROM at L5–S1 at follow-up. ZCQ-S correlated significantly with ZCQ symptom severity score at follow-up ($P < 0.001$).

Discussion and Conclusion: According to the ZCQ-S score for patients with DLS, 94% of patients were satisfied with the surgery. Patient satisfaction was related to postoperative low back and leg pain, leg numbness, physical function, QOL, and fusion method (PLF vs. IF). These results suggest that surgery for single-level DLS has high patient satisfaction. Lumbar interbody fusion is recommended as a fusion method when decompression and fusion are indicated.

The Effect of Pre-Operative Epidural Steroid Use on Volumetric Bone Mineral Density in Patients Undergoing Lumbar Fusion Surgery Measured by Quantitative Computed Tomography

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Introduction: Prior studies have found that lumbar spine surgery has a negative effect on lumbar spine bone mineral density (BMD).¹ However, little is known about additional factors affecting lumbar spine BMD in conjunction with surgery. Recent studies have demonstrated that epidural steroids are associated with a significantly decreased BMD.^{2,3} In this study, we hypothesized that epidural steroid use is a possible modifier for BMD decline after lumbar spine surgery and conducted a retrospective comparative study utilizing quantitative computed tomography (QCT) to measure BMD.

Methods: We reviewed the clinical records and imaging of 296 consecutive patients who underwent posterior lumbar fusion with instrumentation. Patients with both preoperative and postoperative computed tomography of the lumbar spine between 6 to 12 months were included. The preoperative epidural steroid injection history of each patient was reviewed. Patients were grouped as either having no epidural steroid injection history (non-epidural group) or a history of epidural injections (epidural group). Patients were excluded if their history of epidurals could not be determined or if they received an epidural injection after the index surgery. Volumetric BMD (vBMD) measurements by QCT were conducted in L1 to S1 vertebral trabecular bone. The change in vBMD in the vertebra one level above the upper instrumented vertebra (UIV+1), was analyzed and compared between two groups (non-epidural vs epidural). Statistical analyses were conducted utilizing t test for continuous variables, and Chi-square or Fisher exact tests for categorical variables. The statistical significance level was set at $p < 0.05$.

Results: A total of 84 patients met study inclusion criteria. 77.4% of eligible patients received an epidural prior to surgery. Mean age (\pm SD) of the epidural group was 61.9 ± 12.5 and the mean age in the non-epidural group was 64.8 ± 9.4 . There were no significant demographic differences between groups. Volumetric BMD (\pm SD) in UIV+1 was lower (113 ± 37.8 mg/cm³) preoperatively in the epidural group than in the non-epidural group (123 ± 36.1 mg/cm³), but the difference was not statistically significant ($p = 0.313$). The percent change in vBMD postoperatively was significantly smaller ($-8.3 \pm 12.7\%$) in the epidural group than the non-epidural group ($-16 \pm 29.5\%$, $p = 0.018$). The postoperative vBMD was almost the same in both groups (epidural group: 102.8 ± 34.2 mg/cm³, non-epidural group: 102.8 ± 29.5 mg/cm³).

Discussion: Compared to patients with no epidural steroid history, patients with a history of preoperative epidurals had a reduced loss in vBMD in UIV+1. One possible explanation is that epidural cessation may antagonize BMD loss resulting from surgery. BMD loss, however, may be subject to a ceiling effect given the postoperative vBMD in both the epidural and non-epidural groups were nearly identical. These findings also indicate that the effect of two different catabolic factors (surgical insult and epidural steroids) on BMD loss is not necessarily cumulative. Further study is needed to elucidate the association of different catabolic effects on vBMD.

1. Balci A, Kalemci O, Kaya FG, Akyoldas G, Yucesoy K, Ozaksoy D. Early and long-term changes in adjacent vertebral body bone mineral density determined by quantitative computed tomography after posterolateral fusion with transpedicular screw fixation. *Clin Neurol Neurosurg.* 2016;145(2016):84-88. doi:10.1016/j.clineuro.2016.04.014.
2. Kerezoudis P, Rinaldo L, Alvi MA, et al. The effect of epidural steroid injections on bone mineral density and vertebral fracture risk: A systematic review and critical appraisal of current literature. *Pain Med (United States).* 2018;19(3):569-579. doi:10.1093/pm/pnx324.
3. Liu Y, Carrino JA, Dash AS, et al. Lower Spine Volumetric Bone Density in Patients with a History of Epidural Steroid Injections. *J Clin Endocrinol Metab.* 2018;103(9):3405-3410. doi:10.1210/je.2018-00558.

Cost-Effectiveness for Posterior Lumbar Fusion in Patients Aged 80 Years or Older

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Introduction: With the aging of the society, lumbar spinal fusion has been increasingly performed for the elderly patients. The current study aims to figure out the cost-effectiveness of lumbar fusion surgeries for patients aged 80 years or older.

Methods: The subjects of this retrospective study were patients who had undergone lumbar posterior instrumentation surgeries between January 2012 to August 2017. Inclusion criteria were (1) age of 80 years or older, and (2) fusion levels less than four. Patients with history of lumbar fusion were not included. A total of 50 patients (18 males and 32 females, a mean age of 82.9 years) could be assessed cost/quality-adjusted life years (QALY) by patient-reported outcomes at more than one year after surgery. We calculated QALY by converting Oswestry Disability Index (ODI) to Short-Form six-dimension (SF-6D) scores. Majority of fusion procedures were PLIF/TLIF with or without adjacent-level decompressions. Direct hospital costs (COST) for hospital stay due to surgery were collected from hospital administrative data. Cost-effectiveness ratio (CER) were calculated by COST/QALY. According to the past study reported by Fujiwara, we assumed that improvement of quality of life (QoL) at the first postoperative year would be maintained by the second year. CERs at the first and second postoperative year were assessed, assuming that discount rate of medical cost was 2% per year based on Japanese guideline.

Results: The mean follow-up period was 2.3 years. None of these 50 patients required re-admission and re-operation. Perioperative complications were occurred in seven patients (14%), including screw loosening, vertebral fracture and pseudoarthrosis, dural tear, deep wound infection, urinary tract infection, herpes zoster and delirium. The ODI score was 58.9 before surgery, and improved to 25.2 at the final follow-up; SF-6D improved from 0.477 to 0.652. The mean COST was \$29,272 (20,000 – 73,727). Surgery-related cost reached \$18,181 (13,272 – 34,272), which occupied the majority of COST. The mean QALY gained by surgical intervention was 0.175, while CER was \$232,545 at the first postoperative year and \$114,000 at the second year. In those who had peri- and postoperative complications, the mean COST was \$36,454 and QALY gain was 0.145, while CER was \$399,727 at the first postoperative year and \$196,000 at the second year.

Discussion: World Health Organization (WHO) suggested that CER within three times the per-capita GDP should be cost-effective. Since per-capita GDP was reported to be \$38,636 in Japan, 2.95-fold CER at the second year was regard as cost-effective. However, the mean CER was 5.07-fold the per-capita GDP in patients with complications and four of seven patients' CER exceeded three-fold.

Progressive Pedicle Screw Accuracy in Clinical Utilization of Navigated-Robot-Assisted Spine Surgery

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Introduction: In the emerging field of robot-assisted spine surgery, radiographic evaluation of pedicle screw accuracy in clinical application is an area of high interest. This study describes the pedicle screw accuracy of the first 30 cases in which navigated robotic assistance was used in a private practice clinical setting.

Methods: A retrospective, IRB-exempt review of the first 30 navigated-robot assisted spine surgery cases was performed. Radiographic evaluation of screw tip and screw tail offset distance and angulation from preoperative plan to actual final placement based on intraoperative computerized tomography (CT) images was calculated. Additionally, pedicle screw malposition, reposition, and return to operating room (OR) rates were collected. A CT-based Gertzbein and Robbins system (GRS) was used to classify pedicle screw accuracy.

Results: The first 30 cases had 182 pedicle screws placed. Average age was 65 years old and 44% were female. Average body mass index was 29. Diagnoses for surgery were degenerative disc disease (20) and adjacent segment disease (7). The average offset from preoperative plan to actual final placement was 2.05mm from the tip, 1.94mm from the tail, and 2.1 degrees of angulation. Additionally, comparing the first 91 to the last 91 screws placed, significant improvements ($P < 0.01$) were observed in accuracy by 25% in tip placement (2.34 to 1.75), 29% in tail placement (2.26 to 1.61), and 14% in angulation (2.25 to 1.94). Based on the GRS CT-based grading, 99.5% were graded A or B, and only 1 screw was graded C (that screw trajectory was intentionally lateralized for optimal fixation). There were more Grade A pedicle screws placed in the second half of screws (48.4% vs. 41.2%) than in the first half. Two of 182 (1.09%) screws had to be aborted from the robot-assisted technique. There were no returns to the OR for screw-related complications.

Discussion: This data demonstrated a high level of accuracy in the clinical use of navigated, robot-assisted surgery, with no malpositions requiring return to the OR. Additionally, screw placement and angulation accuracy improved with experience.

Perioperative Risk Factors for Early Revisions in Stand-alone Lateral Lumbar Interbody Fusion

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Introduction: Lateral lumbar interbody fusion (LLIF) can be performed as a stand-alone procedure without supplemental posterior instrumentation for select patients with various spinal conditions. Previous reports demonstrated favorable results with stand-alone LLIF, however, a reoperation rate of up to 10% has been reported. It remains unclear what potential perioperative factors are associated with early failure or revision after stand-alone LLIF. The aim of this study was to determine perioperative factors that increase the risk of an early revision surgery after a stand-alone LLIF procedure.

Methods: Data of consecutive patients who underwent a stand-alone LLIF procedure between 2007-2016 at a single academic institution was reviewed. All revision surgeries or recommendation for revision surgery within 12 months after LLIF procedure were documented. As potential contributing variables, age, gender, race, body mass index (BMI), smoking status, history of diabetes, operative levels, preoperative clinical diagnosis, number of fusion levels and the average L1/2 QCT-vBMD value were obtained. Logistic regression analyses were conducted. Cage subsidence was classified as Grade 0 to III representing the percentage (in 25% increments) of level collapse¹, was also evaluated in patients who had radiographs/CT between 6-12 months postoperatively.

Results: 133 patients were eligible for inclusion. 21 patients (15.8%) underwent revision surgery and 4 (3.0%) patients were recommended for revision surgery within one year. The revision surgeries included additional posterior fusion (92.0%), decompression (4.0%), and vertebroplasty (4.0%). The primary reason for revision surgery was due to neurological symptoms or pain (68%). There was no significant difference between the revision (RG) and the non-revision group (NRG) regarding baseline demographics. The average number of levels fused was 2.12 in the RG and 2.14 in the NRG (p=0.547). No significant differences were observed between the RG and NRG in preoperative diagnoses of spondylosis (44.0% vs 54.6%), spondylolisthesis (68.0% vs 59.3%), central spinal canal stenosis (76.9% vs 72.0%), or degenerative scoliosis (Cobb >20°) (56.0% vs 49.1%). In the RG, significantly more patients had the diagnosis of foraminal stenosis (64.0% vs 39.8%, p=0.043). Although the RG trended towards a lower vBMD, this was not a significant result (p=0.097). A non-significant trend towards a higher grade of subsidence (over 50% of level collapse) was observed in the RG (1.67 vs 1.28, p=0.130). Although not statistically significant (p=0.076), patients with preoperative foraminal stenosis and severe subsidence (Grade II or III) demonstrated the highest early revision rate (36.8%) compared to patients with no or one risk factor (10.8% and 20.8%) (Figure1).

Discussion: Our results showed that patients with foraminal stenosis were more likely to have an early revision surgery after a stand-alone LLIF procedure. The most common reason for revision among this group was persistent or recurring neurological symptoms and/or pain. This information can assist in preoperative discussions and management of patient expectations following this minimally invasive procedure. Our results suggest that larger studies may be warranted to determine the likelihood and need for additional surgery in patients with preoperative foraminal stenosis who undergo stand-alone LLIF.

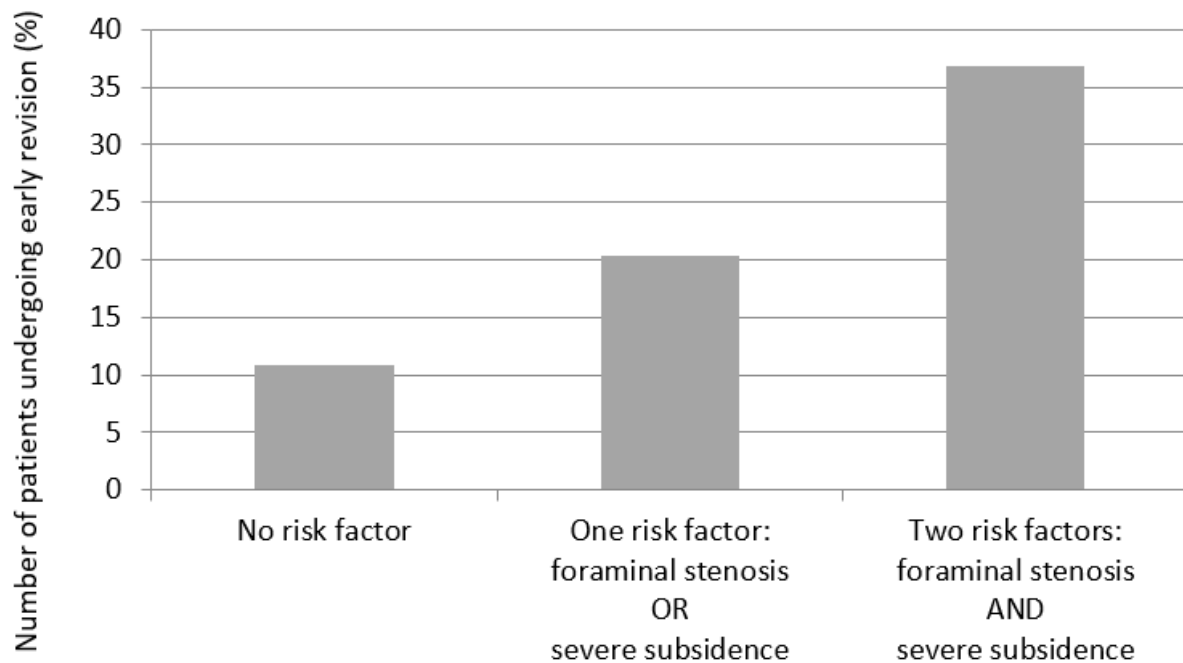


Figure 1. Percentage of early revisions stratified by the number of risk factors.

Marchi L, Abdala N, Oliveira L, et al. Radiographic and clinical evaluation of cage subsidence after stand-alone lateral interbody fusion. J Neurosurg Spine 2013;19:110–8.

Analysis of risk factors for proximal kyphosis after adult degenerative scoliosis

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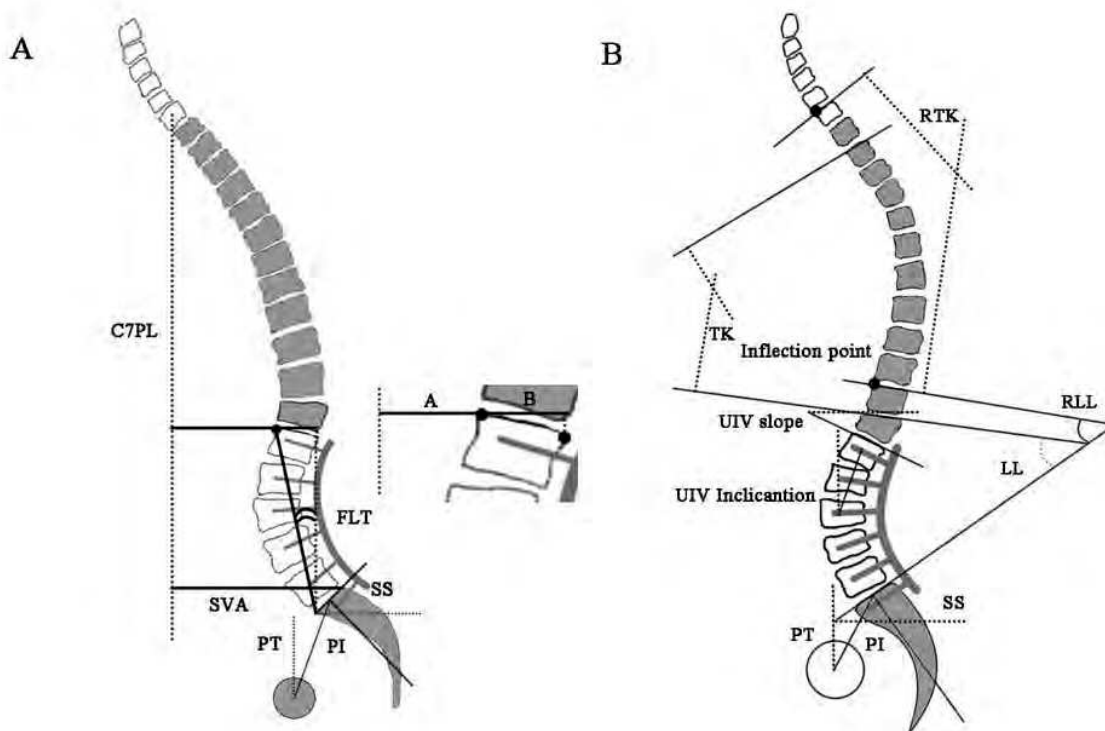
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Introduction: Proximal junctional kyphosis (PJK) is a common complication after long segmental fusion of adult degenerative spinal deformity. The purpose of this study was to analyze the incidence of PJK and related risk factors after posterior lumbar interbody fusion (PLIF) in adult degenerative scoliosis.

Methods: A retrospective analysis of 144 patients with adult degenerative lumbar scoliosis treated with PLIF combined with pedicle screw fixation from June 2013 to January 2016. This study compared the effects of really thoracic kyphosis (RTK) and really lumbar lordosis (RLL) with theoretical lumbar kyphosis (TK) and lumbar lordosis (LL) on PJK. This study were first time to analysis some special parameters as the risk factor for PJK, such as, upper instrumentation vertebrae (UIV) Slope, UIV Inclination, UIVa (UIV and C7 perpendicular distance), UIVb (UIV lever distance), and FLT (Fused lumbar tile).

Results: The preoperative and postoperative PJK patients had less PI-LL than the PJK group ($P=0.038$) and ($P=0.000$). The postoperative SVA values in the PJK group were significantly greater than those in the non-PJK group ($P=0.015$), but the preoperative group no significant difference. Intraoperative blood loss, number of interbody fusion segments, number of laminar decompression segments, lower tibia fusion ratio, and posterior ligament complex (PLC) injury ratio were significantly higher in the PJK group than in the non-PJK group ($P=0.005$, $P=0.041$, $P=0.041$, $P=0.017$, $P=0.000$ and $P=0.000$). The PT value and PI-LL value of non-PJK group were significantly higher than those of PJK group ($P=0.000$) and ($P=0.000$). However, the SS value, LL value, LL-TK value, RLL-RTK value, UIV slope, UIV inclination and RLL value of the non-PJK group were significantly lower than those of the PJK group ($P=0.001$, $P=0.006$, $P=0.001$, $P=0.004$, $P=0.000$, $P=0.005$, $P=0.043$). The multivariate logistic regression model showed independent risk factors for perioperative PJK after adult spinal deformity surgery including: BMI (OR 1.6, $P=0.000$), smoking (OR 3.1, $P=0.016$), and UIV slope (OR 2.0, $P=0.015$) and PI-LL (OR 1.03, $P=0.015$).

Discussion: In this study, the independent risk factors for PJK after posterior lumbar interbody fusion with adult degenerative scoliosis were analyzed by multivariate logistic regression (BMI (OR 1.6, $P=0.000$), smoking (OR 3.1, $P=0.016$), UIV slope (OR 2.0, $P=0.015$) and PI-LL (OR 1.03, $P=0.015$). At the same time, we found a significant correlation between UIVa/b and LL-TK, RLL-RTK and SVA through correlation analysis. UIVa/b can reflect the SVA situation and UIV tilt, and can be used as a predictor of PJK.



1. Jimbo S, Kobayashi T, Aono K, Atsuta Y, Matsuno T. Epidemiology of degenerative lumbar scoliosis: a community-based cohort study. 2012, 37 (20) : 1763-1770.
 2. Schwab F, Dubey A, Gamez L, El Fegoun A B, Hwang K, Pagala M, Farcy J P. Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. 2005, 30 (9) : 1082-1085.
 3. Glattes R C, Bridwell K H, Lenke L G, Kim Y J, Rinella A, Edwards C. Proximal Junctional Kyphosis in Adult Spinal Deformity Following Long Instrumented Posterior Spinal Fusion. 2005, 30 (14) : 1643-1649.
 4. Bridwell K H, Lenke L G, Cho S K, Pahys J M, Zebala L P, Dorward I G, Cho W, Baldus C, Hill B W, Kang M M. Proximal junctional kyphosis in primary adult deformity surgery: evaluation of 20 degrees as a critical angle. 2013, 72 (6) : 899-906.
 5. Sebaaly A, Sylvestre C, El Quehntani Y, Riouallon G, Larrieu D, Boussiere L, Steib J P, Roussouly P, Wolff S, Obeid I. Incidence and Risk Factors for Proximal Junctional Kyphosis. 2018, 31 (3) : E178-E183.
- Liu F Y, Wang T, Yang S D, Wang H, Yang D L, Ding W Y. Incidence and risk factors for proximal junctional kyphosis: a meta-analysis. 2016, 25 (8) : 2376-2383.

Does the actual lordosis gain following use of interbody grafts in fusion operations match the expected gain based on the lordosis of graft itself?

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Introduction: Degenerative disease of the lumbar spine is a major cause of morbidity and chronic pain in the aging population. Surgical correction is often required for relief of symptoms. Reduce motion across the painful vertebral segment as well as restoring sagittal alignment are associated with improved clinical outcomes. Interbody graft design allows for reliable fusion as well as gain in segmental lordotic angle through differential distraction between the anterior and posterior ends of the vertebral bodies. This study aims to assess the effectiveness of different graft types by measuring the gain in segmental lordosis at the level of fusion.

Methods: This is a retrospective study that will look at all lumbar interbody fusion procedures where a graft has been used from June 2017 to June 2018. Inclusion criteria included patients with degenerative disease of the lumbar spine that have undergone fusion surgery with the use of an interbody graft. The study assessed lateral radiographs taken preoperatively and immediately post-operatively. The radiographs were measured for the degree of lumbar lordosis and segmental lordotic angle using the Cobb method. Patient charts were reviewed to collect demographic information, as well as graft(s) model used. The lordosis of the graft was compared to the change in lumbar lordosis between pre-op and post-op measurements.

Results: 80 patients were included in this study. The grafts used included a range of lordosis angles (0,6,8,10,12,15°). The date of post-operative radiologic assessment ranged from 2 to 6 weeks post operatively. The majority of patients undergoing surgery had an improvement in sagittal alignment, with mean change in lumbar lordosis of 2° and mean change in segmental lordosis of 4°. There was poor correlation between the graft lordosis and segmental lordosis ($R^2 = 0.0374$).

Conclusion: Graft lordosis does not predict post-operative segmental and lumbar lordosis changes. This is likely due to the presence of other contributing factors, such as surgical technique, level of fusion, as well as the severity of degenerative disease.

Increased PT/SS may play an important role in the pathogenesis of lumbar spondylolisthesis with degenerative lumbar scoliosis

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Introduction: Recently, many authors have suggested the role of sacropelvic morphology and balance in the pathogenesis of various spinal disorders, including degenerative spondylolisthesis, adolescent idiopathic scoliosis, and adult spinal deformity. However, there have been few studies specifically describing the sacropelvic morphology and balance in patients with lumbar spondylolisthesis and degenerative lumbar scoliosis (LSDLS), especially patients with spondylolysis. Our purpose was to explore the clinical and spinopelvic differences in LSDLS and standalone lumbar spondylolisthesis (SALS), and identify the risk factors for LSDLS.

Methods: In this case-control study, We retrospectively analyzed 130 patients with lumbar spondylolisthesis seen between 05/2013 and 12/2016 in our hospital. Propensity score matching was used to reduce an age distribution imbalance between the two groups. Clinical and spinopelvic parameters were compared by independent samples t test and chi-square test. The PACS (Picture Archiving & Communication System) measuring tool was used for radiographic measurements. Measurement differences may exist between different observers, so all measurements were performed by a single researcher, and the average value of two measurements was taken. All data were processed with the SPSS software package, version 24.0 (SPSS Inc., Chicago, IL, USA). Nonlinear binary logistic regression analysis was used to analyze the independent factors.

Results: There was no significant difference between groups for body mass index, level of intercrest line, level of spondylolisthesis, grade of spondylolisthesis, sagittal translation, segmental angulation, thoracic kyphosis, or sagittal vertical axis. The LSDLS group had significantly lower lumbar lordosis (LL) than the SALS group. The LSDLS group showed significantly greater pelvic tilt (PT) and ratio of PT to SS (sacral slope) (PT/SS), and lower SS. The pelvic incidence (PI) was not significantly different. The LSDLS group showed stronger significant differences in PT/SS compared to the SALS group. With each 0.1 increase in PT/SS, the risk of LSDLS increased 1.465 times.

Conclusions: In conclusion, patients with spondylolysis are less prone to DLS. Lower LL and SS, and higher PT are associated with the occurrence of LSDLS. Increased PT/SS may play an important role in the pathogenesis of LSDLS. Measurement of these spinopelvic parameters can assist in monitoring progression of disease in patients and ultimately allow physicians to provide better treatment and care.

Spinal cord stimulation therapy has the effect of reducing overdose drugs for chronic severe pain patients

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Introduction: In recent years, spinal cord stimulation therapy (SCS) as a treatment for refractory pain has been applied clinically. In April 2014, we established the Chiba SCS Working Group, consisting of 8 associated facilities. SCS therapy under the initiative of spinal surgeon has been implemented. Many patients used many analgesics including opioids

In this study, we examined the effect, including whether we can reduce overdose through the intervention of SCS therapy.

Method: From April 2014 to December 2016, SCS therapy was performed in our SCS group, and all patients who passed 6 months or more were investigated retrospectively. Evaluation items are the target disease/condition, Visual Analogue Scale (VAS) before and after SCS therapy, Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ), and the change in analgesic drugs amounts. In addition, the activities during the day was evaluated objectively by using the behavior monitoring device detained.

Results: There were 34 patients undergoing SCS, including 18 cases of Failed Back Surgery Syndrome, 9 cases of lower back pain due to the scoliosis, 3 cases of obstructive arteriosclerosis, 1 below level pain after cervical spinal surgery, 1 patient with inguinal pain due to rheumatism, 1 with nerve compression due to tumor, and 1 with agony portion.

All cases were with strong pain and difficult to control even with a strong opioid or many drugs.

There were 7 cases of opioid use in 34 cases and 30 cases of use of two or more kinds of analgesic drugs. The range of back pain (VAS) was from 80.6 to 42.8, and leg pain improved significantly from 66.3 to 32.2 after SCS implementation. In addition, the bedtime decreased from 70.9% to 65.2%, and the activity time increased. About the changes in each item of JOABPEQ, pain-related disorder: 26.2 to 38.9, lumbagal dysfunction: 19.7 to 28.6, walking dysfunction: 14.3 to 27.0, and the score improved by 20 or more was pain and gait function. 71% patients were able to withdraw opioid and 91% were able to reduce analgesics.

Discussion: In this study, SCS therapy significantly improved pain and gait function. In most cases, it led to the withdrawal of opioids and the relief of overdose of analgesics. The reducing of analgesics leads to reduction of the physical burden on the patient and to a medical economic effects.

In conclusion, SCS is effective therapy for avoiding overdose of analgesics including opioids.

Difference in the Amount of Analgesics Used after Spinal Posterior Fusion Surgery: Comparison between Regular and On-demand Prescription

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Introduction: Although pain management after surgery is very important, it should be avoided that analgesics are aimlessly continued to prescribe for patients who have no need. We changed prescription of postoperative analgesics from regular to on-demand in 2016. The purpose of this study is to investigate the difference in the amount of analgesics used by changing the prescription of postoperative analgesics during hospitalization from regular to on-demand.

Methods: The subjects were 100 patients who were prescribed celecoxib (100mg) on-demand after posterior thoracic and lumbar spinal instrumentation surgery between 2016 and 2017 (on-demand group). As for the method of administration of on-demand group, all analgesics were managed by the nurse, and it was confirmed whether or not to use analgesics for patients before meals, and we prescribed them after meals when they hoped. Patients with spinal tumor, spinal infection, idiopathic scoliosis, postoperative infection, and postoperative hematoma were excluded from this study. One hundred patients who were prescribed celecoxib regularly (200mg/day) between 2015 and 2016 were used as a control (regular group). Analyses were carried out between these groups regarding postoperative hospital stays, Visual Analogue Scale of low back and leg pain at discharge, satisfaction score at discharge, the amount of postoperative celecoxib and cost of all analgesics.

Results: On-demand group included 46 males and 54 females, mean age 69 years, and regular group included 60 males and 40 females, mean age 72 years. There were no significant differences between two groups regarding postoperative hospital stays (on-demand group vs regular group: 27.2 days vs 27.3 days, $p = 0.921$), low back pain (19.4 vs 17.8, $p = 0.577$), leg pain (14.9 vs 19.9, $p = 0.100$), satisfaction score (72.8 vs 75.6, $p = 0.383$). Regarding the amount of postoperative celecoxib, there was significant difference between two groups (17 tablets vs 43 tablets, $p < 0.001$). Regarding cost of all analgesics, there was significant difference between two groups (1238 JPY vs 3209 JPY, 1 JPY = 0.0089 USD, $p < 0.001$). The average amount of celecoxib in on-demand group was already significantly less than that of regular group from 1st week after surgery ($p < 0.001$); 7.5 tablets vs 14 tablets (1st week), 4.1 vs 12 (2nd week), 3.2 vs 9.5 (3rd week), 2.4 vs 5.3 (4th week).

Discussion: There were no significant differences between on-demand group and regular group in term of postoperative hospital stays, low back and leg pain at discharge, and satisfaction score at discharge in this study. Our results suggested that on-demand prescription might reduce unnecessary analgesics prescription, and decrease medical cost. The amount of analgesics at 1st week after surgery in regular group was used more than on-demand group. Regular prescription might lead to excessive prescription from 1st week.

EHR-based retrospective analysis of patients undergoing long-segment lumbar spine fusion at a single academic institution yields patient-specific prediction of length of stay after surgery

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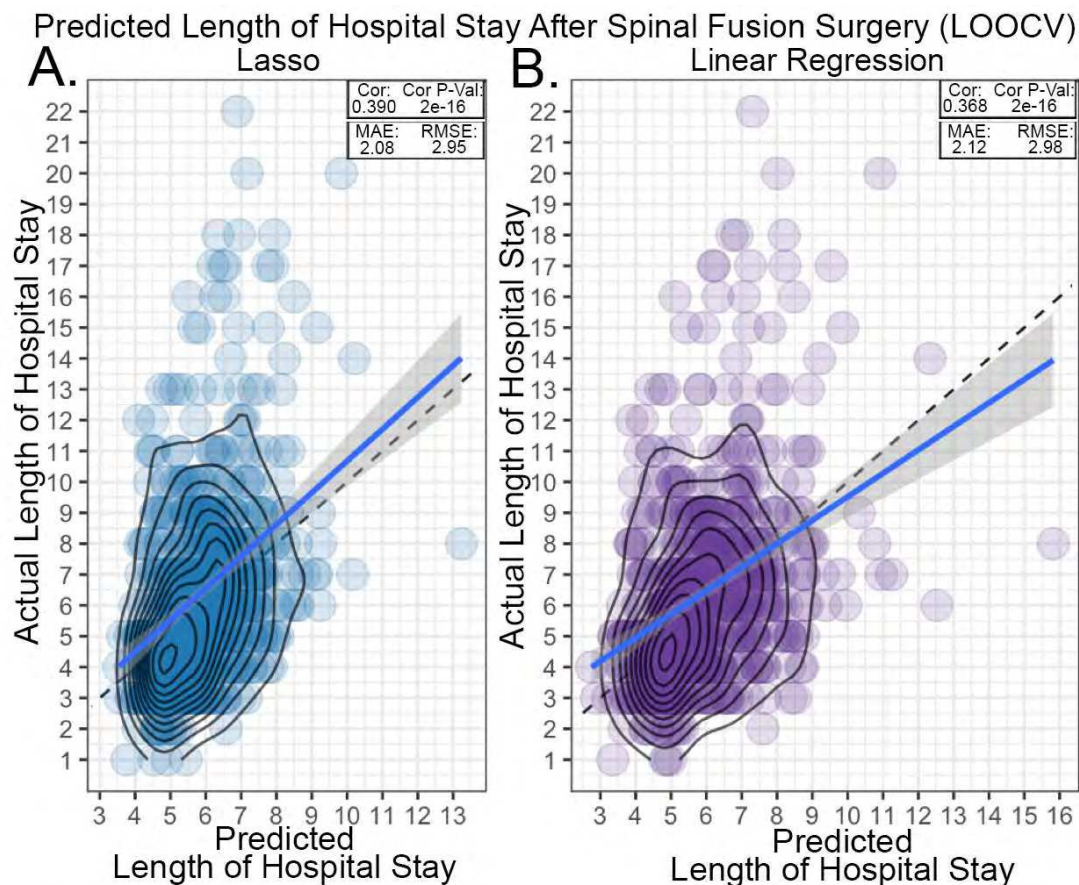
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Background: With the advent of Electronic Health Records (EHRs), the number of patients available for analyzing common and rare medical procedures is increasing, rivaling that of even the largest prospective datasets. Spinal fusion surgery for adult spinal deformity (ASD) is an increasingly commonplace surgery, for which studies using large datasets have largely been based on administrative claims. In this study, we replicate for the first time using comprehensive EHR data to study length of stay (LOS) after long segment lumbar spine fusion.

Methods: Structured data elements were extracted from the EHR at a single institution, including demographic variables, ICD-10 diagnosis codes, and medications. All patients undergoing posterior lumbar spine fusion including 3 more levels were identified using CPT codes and were included. We perform logistic factor, multivariate linear, machine learning (lasso) analyses to study factors influencing length of stay in hospital after spinal fusion surgery.

Results: 615 patients were included. Average length of stay was 6.43 days. The following variables were associated with increased LOS: comorbidities, including chronic kidney disease (beta: 2.1) and history of major adverse cardiovascular events (beta: 0.98), socioeconomic factors, female gender (beta: 0.88). Antihyperlipidemic medication was associated with reduced LOS (beta: -0.74). The predictive model for LOS had a correlation of 0.390 (p-value: < 0.001.)

Conclusion: In this study, we present the first analysis and prediction method using EHR data for length of stay in hospital after long segment posterior lumbar fusion. We expect this analysis to serve as a framework for future studies using EHR datasets, adding new knowledge and external validation to traditional studies.



Correlation between ODI, PROMIS and SF-12 in Minimally Invasive Lumbar Spinal Surgery

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Introduction: As the focus in spine surgery shifts from radiographic to patient-centric outcomes, patient-reported outcomes measures (PROMs) are becoming increasingly important. They are linked to patient satisfaction, and are thus being used to assess healthcare expenditure, determine compensation and evaluate cost-effectiveness. It is evident that PROMs are important to various stakeholders, including patients, physicians, payers and healthcare institutions. Thus, it is vital to establish methods to interpret and evaluate these outcomes. The purpose of this study is to evaluate the correlation between Oswestry Disability Index (ODI), Patient Reported Outcome Measurement Information System Physical Function (PROMIS-PF) and Short Form-12 Physical Health Score (SF-12 PHS) in patients undergoing minimally invasive lumbar spinal surgery.

Methods: PROMs collected pre-operatively and 2 weeks, 6 weeks, 3 months, 6 months and 1 year post-operatively of patients undergoing lumbar spine surgery were analyzed using Pearson product-moment correlation.

Results: Of the 292 patients included, 158 underwent lumbar decompression surgeries and 134 underwent lumbar fusions. ODI decreased from 40.84±19.23 pre-operatively to 16.01±12.84 at 1 year. Similarly, PROMIS-PF and SF-12 PHS improved from 35.51±7.92 to 47.78±11.55 and 32.37±8.38 to 43.35±10.43, respectively. A statistically significant, negative correlation was seen between ODI and PROMIS-PF at all time-points, which was strong pre-operatively ($r=-0.673, n=256, p<0.0001$) and at 2 weeks ($r=-0.715, n=228, p<0.0001$), 6 weeks ($r=-0.779, n=190, p<0.0001$), 3 months ($r=-0.732, n=130, p<0.0001$) and 6 months ($r=-0.685, n=80, p<0.0001$); and moderate at 1 year ($r=-0.517, n=22, p=0.010$). A statistically significant, negative correlation was also seen between SF-12 PHS and ODI at all time-points, which was weak pre-operatively ($r=-0.384, n=287, p<0.0001$), but strong in the post-operative period (2 weeks: $r=-0.625, n=272, p<0.0001$; 6 weeks: $r=-0.686, n=230, p<0.0001$; 3 months: $r=-0.761, n=171, p<0.0001$; 6 months: $r=-0.789, n=108, p<0.0001$; and 1 year: $r=-0.740, n=31, p<0.0001$). There was a statistically significant positive correlation between SF-12 PHS and PROMIS-PF at all time-points, which was weak pre-operatively ($r=0.393, n=255, p<0.0001$); strong at 2 weeks ($r=0.630, n=224, p<0.0001$), 6 weeks ($r=0.676, n=190, p<0.0001$), 3 months ($r=0.781, n=128, p<0.0001$) and 6 months ($r=0.718, n=78, p<0.0001$); and moderate at 1 year ($r=0.548, n=22, p=0.008$).

Discussion: While ODI and SF-12 have been used to evaluate outcomes for several years, PROMIS is a new outcome measure that is increasingly being implemented. The results of our study show that PROMIS-PF correlates strongly with both, ODI and SF-12 PHS. These findings suggest that PROMIS may be a good surrogate for these legacy outcome measures, as it not only captures disease-specific disability in these patients but also reflects the impact on overall physical health. Larger studies are warranted to evaluate the true utility and value of this outcome measure in common lumbar spinal conditions, and methods to interpret the clinical relevance of PROMIS scores need to be established.

Table 1: Mean PROM Scores

	ODI	PROMIS-PF	SF-12 PHS
All Lumbar Procedures			
Pre-operatively	40.84 ± 19.23	35.51 ± 7.92	32.37 ± 8.38
2 weeks	35.53 ± 22.18	36.62 ± 9.35	33.20 ± 10.25
6 weeks	28.72 ± 20.42	40.57 ± 9.14	36.84 ± 10.09
3 months	23.51 ± 18.38	43.76 ± 10.20	39.83 ± 10.57
6 months	19.66 ± 16.24	45.55 ± 9.30	41.46 ± 10.56
1 year	16.01 ± 12.84	47.78 ± 11.55	43.35 ± 10.43
Lumbar Decompressions (n=158)			
Pre-operatively	42.53 ± 20.33	35.11 ± 8.17	31.17 ± 7.95
2 weeks	29.05 ± 19.89	38.96 ± 8.80	35.89 ± 10.94
6 weeks	24.23 ± 18.68	42.18 ± 9.09	38.61 ± 9.74
3 months	21.90 ± 18.53	45.13 ± 10.91	41.35 ± 10.39
6 months	19.23 ± 16.96	44.49 ± 9.50	42.11 ± 11.22
1 year	17.47 ± 13.10	46.13 ± 12.35	42.78 ± 8.76
Lumbar Fusions (n=134)			
Pre-operatively	38.91 ± 17.80	36.01 ± 7.64	33.83 ± 8.69
2 weeks	43.52 ± 22.30	33.68 ± 9.23	30.58 ± 8.76
6 weeks	33.49 ± 21.15	38.88 ± 8.92	34.87 ± 10.14
3 months	25.01 ± 18.21	42.64 ± 9.51	38.42 ± 10.60
6 months	20.02 ± 15.75	46.46 ± 9.14	40.89 ± 10.01
1 year	15.08 ± 12.95	48.73 ± 11.37	43.71 ± 11.58

Table 2: Correlations between various PROMs

	Number of observations (n)	Pearson Correlation Co-efficient (r)	Strength of Correlation	p - value
ODI and PROMIS-PF				
Pre-operatively	256	-0.673	Strong	<0.0001
2 weeks	228	-0.715	Strong	<0.0001
6 weeks	190	-0.779	Strong	<0.0001
3 months	130	-0.732	Strong	<0.0001
6 months	80	-0.685	Strong	<0.0001
1 year	22	-0.517	Moderate	0.010
SF-12 PHS and ODI				
Pre-operatively	287	-0.384	Weak	<0.0001
2 weeks	272	-0.625	Strong	<0.0001
6 weeks	230	-0.686	Strong	<0.0001
3 months	171	-0.761	Strong	<0.0001
6 months	108	-0.789	Strong	<0.0001
1 year	31	-0.740	Strong	<0.0001
SF-12 PHS and PROMIS-PF				
Pre-operatively	255	0.393	Weak	<0.0001
2 weeks	224	0.630	Strong	<0.0001
6 weeks	190	0.676	Strong	<0.0001
3 months	128	0.781	Strong	<0.0001
6 months	78	0.718	Strong	<0.0001
1 year	22	0.548	Moderate	0.008

Prevention of nerve root thermal injury caused by bipolar cauterization near the nerve roots

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Introduction: In spine surgery, bipolar cauterization of epidural venous plexus near the nerve root is an essential procedure to control bleeding. Although a potential risk of neurological thermal damage exists, the underlying mechanism and prevention have not been elucidated. This study aimed to clarify whether bipolar cauterization near the posterior branches of nerve root causes neurological damage, using a rabbit model. We also verified the three methods to prevent nerves from being injured: first, we used saline irrigation during bipolar cauterization; second, we changed the direction of bipolar forceps, and third, we injected corticosteroid locally after bipolar cauterization.

Methods: On the fascia of the paraspinal muscle of the rabbits, temperature measurements were performed. Bipolar forceps were set in parallel direction. A soft wire thermometer was set on the fascia 1 mm away from the midpoint of bipolar forceps. The power was set to 25 W, and cauterization duration was four seconds.

Bipolar forceps were set parallel to posterior branches of nerve roots arising from L3 to L5 and cauterized soft tissue at 1 mm away from each nerve. Nerve specimens were collected immediately after euthanization and stained using hematoxylin and eosin (H&E) and Luxol fast blue (LFB) stains. Nerve root injury was evaluated using microscopic evaluation. In the sham group, all procedures except for bipolar cauterization were performed.

To evaluate the effectiveness of saline irrigation, temperature measurement was performed in the same manner as described above and added saline irrigation during bipolar cauterization. Subsequently, additional 12 nerves were operated for histological evaluation.

To detect the difference of the direction of bipolar forceps, we set bipolar forceps in the perpendicular direction and performed temperature measurement on the fascia of the paraspinal muscle.

To verify the effectiveness of local injection of corticosteroid, additional 12 nerves were operated; the operative procedure was same as described above, and local injection of corticosteroid (20 µg/kg of triamcinolone acetonide per nerve) was added after bipolar cauterization in the parallel direction.

Results: After bipolar cauterization, temperature of the surrounding site reached 60.9 °C, and 47.8% of the nerves were histologically injured. Using saline irrigation, thermal elevation was significantly suppressed up to 42.7 °C ($p < 0.01$), and no nerve was histologically injured. When bipolar cauterization was performed in the perpendicular direction, temperature of the surrounding site reached only 40.4 °C ($p < 0.01$). Locally injected corticosteroid reduced the incidence of nerve injury to 25.0%. However, a significant increase in nerve damage remained compared to the sham group ($p < 0.01$).

Conclusion: Bipolar cauterization near the nerve roots can increase the temperature of nerve roots and cause thermal nerve root injury, despite no accidental direct nerve root injury. Using saline irrigation, or setting bipolar forceps perpendicular to nerve roots, thermal elevation could be suppressed and nerve injury could be prevented. Therefore, it is recommended that surgeons set bipolar forceps perpendicular to nerve roots or use saline irrigation for the prevention of nerve root injury.

Increased axial facet angle correlates with poor percutaneous pedicle screw placement

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Introduction: The purpose of this study was to test the hypothesis that axial facet angle correlates with poor pedicle screw placement (and especially facet violation) in percutaneous fluoroscopy-guided pedicle screw placement.

Methods: 95 consecutive patients who underwent minimally-invasive instrumented fusion of the lumbar or lumbosacral spine with percutaneous fluoroscopy-guided pedicle screw placement between L4 and S1 were included. Postoperative CT was used to categorize pedicle screw placement into three categories: good (no cortical breach), acceptable (cortical breach within safe zone and/or any amount of tip breach), poor (outside of safe zone, and/or violation of topmost unfused facet joint, and/or endplate violation into unfused level). Safe zone was defined as 4mm lateral breach or 2mm medial breach of pedicle cortex (1,2; Figure 1). Axial facet angle was measured using Centricity PACS (GE Healthcare, Chicago, IL) built-in angle measurement against a mid-sagittal line (Figure 1). Global mean axial facet angles at L4, L5, and S1 were calculated using all involved levels. Axial facet angles associated with poorly placed screw were then calculated and compared to the global mean axial facet angles at L4 and L5 using the two-tailed t-test. Sub-group analysis was finally performed for facet violation alone as cause for poor pedicle screw placement.

Results: After exclusion of pedicles that did not have sufficiently measurable pre-operative axial facet angle, a total of 349 pedicle screws were analyzed. Of the total, 38 (10.7%) were categorized as poor placement, and of these 31 (82%) were due to topmost unfused facet level violation. Global axial facet angle means were 36.8 degrees for L4 ($\sigma = 11.3$, $n = 115$), 45.8 for L5 ($\sigma = 11.4$, $n = 161$), and 50.5 for S1 ($\sigma = 11.4$, $n = 73$). Mean axial facet angles associated with poorly placed screws were 42.7 degrees for L4 ($\sigma = 11.6$, $n = 15$) and 51.4 degrees for L5 ($\sigma = 10.2$, $n = 23$). These means were higher than the global means (Figure 2) at L4 ($p = 0.063$) and L5 ($p = 0.028$). Sub-group analysis demonstrated that the mean axial facet angles associated with topmost unfused facet level violation were 44.0 degrees for L4 ($\sigma = 10.9$, $n = 14$) and 53.2 degrees for L5 ($\sigma = 9.61$, $n = 17$). These means were significantly higher than the global means (Figure 2) at L4 ($p = 0.027$) and L5 ($p = 0.009$). No poor screw placement were found at the S1 level and so was not included in this analysis.

Discussion: Increased axial facet angle significantly correlates with poor screw placement and especially with facet violation in percutaneous fluoroscopy-guided pedicle screw placement.

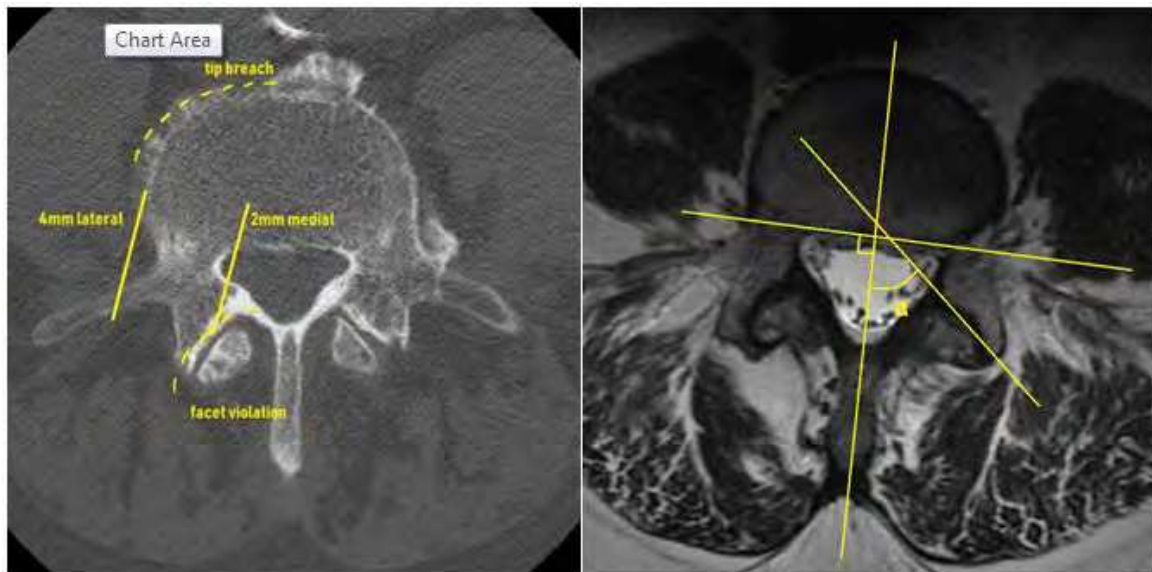


Figure 1: (left) demonstration of pedicle screw safe zone, location of facet violation and tip breach. (Right) Example axial facet angle (a) of the left L5 facet.

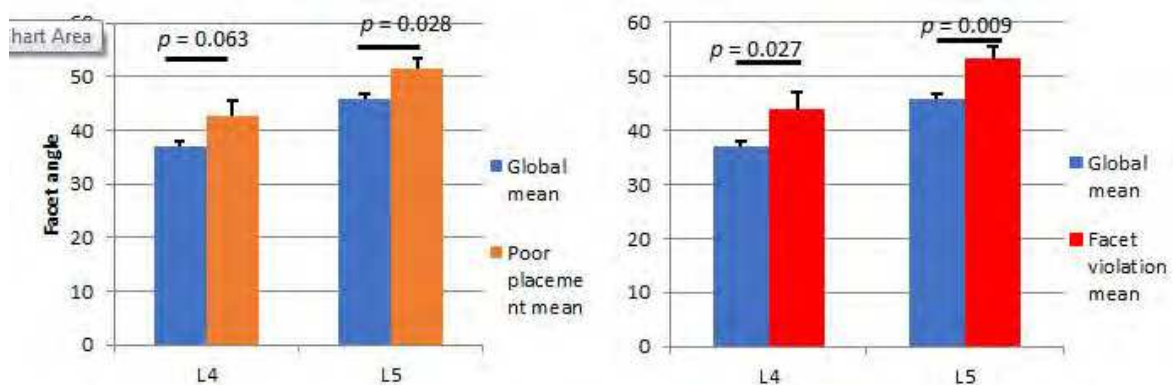


Figure 2: Mean axial facet angle of all poorly placed pedicle screws (left) and of those with facet violations only (right) compared to global L4 and L5 axial facet angle means.

Pre-operative muscle health impacts the time it takes to reach minimally clinically important differences in health related quality of life scores for one level lumbar fusions

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Introduction: There is evidence that degenerative changes in paralumbar musculature impact conditions like low back pain, lumbar spinal stenosis and lumbar degenerative kyphosis. For patients undergoing spinal surgery we hypothesized that paralumbar muscle health would alter the time it took for patients to reach minimal clinically important differences (MCIDs) in health related quality of life scores (HRQOLs).

Methods: We performed a retrospective review of patients that eventually went on to undergo either a lumbar decompressive surgery or a one level lumbar spinal fusion. We analyzed magnetic resonance imaging (MRI) to quantify muscle health using the lumbar indentation value (LIV) which is validated method of measuring the relative cross-sectional area of lumbar musculature. T2 axial slices from the disc space at the operative level were analyzed. We separated our cohort of patients into whether they had a lumbar decompression alone or one level lumbar decompression/fusion. Health related quality of life (HRQOL) scores were collected on these patients in the pre-operative period and the post-operative period up to 1 year out from surgery. These scores included the Visual analog back and leg scores (VAS leg and VAS back), the Oswestry Disability Index (ODI), Short Form 12 (SF-12) mental health scores (MHS) and physical health scores (PHS). We defined MCID as has been previously reported in the literature. We then correlated the LIV calculated off pre-operative MRI and correlated this finding with time to MCID using a linear regression analysis.

Results: A total of 85 patients were included within our analysis. The average age was 58.4 +/- 15.7 years old and there were 45 men and 40 women. There were 93 disc spaces operated on within this cohort. The majority of patients undergoing a lumbar decompression (LD) had a diagnosis of disc herniation (49.2%) and the majority of patients that had a lumbar fusion (LF) were diagnosed with lumbar spinal stenosis (93.1%). We found that the average LIV for LD patients was 16.2 +/- 6.5mm and for LF patients was 17.1 +/- 6.6mm. There was no statistically significant correlation between time to MCID for ODI, SF-12 MHS, SF-12 PHS, VAS leg, or VAS back scores and LIV for patients undergoing a lumbar decompression. There was a statistically significant inverse relationship between time to MCID for ODI ($p = 0.02$) and LIV and time to MCID for SF-12 MHS ($p = 0.04$) and LIV (i.e. higher LIV correlated with lower time to MCID for ODI and SF-12 MHS).

Discussion: These results emphasize the need for evaluation of paralumbar muscle health for patients undergoing lumbar surgery. Specifically, lumbar muscle health correlates with time to MCID for ODI and SF-12 MHS for patients undergoing lumbar fusion surgery. Further investigations are needed to determine how improvement of cross-sectional area of paralumbar muscle impacts MCID for patients undergoing lumbar surgery.

Clinical and radiological result of facet fusion using a ligamentum flavum floating method for degenerative spondylolisthesis

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Introduction: On the basis of previous clinical studies of instrumented facet fusion (FF) for degenerative lumbar spondylolisthesis (DLS), we have introduced a ligamentum flavum (LF)-floating method (LFF-FF), which might be less invasive to the dura matter as a decompression procedure than removing the LF. The objective was to evaluate clinical outcomes and MRI findings after LFF-FF for cauda equina syndrome caused by unstable DLS.

Methods: In the present study, we included 42 consecutive patients with unstable DLS who underwent LFF-FF. The surgery used a 5-cm midline skin incision, and bilateral laminar fenestration around the LF using high-speed drills, allowing a floating LF. The thickened LF was not removed but remained floating on the dural sac. FF was achieved using autologous bone harvested from the spinous process. Percutaneous pedicle screws were then inserted through the fascia. The following variables were compared between patients in the LFF-FF group and a group of 44 patients who underwent conventional FF: operating time; intraoperative bleeding; drain bleeding volume 2 days after surgery (DBV); the early clinical outcomes at 1 year after surgery assessed using a visual analogue scale (VAS) of buttock and lower limb pain (BLP-VAS) and buttock and lower limb numbness (BLN-VAS); and the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ). Furthermore, the cross-sectional area of the thecal sac (CSATS) was measured on MR images preoperatively, at a week, at 1 month, and at 3 months postoperatively in all patients in the LFF-FF group.

Results: The mean operative time was 146 min, blood loss was estimated to be 69 g, and DBV was 112 mL in patients in the LFF-FF group. The patients in the LFF-FF group had significantly lower DBV and less operative time than patients in the FF group. All LF floating phenomena occurred a week after surgery, and no presence of hematoma in contact with the dura was found. The mean CSATS increased significantly 148% at a week, 202% at a month, and 238% at 3 months after surgery. In patients in the LFF-FF group, JOABPEQ category scores demonstrated therapeutic effectiveness in 89% of patients for low back pain, 86% for walking ability, and 75% for social ability. BLP-VAS and BLN-VAS scores were reduced to 27% and 37% of their preoperative values, respectively. There were no significant differences in any preoperative scores, postoperative scores, or therapeutic effectiveness between the two groups.

Discussion: The results indicate that LFF-FF causes less blood loss after surgery and requires a shorter operating time than conventional FF. These advantages are probably because LFF-FF does not require exposure of the dura matter. The LF floating method is considered to result in effective decompression of the dural sac because of the good clinical outcomes and MRI findings of LFF-FF compared with FF. LFF-FF can be thought of as less invasive surgery because of the reduced blood loss and operative time saved, and may reduce the risk of dural tears and postoperative epidural hematomas because LFF-FF does not expose the dura matter.

A study of the risk for lumbar segmental artery injury using contrast computed tomography in the oblique lumbar interbody fusion

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Introduction: Oblique lumbar interbody fusion (OLIF) has been commonly performed for lumbar degenerative diseases and adult spinal deformities. Although some studies using magnetic resonance imaging (MRI) reported a risk of segmental artery injury, there are few studies evaluating the detailed anatomy of segmental arteries using contrast enhanced computed tomography (CT). The purpose of this study is to investigate the anatomical features and risk of lumbar segmental artery injury using contrast CT.

Methods: Contrast enhanced CT was used for 46 preoperative patients (12 male, 34 female; age 66.4 ± 1.6 years) with lumbar degenerative disease or adult spinal deformity undergoing OLIF from January 2016 to May 2018. Accurate coronal images were reconstructed on the anterior and posterior thirds of each vertebra between L1-2 and L4-5 using image analysis software. The distances from the intervertebral discs to their adjacent segmental artery were measured. When the distance from the intervertebral disc to the segmental artery was 10 mm or less, we considered that the vertebra has the risk of segmental artery injury, because the radius of the retractor with the fixing pin is 10 mm. Furthermore, the presence of a segmental artery running vertically over the intervertebral disc was also evaluated. The relationships between the risk of segmental artery injury and the side for approach (convex or concave), the level of lumbar vertebra, and each intersegmental Cobb angle were analyzed.

Results: The risk for segmental artery injury was 1.1%–31.5% from L1 to L5, respectively. In particular, the L4 segmental artery had high risk of injury (31.5%) in the posterior third of the L4-5 intervertebral disc. The risk of segmental artery injury was higher in cases with an intersegmental Cobb angle of 10° or more than it was in the case of a Cobb angle $<10^\circ$. Additionally, all the risks for segmental injury were found only on the concave side with scoliosis. An artery that coursed vertically over the intervertebral disc existed in L2-3 to L4-5 and was found in 6.5% of all cases examined.

Discussion: We found there was a high risk of segmental artery injury on the concave side with scoliosis and an intersegmental Cobb angle of 10° or more, or on the posterior third and caudal side of the L4 vertebral body, when fixing the OLIF retractor using a pin. Arteries that course vertically over the intervertebral disc exist in 6.5% cases of lumbar degenerative disease or adult spinal deformity treated with OLIF. If the artery is present on the opposite side of the approach, it is difficult to stop bleeding. Therefore, to avoid segmental artery injury in the OLIF procedure, contrast CT should be performed to clarify its location before surgery.

What makes the early outcome of spinal metastasis surgery unsatisfactory? A retrospective study

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Introduction: Spinal metastasis is a growing problem in patients with cancer. We have previously reported the efficacy of spinal metastasis surgery for maintaining or improving quality of life by alleviating pain and preserving neurologic function. On the other hand, spinal metastasis patients often have reduced general condition and might get even worse after spinal metastasis surgery. The aim of the current study was to investigate the poor prognosis factors of early outcome of spinal metastasis surgery.

Methods: One hundred twenty three patients with spinal metastasis who underwent spine surgery from November 2013 to August 2018 were included in this study (66 males and 56 females, the average age was 65.1). We defined the patients who died within one month after surgery, had worsening of Performance Status (PS) or pain (Numerical Rating Scale: NRS) one month after surgery, as early deterioration group. We also defined the other patients as improvement group. Age, gender, primary tumor, location of spinal metastasis, spinal instability neoplastic score (SINS), presence or absence of visceral metastasis, operation time and blood loss during the operation were studied.

Results: The median survival time, preoperative and one-month postoperative median PS of overall patients were 4.9 months, 3 and 2, respectively. The average NRS of overall patients significantly improved after surgery (preoperation 4.7, postoperation 2.0, $p < 0.01$). As for early deterioration group, 14 patients (11.4%) were included. Six patients died within one month, 4 patients each had worsening of PS or pain. Three of them had renal cell carcinoma as the primary tumor, two each had hepatocellular carcinoma, pulmonary adenocarcinoma or carcinoma of unknown primary, one each had prostatic carcinoma, carcinoma of the cervix uteri, carcinoma linguae, malignant lymphoma or rhabdomyosarcoma. They were classified as rapid growth or moderate growth based on Katagiri New Score, implying relatively higher malignancy. Ten of them had brain or visceral metastasis. The spinal metastasis in early deterioration group located from C2 to T11. The scores of location component of SINS were 1 in 5 patients, 2 in 2 patients and 3 in 7 patients. Age, gender, operation time and blood loss during the operation did not show significant difference between the early deterioration group and the improvement group. Patients who died within one month or had worsening of PS had continuous tumor increase or metastasis progression and progression of reduced general condition even after surgery. The worsening of pain was caused by the metastasis of their femurs. Spinal surgery, including some complications such as malposition of screws, did not cause the early deterioration.

Discussion: About 11% of patients who had spinal metastasis surgery had early unsatisfactory outcome. Although the rate might be acceptable, we believe it should not happen considering the limited prognosis of cancer patients. Although current study could not identify the influential factors of the early deterioration of spinal metastasis surgery, further studies are needed to create the optimal medical care system of spinal metastasis.

An analysis and study on the changes of Lumbar function curve after single segment TLIF in patients with lumbar degenerative disease

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Introduction: Various spinal shapes and positional parameters have been described by radiographic assessment of asymptomatic volunteers to understand human sagittal balance in the standing position. But, there is few literatures regarding the difference between pre- postoperative. We study the characteristics and regularity of lumbar vertebral function curve classification after single segment transforaminal lumbar interbody fusion in patients with lumbar degenerative disease.

Methods: Retrospective analysis of 560 patients with lumbar degeneration and accepted TLIF surgery in our hospital from 2010 to 2015, according to the inclusion and exclusion criteria, 121 cases who accepted the lumbar vertebral single segment TLIF surgery and has the complete follow-up data were included in, there were 63 males and 58 females were included, the range of age was 20-62 years, and the mean age was 47.2 years. All patients underwent transforaminal lumbar interbody fusion (TLIF) surgery by the same surgeon. Based on the adjusting Roussouly lumbar spine classification method proposed by Weishi Li, the lumbar sagittal parameters were measured, which include the pelvic incidence (PI), sacral slope (SS), lumbar sacral angle (LSA), thoracic lumbar kyphosis (TK), sagittal vertical axis (SVA). The clinical efficacy was assessed by VAS and JOA scores. In order to analysis the changes of lumbar vertebral function curve and the parameters of spine pelvic sagittal parameters at different time points before and after the surgery and their relationship.

Results: The VAS and the JOA scores of all the patients were significantly improved after the surgery ($P < 0.05$). When we measure the spino-pelvic parameters, we found that there were no significant differences in SS before and after the surgery ($P > 0.05$), but there were significant differences in LSA, TK, L1SPI, T9spi and SVA before and after the surgery ($P < 0.05$), among which the change of SVA was significantly, C7PL was significantly backward shifted ($P < 0.05$). According to the lumbar spine classification proposed by Weishi Li, there were 22 cases of type I, 28 cases of type II, 35 cases of type III and 36 cases of type IV relatively. Among the patients, there were 64% of the patients whose lumbar spine classification were changed after the surgery, including 14 cases of type I, 15 cases of type II, 19 cases of type III and 30 cases of type IV relatively. Analysis of the related factors of the changes of the lumbar lordosis, we found the correlation coefficient between the changes of the intervertebral and the lumbar lordosis of the non-operative segment after the surgery is higher than the operative segment, there r value is 0.899 and 0.422 relatively ($P < 0.05$).

Insufficient augmentation of bone cement causes recompression of the augmented vertebra after balloon kyphoplasty

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Introduction: Balloon kyphoplasty (BKP) is a minimally invasive technique for vertebral compression fractures (VCFs). Significant pain relief and early mobilization can be achieved after the procedure (1-2). However, during follow-up, we observed recompression of the augmented vertebra (RAV) with significant vertebral height loss (VHL). In the light of previous studies, no critical factors related to RAV after BKP have been clearly described. The purpose of the present study was to investigate RAV after BKP in terms of cement augmentation.

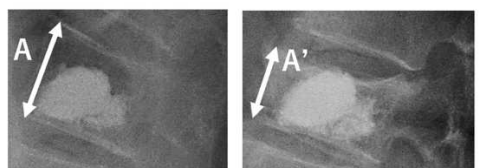
Methods: Eighty-seven patients with osteoporotic VCFs underwent BKP at our institution between January 2011 and October 2014. A total of 88 fractures were treated during this period. Each operated vertebra was sequentially measured for the height of its anterior vertebra (HA) on lateral radiographs. We calculated VHL as an indicator of RAV. VHL was calculated as the difference in HA between postoperative and 3 or 6 months after the procedure. RAV was defined as a VHL of >5.0 mm (Figure 1). Moreover, as an indicator of cement augmentation, cement augmentation ratio (CAR) was calculated as the ratio of the maximum height of polymethylmethacrylate (PMMA) to the max distance between the upper and lower endplates (Figure 2).

By using these measurement items, we evaluated the following factors: 1) incidence rate of RAV, 2) comparison of CARs between the RAV and non-RAV groups, 3) correlation between CAR and VHL at 6 months after the procedure, and 4) incidence of reoperation.

Results: The incidence rate of RAV was 36.4% at 3 months after the procedure and 38.6% at 6 months after the procedure. CAR was 68.3% in the RAV group and 77.2% in the non-RAV group, indicating that the CAR in the RAV group was significantly less than that in the non-RAV group. A negative correlation ($r = -0.32$, $p = 0.0051$) was found between CAR and VHL (Figure 3). None of the patients in the non-RAV group and 2 patients in the RAV group had a reoperation.

Discussion: Kim et al. conducted a biomechanical study using osteoporotic cadaveric fractured vertebral bodies treated with percutaneous vertebroplasty or BKP under repetitive loading conditions. They revealed that cyclic loading compressed the osteoporotic cancellous bone between the PMMA and the endplates, which resulted in VHL (3). Li et al. and Hou et al. quantified that the distance between the PMMA and the endplates was an important risk factor of RAV after BKP (4-5). Kim et al. also found non-augmented bony areas between the PMMA and the two endplates, which resulted in greater height loss in BKP (6). Consistent with these studies, our study revealed that RAV correlated with CAR and that the remaining non-augmented bony areas between the PMMA and both endplates were prone to be compressed after the procedure.

Conclusion: In conclusion, our study indicated that low CAR posed a greater risk of RAV after BKP. For prevention of recompression, augmented PMMA should come in contact with both the upper and lower endplates.



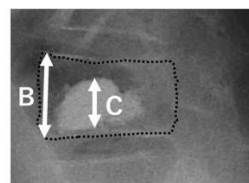
Left: postoperative radiograph Right: radiograph at 3 months or 6 months after BKP

Height of anterior vertebra (HA) : A, A'

Vertebral height loss (VHL) : A-A'

Recompression of the augmented vertebra (RAV) : $VHL \geq 5\text{mm}$

Non-RAV : $VHL < 5\text{mm}$



B : Max distance between the upper and lower endplates

C : Max height of PMMA

Cement augmentation ratio(CAR) = $C/B \times 100$

Figure 1

Figure 2

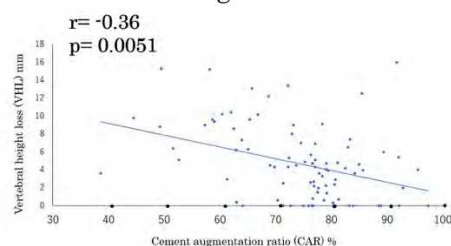


Figure 3

1. Wardlaw D, Cummings SR, Van Meirhaeghe J, Bastian L, Tillman JB, Ranstam J, Eastell R, Shabe P, Talmadge K, Boonen S. Efficacy and safety of balloon kyphoplasty compared with non-surgical care for vertebral compression fracture (FREE): a randomized controlled trial. *Lancet*. 2009;373:1016-1024.
 2. Klazen CA, Lohle PN, de Vries J, Jansen FH, Tielbeek AV, Blonk MC, Venmans A, van Rooij WJ, Schoemaker MC, Juttman JR, Lo TH, Verhaar HJ, van der Graaf Y, van Everdingen KJ, Muller AF, Elgersma OE, Halkema DR, Fransen H, Janssens X, Buskens E, Mali WP. Vertebroplasty versus conservative treatment in acute osteoporotic vertebral compression fractures (Vertos II): an open-label randomized trial. *Lancet*. 2010;376:1085-1092.
 3. Kim MJ, Lindsey DP, Hannibal M, Alamin TF. Vertebroplasty versus kyphoplasty: biomechanical behavior under repetitive loading conditions. *Spine(phila Pa 1976)*. 2006;31:2079-2084.
 4. Li D, Wu Y, Huang Y, Augustine B, Yue J. Risk factors of recompression of cemented vertebrae after kyphoplasty for osteoporotic vertebral compression fractures. *Int Orthop*. 2016;40:1285-1290.
 5. Hou Y, Yao Q, Zhang G, Ding L, Huang H. Polymethylmethacrylate distribution is associated with recompression after vertebroplasty or kyphoplasty for osteoporotic vertebral compression fractures: A retrospective study. *PLoS One*. 2018;13:e0198407.
- Kim YY, Rhyu KW. Recompression of vertebral body after balloon kyphoplasty for osteoporotic vertebral compression fracture. *Eur Spine J*. 2010;19:1907-1912.

Indirect decompression with lateral interbody fusion for severe degenerative lumbar spinal stenosis: minimum 1-year MRI follow-up

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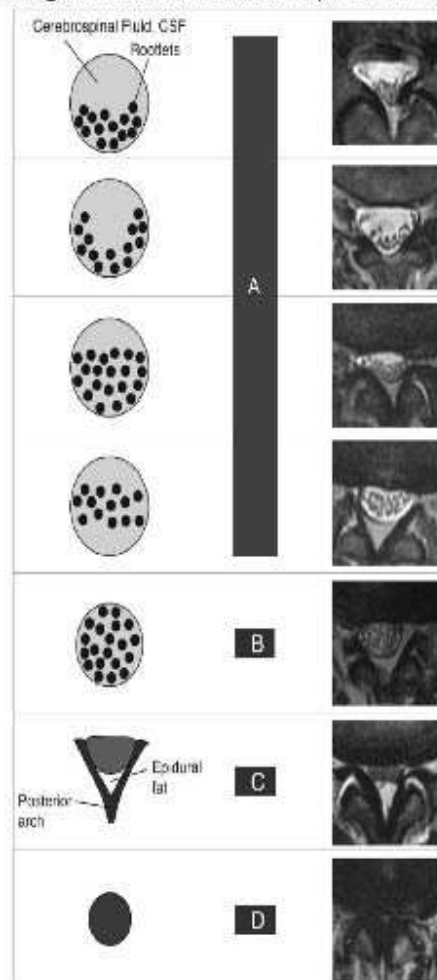
Introduction: Conventional surgical treatment for symptomatic degenerative lumbar spinal stenosis includes direct posterior decompression with or without fusion. Prior studies have shown that lateral interbody fusion (LIF) without posterior decompression can improve neurological symptoms through “indirect decompression” that results from restoration of intervertebral and foraminal heights. However, the extent of severity of canal stenosis to which the indirect decompression is effective, still remains unclear. The purpose of this study is to assess the efficacy of lateral interbody fusion without posterior decompression in degenerative lumbar spinal spondylosis with severe stenosis on preoperative magnetic resonance imaging (MRI).

Materials and Method: We included 23 patients (26 levels) who underwent oblique lateral interbody fusion (OLIF) with supplemental percutaneous pedicle screws without posterior decompression. These patients were preoperatively diagnosed with severe degenerative lumbar stenosis based on previously published criteria (Grade C or D, Fig 1) on MRI. The surgical levels were limited to L3/4 or L4/5. All the patients satisfied minimum 1-year MRI follow-up. We compared the cross-sectional area (CSA) of the thecal sac as well as clinical outcome score (Japanese Orthopaedic Association [JOA] Score) between preop, 3-week postop, and 1-year postop. The postoperative change in severity of foraminal stenosis was also assessed on MRI. The fusion status and disc height was investigated based on computed tomography scan at 1-year follow-up.

Results: The CSA improved over time, increasing from 49.8 mm² preoperatively to 85.2 mm² at 3-week postop and 128.6 mm² at last follow-up (average 26.3 months) (P < 0.001). The foraminal stenosis on MRI improved at 3-week postoperatively and maintained at 1-year follow-up (preop Grade 0.8 vs postop Grade 0.2). The neurological symptoms were also improved (70.9% improvement rate of JOA Score at 1-year follow-up). The fusion rate at 1-year follow-up was 88.0% and the disc heights were significantly restored (preop 5.8mm vs postop 9.5mm, P=0.018). The patients showing poor CSA expansion (<200% expansion rate) had higher prevalence of pseudarthrosis than those with significant CSA expansion (>200% expansion rate) (37.5% vs 0.0% of pseudarthrosis). As for perioperative complication, transient thigh pain (n=1), incidental anterior longitudinal ligament rupture (n=1), and retroperitoneal hematoma (n=1) were observed. There were no perioperative neural complications.

Conclusions: Lateral interbody fusion without direct decompression provided successful clinical outcome, restoring disc height and indirect expansion of thecal sac, which can be a safe and effective surgical option for severe degenerative lumbar stenosis. Achieving solid fusion is critical to maintain the expansion of dural sac through the postoperative period.

Fig 1. Grading Criteria for Lumbar Spinal Stenosis on MRI



Spike vs. Keel: Does Endplate Design of Lumbar Artificial Discs Affect Radiographic Outcomes?

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Introduction: The purpose of the study was to determine if different endplate designs for lumbar total disc replacement (TRD) devices impact long term radiographic outcomes in patients, and whether the outcomes are the same for L4-L5 and L5-S1 index level procedures.

Methods: This is a post-hoc analysis of 282 patients who received single level TDR (L4-L5 or L5-S1) to treat degenerative disc disease. Patients were grouped based on device and endplate design: mobile core device (MCD) with either spike (n=115) or keel endplate (n=102), and constrained core device (CCD) with keel endplate (n=65). Radiographic outcomes, including flexion-extension range of motion (ROM), adjacent segment disease (ASD) of the superior level, and heterotopic ossification (HO) was assessed at 24 mos and 5 yrs post-TDR.

Results: ROM was maintained at or above baseline values for both spike and keel MCD at 24 mos (7.8° (p<0.05) and 6.3°, respectively) and 5 yrs (6.7° and 5.6°), whereas ROM was significantly lower with keel CCD at both time points (4.5° (p<0.02) and 2.8° (p<0.05)). Overall, motion was greater at L4-L5 than L5-S1 for all device and endplate designs. However, at L5-S1 motion was best preserved with keel MCD (Δ ROM: 1.8° and 0.6°) and deteriorated most with keel CCD (Δ ROM: 0.8° and -0.4°) at 24 mos and 5 yrs. In addition, at 5 yrs ROM success (Δ ROM > 0°) was significantly greater with keel MCD compared to keel CCD at L5-S1 (77% vs. 48%, p<0.05), but the same between groups at L4-L5. The percent of patients presenting with new or worsening ASD at 5 yrs was lowest for patients with spike MCD (2.9%) and highest with keel CCD (15.4%, p<0.05). ASD developed/worsened superior to L5-S1 for patients with keel CCD, but equally for both treatment levels in patients with keel MCD. A greater proportion of patients in all groups developed HO over time, whereby a greater percentage of patients with keel CCD developed Class I and II HO at L4-L5 (p<0.05) and Class III and IV HO at L5-S1. Overall, subsidence and migration rates were higher for patients with keel CCD (4.6% and 1.5%) compared to spike MCD (1.7% and 0.9%) and keel MCD (1.0% and 2.0%).

Discussion: Radiographic outcomes were generally better at L4-L5 than L5-S1 for all device and endplate designs. However, at L5-S1 motion was best preserved in a greater proportion of patients with keel MCD. Furthermore, ASD had a greater propensity to develop/worsen with keel CCD at L5-S1 whereby index level motion was significantly lower than baseline.

A Comparative Study between SRS-22 and SJ-27 to Evaluate Surgical Outcome in the Japanese Patients with Adolescent Idiopathic Scoliosis; Are there any cultural and social differences?

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Introduction: Scoliosis Research Society (SRS)-22 is the most widely accepted disease-specific and patient-reported outcome measure for adolescent idiopathic scoliosis (AIS). Although Japanese translated-version of the SRS-22 has been introduced, some studies pointed out that there were some differences between the Japanese and American population. It may be attributed to the cross-cultural and -social difference. Scoliosis Japan (SJ)-27 is a new patient-reported QOL questionnaire specially for the Japanese individuals with AIS. Its validity and reliability have been proved (Shirado ISSLS 2011, Doi BMC Musculoskeletal Disorders 2018). The purposes of the current study were to compare surgical outcome using both QOL measures and to investigate whether there are any differences between them.

Methods: The AIS patients treated surgically with a minimum of 2-year follow-up were investigated. All of them completely answered SRS-22 and SJ-27 before and after the surgery. SJ-27 is a self-administered, disease-specific measure, and consists of 27-items being graded with a 5-point scale from no impairment (0 point) to severe impairment (4 points). Those are then arithmetically added to produce a total score (maximum 108 points). The higher the score, the worse the QOL. The correlation between SJ-27 and SRS-22 was assessed using Spearman rank-order correlations. One-way ANOVA was used to compare the change of SJ-27 and SRS-22 scores before the surgery, 1 and 2 years postoperatively. Statistical significance was defined as a p-value of less than 0.05.

Results: A total of 38 patients met the inclusion criteria. All patients were females. The average age at index surgery was 16.2 years, with a range of 11-23. Average preoperative Cobb angle was 54.6°, with a range of 40°-76°. Average Cobb angle at final follow-up was 13.8°, with a range of 6-27°. Correlation coefficient between SRS-22 and SJ-27 was -0.67, -0.65, and -0.38 before the surgery, 1-year postop. and 2-year postop., respectively. The median total SRS-22 score was 3.8±0.4, 4.3±0.3, and 4.3±0.6 before the surgery, 1-year postop. and 2-year postop., respectively. A total score of SJ-27 was 31.1±17.8, 16.3±11.5, and 17.1±19.2 before the surgery, 1-year postop. and 2-year postop., respectively. Both measures equally showed significant QOL improvement after the surgery. The following 2 questions in SJ-27 revealed average point more than 1 at the final follow-up: Q15 "Do you become anxious when standing in front of a group of people?", Q18 "To what extent are you self-conscious about the x-ray images on your back?". Q16 "To what extent are you reluctant to participate in sporting events or performances?" revealed average point more than 1 at the 1-year postop.

Discussion: The current study demonstrated that acceptable correlation existed between SRS-22 and SJ-27 to evaluate the surgical outcome in the Japanese AIS patients. The same trend was observed in both measures throughout the course. However, improvement in some questions in SJ-27 proved to be insufficient. It may suggest that the Japanese AIS patients have more negative body image, compared to the American. The QOL of AIS patients should be measured with caution in cultural, social, and psychological differences among the countries.

Is there any differences between autogenous bone graft and local bone graft in achieving bone union following lumbar fusion surgery? An evaluation of up to three-level fusion

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Introduction: There are no studies comparing the union rates of iliac crest bone graft (ICBG) and local bone graft in lumbar fusion up to three-level lumbar spine fusion. The purpose of this study was to compare the radiologic union rates between ICBG and local bone graft in one- to three-level lumbar fusion

Methods: We retrospectively examined 158 consecutive patients who underwent one- to three-level lumbar fusion surgery due to lumbar spinal stenosis. Patients were divided into two groups based on the ICBG and the local bone graft. Fusion status of the anterior or posterior segments was evaluated by plain radiographies obtained at 24 months postoperatively. If at least either the anterior or posterior segment was fused, that segment was regarded as having achieved fusion and was termed "combined segment union." The definition of overall union was achieving combined segment union in all surgical segments in a single patient.

Results: For each ICBG group and local bone graft group, fusion rate of the anterior and posterior segments and union rate of the combined segments and overall patient union outcomes at postoperative 2 years were not different between the groups, regardless of surgery level. In the overall union rate according to the fusion level, ICBG group showed constant overall fusion rate according to the fusion level (i.e., 96.9%, 96.9%, and 95.2 % for one-, two-, and three-level fusion), but tended to decrease with increasing level in the local bone graft group (100%, 95.8%, and 88.9% for one-, two-, and three-level fusion, respectively) without statistically significant differences.

Discussion: Local bone graft showed a comparable union rate to autogenous ICBG even in the case of three-level lumbar fusion surgery. The union rate of three-level fusion was not inferior to those of one- or two-level fusion in both ICBG and local bone graft patients. Local bone graft could be regarded as an adequate option for not only one- or two-level lumbar fusion but also three-level fusion surgery.

Chronic compartment syndrome engaging the erector spina muscles in the lumbar spine can develop into an acute compartment syndrome

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Introduction: Acute compartment syndrome in the lumbar spine region have been reported to occur occasionally, but sparsely. Even more rare are chronic compartment syndromes in this region. For both of these conditions elevated intramuscular pressure (IMP) lead to severe ischemic pain. The circulatory dysfunction can further cause irreversible tissue damage if IMP is high enough and remains over a period of time. In its chronic form, the compartment syndrome symptoms are provoked by loading or heavy exercise of the muscle and the post exercise the pain subsides as the IMP decline. In the acute form, the syndrome is most often caused by trauma or intoxication and triggered by pressure on muscular tissue in a closed compartment.

Methods: A 35-year-old male under investigation for hypogonadism without any medical treatment or any other drug intake is described in this case report. During five years, the patient had suffered from exercise induced low back pain. Investigations including clinical examinations and MRI have not been able to provide any explanation for the pain. The patient was admitted to the emergency unit with severe left sided low back pain at 5 am after heavy work the previous night. The patient was examined with IMP measurement, MRI and laboratory tests and later underwent surgical treatment.

Results: The intramuscular pressure (IMP) was 98 mmHg in the left erector spinae muscle compartment and 29 mmHg in the contralateral compartment prior to surgery. The patient experienced no pain at the right side at this time. Acute MRI was performed and demonstrated no abnormal findings. Serum analyse of myoglobin was 6122 mkgr/L (reference value <90). Fasciotomy of left side was performed and instantly relived the pain symptom. The muscles were pale but viable upon inspection and no tissue was removed. Biopsy samples taken revealed normal tissue morphology. Five months later due to remaining lumbar pain problems localized at the right side where no surgery had been performed, a more thorough investigation were initiated. After a provocation test, the intramuscular pressure was 60 mmHg, and the diagnose criteria for a chronic compartment syndrome was fulfilled. Fasciotomy on the right side was thereafter performed and the symptoms resolved.

Discussion: Chronic compartment syndrome in the lumbar spine muscular compartment might be an overlooked diagnosis which could be an explanation to exercise elicited low back pain.

The connection between an acute and a chronic compartment syndrome in the lumbar spine region as described here has previously not been reported on.

Speculatively, this might occur both in young sport active persons in a similar manner as with the lower leg exertional compartment syndrome. In addition, it may also occur in the elderly group of individuals with a problem of sagittal imbalance, where the m. erector spina is exposed for heavy and almost constant load.

The strategy for osteoporotic vertebral fracture based on its fracture types

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Introduction: There is no classification for osteoporotic vertebral compression fracture, and we use the Denis classification for convenience. We established a new classification of osteoporotic vertebral compression fracture on its fracture types.

Materials and methods: Subjects comprised 81 consecutive patients with osteoporosis aged ≥ 50 years (17 males and 64 females) who underwent spinal instrumentation surgery for osteoporotic vertebral compression fracture between 2008 and 2016. All patients have a minimum 1-year radiographic and clinical follow-up. In order to be included in the study, the patients had to meet the following criteria: (1) be over 50 years old at the time of surgery; (2) undergo an instrumented spinal fusion on the lumbar spine for the treatment of osteoporotic vertebral compression fractures. We classified the types of fracture according to Denis burst fracture classification and added originally two more types, type A; fractures of both end plates, type B; fractures of the superior endplate, type C; fractures of the inferior endplate, and type D; fractures of the mid-portion of vertebral body without any injury of both endplates. The Kappa value was used to treat intraobserver reliability.

The procedures, operation time, estimated blood loss and complications for each type were estimated retrospectively. Radiologically, local kyphosis, which is the angle between the caudal endplate of fractured vertebra and the cephalad endplate of cephalad vertebra from a fractured vertebra, was measured at pre-, postoperation, and at follow-up.

Results: There were 27 cases in type A, 35 cases in type B, 13 cases in type C, and 5 cases in type D. The procedures for type A were total posterior-approach vertebral replacement with rectangular parallelepiped cages (T-PAVREC) or vertebral column replacement (VCR) with X-CORE in 24 cases (89%). The procedure for type B was partial PAVREC which preserve caudal one-third of pedicle in 27 cases (77%). The procedures for type C were PLIF in 6 cases (46%), and VCR with X-CORE in 5 cases (38.5%). Four cases out of five were DISH and posterior fusion surgery was selected. Kappa value was 0.88. The fixed number was averaged 5.5, operation time was averaged 4.4 hours, and blood loss was averaged 631g respectively. There was no difference between the types in operation time and bleeding. Surgical site infection occurred in one case, hematoma in one case, and paralysis due to nerve compression from local bone graft in two cases. There was no difference between T-PAVREC and P-PAVREC on operation time and estimated blood loss.

Conclusion: A new classification of osteoporotic vertebral compression fracture on its fracture types was useful to decide surgical procedure.

Minimally Invasive Transforaminal Lumbar Interbody Fusion (MI-TLIF) vs Minimally Invasive Lateral Lumbar Interbody Fusion (MI-LLIF): A comparison of immediate post-operative outcomes for the assessment of decompression

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Introduction: Surgical decompression to relieve pressure on neural structures can be performed by direct decompression (i.e. resection of impinging tissue), indirect decompression (i.e. distraction between vertebrae to increase the space), or a combination of the two. The purpose of this study is to compare outcomes of surgical procedures that involve direct and indirect decompression (i.e. MI-TLIF) to procedures that involve only indirect decompression (i.e. MI-LLIF), to assess if the additional direct decompression in MI-TLIF results in better outcomes.

Methods: Clinical outcomes, including length of stay, post-operative pain, in-hospital complications and need for additional direct decompression surgery, and patient-reported outcomes (PROs), including ODI, VAS and SF-12 in patients undergoing MI-TLIF and MI-LLIF were compared using chi-square test for categorical and student's t-test for continuous variables. Mixed ANOVA was used to assess if the change in PROs from pre-operatively to post-operatively was different between MI-TLIF and MI-LLIF.

Results: Of the 72 patients, 49 had MI-TLIF and 23 had MI-LLIF. There were no significant differences in age ($p=0.255$), sex ($p=0.157$) or BMI ($p=0.933$). The number of levels operated was greater in the MI-LLIF group compared to MI-TLIF (1.43 vs 1.12, $p=0.047$), with almost 90% of MI-TLIFs being 1-level procedures and none 3-level. In contrast, 65% of MI-LLIFs were 1-level, 26% 2-level and 8.7% 3-level procedures. The level(s) operated were different, with over 60% of MI-TLIFs at L4-L5 and 34.5% at L5-S1, compared to 51.6% of MI-LLIFs at L3-L4, 24.2% at each L2-L3 and L4-L5, and none at L5-S1. There was no significant difference in procedural time ($p=0.281$), length of stay ($p=0.216$), post-operative pain ($p=0.180$), or in-hospital complications ($p=0.384$). Additionally, no patient in the MI-LLIF group required subsequent direct decompression surgery due to persistence of symptoms. ODI, VAS leg, SF-12 MHS, SF-12 PHS and PROMIS-PF did not differ between the groups preoperatively or at 2-weeks. VAS back pain was worse in the MI-LLIF group at both time-points ($p=0.020$). Additionally, the change in PROs did not differ between the groups (ODI: $p=0.970$, VAS back: $p=0.982$, VAS leg: $p=0.667$, SF-12 PHS: $p=0.848$, SF-12 MHS: $p=0.495$, PROMIS-PF: $p=0.744$).

Conclusion: There was no difference in outcomes between those who underwent MI-LLIF (indirect decompression), and those who underwent MI-TLIF (indirect and direct decompression). Thus, in an appropriately selected patient, indirect decompression can provide results that are comparable to direct decompression. Underlying pathology, operative level and goals of the surgery should be kept in mind when selecting the procedure.

Table 1: Demographics, Operative Variables and Clinical Outcomes

	MI-TLIF (n=49)	MI-LLIF (n=23)	p-value
DEMOGRAPHICS			
Age (in years)	58.88 ± 12.31	61.77 ± 8.84	0.255
Gender			0.116
• Male	18 (36.7%)	13 (56.5%)	
• Female	31 (63.3%)	10 (43.5%)	
Body Mass Index (kg/m ²)	27.57 ± 7.31	27.44 ± 3.99	0.933
OPERATIVE VARIABLES			
Number of Levels	1.12	1.43	0.047
• 1 Level	43 (87.8%)	15 (65.2%)	0.025
• 2 Level	6 (12.2%)	6 (26.0%)	0.145
• 3 Level	0 (0.0%)	2 (8.7%)	0.043
Levels Operated			
• L2-L3	1 (1.8%)	8 (24.2%)	0.0008
• L3-L4	0 (0.0%)	17 (51.5%)	<0.0001
• L4-L5	35 (63.6%)	8 (24.2%)	0.0004
• L5-S1	19 (34.5%)	0 (0.0%)	0.0002
Length of Procedure (minutes)	105.31 ± 29.56	126.00 ± 85.63	0.281
OUTCOMES			
Length of Hospital Stay (hours)	45.39 ± 32.99	35.64 ± 23.43	0.216
Post-operative Day Zero Average Pain Scores (NRS 0 – 10)	5.42 ± 1.94	4.65 ± 2.37	0.180
In-hospital complications	5 (10.2%)	1 (4.2%)	0.384
• Urinary Retention requiring catheterization	2	1	
• Nausea and Vomiting	2	0	
• Ileus	1	0	
• Fever	1	0	

Table 2: Patient-reported Outcomes

	MI-TLIF	MI-LLIF	p-value
ODI			
• Pre-operative	38.19 ± 21.65	40.13 ± 17.06	0.704
• 2 weeks post-operative	42.05 ± 24.24	43.39 ± 22.67	0.825
• Change in ODI by type of fusion			0.970
VAS Back Pain			
• Pre-operative	5.38 ± 3.11	7.00 ± 2.36	0.020
• 2 weeks post-operative	4.50 ± 2.73	6.13 ± 2.58	0.020
• Change in VAS back pain by type of fusion			0.982
VAS Leg Pain			
• Pre-operative	5.51 ± 3.30	6.57 ± 2.73	0.195
• 2 weeks post-operative	4.86 ± 6.89	5.22 ± 3.14	0.812
• Change in VAS leg pain by type of fusion			0.667
SF-12 Physical Health Score (PHS)			
• Pre-operative	33.67 ± 10.06	33.27 ± 8.09	0.870
• 2 weeks post-operative	31.28 ± 10.34	29.89 ± 7.42	0.566
• Change in SF-12 PHS by type of fusion			0.848
SF-12 Mental Health Score (MHS)			
• Pre-operative	48.06 ± 12.17	45.85 ± 12.03	0.482
• 2 weeks post-operative	47.90 ± 11.36	48.39 ± 12.41	0.871
• Change in SF-12 MHS by type of fusion			0.495
PROMIS Physical Function			
• Pre-operative	36.59 ± 9.74	34.31 ± 5.80	0.259
• 2 weeks post-operative	33.93 ± 8.71	30.66 ± 5.75	0.186
• Change in PROMIS-PF by type of fusion			0.744

Anatomical study of the lumbar segmental artery and vein to prevent vascular complications during lateral lumbar interbody fusion

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Introduction: Lateral Lumbar Interbody Fusion (LLIF) is getting popular to acquire strong correction and reduce operation time and bleeding. However, potential complications due to the specificity of this technique have been arising. One of the common complication of this technique is the segmental artery or vein injury. In Japan, the segmental artery injury has been reported in 0.4% of 2932 LLIF cases. Once the segmental artery or vein is injured, it is difficult to stop bleeding in a small field of view, so it is important to understand its pathway and anatomical characteristics before surgery to prevent complication. The purpose of this study is to investigate anatomical features of lumbar segmental artery and vein pathway by using CT angiography to prevent segmental artery or vein injury.

Methods: Sixty patients who underwent CT angiography for the purpose of the preparation of spine surgery or detailed examination of digestive tract tumor were included in this study. Twenty-eight was male and 32 was female. Age was 68.4 years old in average. CT angiography was reconstructed to 3D image to detect the pathway of the segmental artery and vein at the vertebra body and disc. Each vertebral height and distance from the caudal endplate to segmental artery were measured at the anterior 1/3 of vertebra, center of vertebra and the posterior 1/3 of the vertebra. The anomaly of the pathway of the segmental artery and vein was also studied.

Results: L1 segmental artery was located at 8.8mm (at anterior 1/3), 12.2mm (at the center) and 12.2mm (at posterior 1/3) from caudal endplate in average. L2, L3, L4 and L5 segmental artery were located at 8.2mm, 11.2mm, 10.5mm and 11.4mm, 12.0mm, 9.4mm and 14.9mm, 12.4mm, 6.8mm and 10.6mm, 7.7mm, 5.5mm in each. L1 and L2 segmental artery run from caudal to cranial, L3 runs in parallel and L4, L5 run from cranial to caudal. L1 and L2 segmental artery were close to caudal endplate at minimum 1.7mm. L4 segmental artery was close to cranial endplate at minimum 2.7mm. So there is a risk of vascular injury by OLIF's pin at those levels in some cases. Three segmental arteries (5%) and 4 segmental veins (6%) run on disc vertically which has a risk of direct or contralateral vascular injury at L2/3 and L4/5. Twenty eight segmental artery at L1/2 and L2/3 run very close to the anterior disc that has a risk of injury by anterior retractor.

Discussion: The segmental artery of L1, L2 caudal and L4 cranial runs so close to the end plate that have risk of segmental artery injury by OLIF's pin. At L2/3, L4/5, segmental artery or vein were located on disc in some cases, so that have a risk of direct or contralateral injury by sim or Cobb. At L1/2 and L2/3 anterior retractor has risk of segmental artery injury because segmental artery run very close to the disc at anterior part. It is important to evaluate the pathway of the segmental artery and vein by using CT angiography before the operation to perform LLIF safely.

Hand grip strength can be a useful surrogate marker for postoperative changes in spinopelvic alignment in patients with lumbar spinal stenosis

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Introduction: Few studies have examined the changes in global sagittal alignment and corresponding factors like hand grip strength (HGS) and muscle performance tests after surgery for lumbar spinal stenosis (LSS). The purpose of the study was to determine whether HGS can be a surrogate marker of global sagittal alignment changes after decompression with fusion surgery for LSS.

Methods: A total of 91 consecutive patients who underwent spine fusion surgery for LSS were included. Preoperatively and at 1 year after posterior decompression and fusion surgery, we analyzed radiological spinopelvic parameters and clinical outcomes parameters including sagittal vertical axis (SVA), lumbar lordosis (LL), pelvic tilt (PT), pelvic incidence (PI), global tilt (GT), T1 pelvic angle (T1PA), Oswestry Disability Index (ODI), Euro-Qol 5D index (EQ-5D), and visual analog scale (VAS) scores for back or leg pain. To assess muscle performance, three functional mobility tests (6-meter walk test (SMT), timed up and go test (TUGT), sit-to-stand (STS) test) and HGS were assessed. A multiple linear regression analysis was performed to examine the relationship between covariates including HGS and postoperative SVA.

Results: HGS was significantly correlated with age, preoperative SVA, postoperative SVA, ODI, EQ-5D, and the muscle performance tests. HGS was associated with changes in preoperative SVA 1 year after surgery using multiple linear regression analyses with HGS as the independent variable and postoperative SVA as the dependent variable.

Discussion: We observed that HGS and the postoperative radiologic parameters were significantly related and could affect postoperative global sagittal alignment. We also found that HGS was associated with postoperative muscle performance and preoperative/postoperative clinical outcomes. Multiple studies to date have shown a correlation between clinical outcomes and preoperative HGS after hip fracture, esophageal cancer, and degenerative spinal stenosis surgery, in which cases a high HGS demonstrates better surgical outcomes. These results are similar to those of our study evaluating the correlation between HGS and surgical outcomes in LSS. To determine HGS as a predictor of postoperative sagittal alignment, multiple linear analyses were performed. For all covariates except HGS, there were no statically significant associations with postoperative SVA. Thus, HGS may be a factor indicating global sagittal alignment that contributes to muscle performance such as the paraspinal muscles, which balance the global sagittal alignment. A decrease in muscle performance status implies that the sagittal alignment is likely unbalanced in older patients due to the aging process, consistent with the definition of sarcopenia. Our study findings suggested a cut-off value of HGS that could determine non-balanced alignment according to the above equation (HGS value, 14.01 kg). It is meaningful in that, although the value is lower than a cut-off value of a high and low HGS, which is set by the Asian Working Group for Sarcopenia, the HGS value can be a reference point for predicting postoperative sagittal alignment. In addition, these results could help clinicians predict the degree of improvement in preoperative non-balanced sagittal alignment before surgery, which is valuable for surgical strategy planning.

Penetrating endplate screw for spinal fractures with diffuse idiopathic skeletal hyperostosis (DISH)

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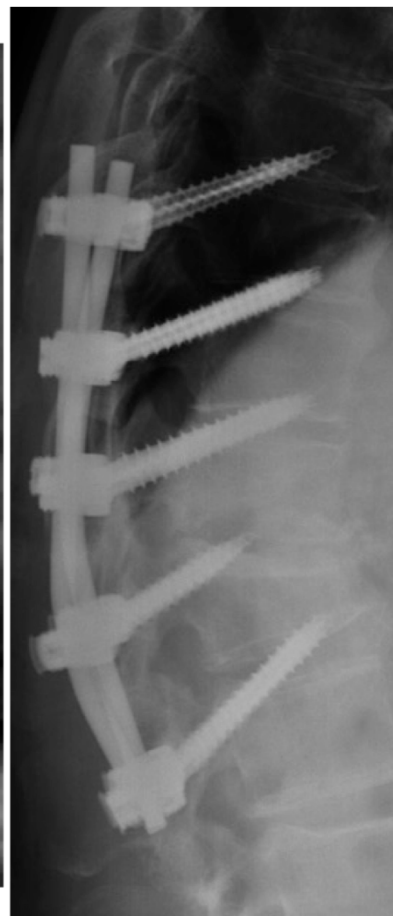
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Introduction: Diffuse idiopathic skeletal hyperostosis (DISH) is a non-inflammatory skeletal disease characterized by calcification and ossification of soft tissue, predominantly ligaments and entheses. Spinal fractures in patients with DISH cause severe back pain and delayed paralysis because of an immobilized spinal column and hyper-instability. The characteristics of patients with ankylosing spinal disorders, such as auto-fusion creating fractures with long lever arms, require techniques more similar to long bone fracture fixation. Specifically, multiple points of fixation are required for stability. However, less invasive surgery and strong fixation are a theoretically attractive option in these patients because these patients also tend to be of advanced age with multiple comorbidities and have severe osteoporosis. The authors applied a penetrating endplate screw (PES) technique, in which a pedicle screw was inserted intradiscally, for thoracolumbar DISH fracture patients. The purpose of this study is to report the results of PES for patients with DISH spinal fractures.

Methods: Twenty-three patients with thoracolumbar DISH fractures who underwent surgical treatment in our institution between 2011 and 2018 were analyzed in this study. DISH was defined by Resnick's and Mata's criteria on preoperative CT scans. Twelve males and 11 females, 68 to 92 y.o. (average: 79.8) were included. Posterior fixation was performed in 15 cases using PES after 2015 (PES group). Eight cases before 2015 were operated using regular pedicle screws (PS group). PES screws were inserted by minimally invasive surgery (MIS) in all cases. We investigated the localization of the fractured vertebral body, the range of fixation, and clinical results.

Results: Pain relief was achieved after surgery in all cases. Ninety-four screws were used in the PS group, and 172 screws in the PES group, of which 138 were PES. Eight screws loosened in the PS group, 4 PS screws loosened in the PES group, but no PES loosened in the PES group. Because of the loosening and back out of screws, reoperation was needed in two cases in the PS group. There was one infection in the PS group. No additional surgeries were necessary in patients with posterior fixation in the PES group.

Discussion: The operative care of patients with DISH after a spine fracture is not well represented in the literature. Our results indicate that PES was a safe and easy technique for DISH because there were no complications from screw insertion intradiscally. It is still unclear how to penetrate the upper endplate of the fractured vertebral body and lower endplate of the upper vertebral body. Further analysis is required to clarify how to choose the best trajectory and insertion point for PES. However, no screw loosening was detected and no additional surgeries were required in the PES group in this study. PES screws are considered safe and effective for thoracolumbar fracture in DISH patients.



Stabilizing the Unstable Osteoporotic Vertebral Fracture is Critical to Preventing the not only the pain but also Further Progression of Spinal Canal Stenosis due to Fractured Vertebrae

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Introduction: As we are faced with a super-aging society, the number of patients experiencing osteoporotic vertebral fractures (OVFs) is increasing. Additionally, progression of collapsing vertebrae can lead to further posterior vertebral wall damage, and burst fracture can result in bony fragments in the spinal canal. This may cause neuropathic pain, including common chronic low back pain. Posterior spinal fusion with instrumentation was generally performed for OVF. However, since March 2014, we adopted balloon kyphoplasty (BKP) for OVF. BKP is less invasive than conventional instrumentation surgery; however, the effectiveness of BKP for OVF, especially with posterior wall injury, remains unclear. The purpose of this study is to evaluate whether BKP could prevent further progression of canal stenosis adjacent to a clinical vertebral fracture to evaluate the progression of spinal canal stenosis after surgery.

Methods: We assessed the most stenotic spinal canal adjacent to or at the site of the fractured vertebrae using axial view MRI or CT images. We evaluated the number of morphometric vertebral fractures (\geq SQ grade 2) in upright total spine Xp. To evaluate the influence of bone metabolism and bone mineral density, TRACP-5b, P1NP, and DXA (%YAM) were determined before surgery and at the last follow-up (at least 1 year).

Results: The mean patient age at surgery was 79.4 years. Of the 32 patients, 24 showed canal stenosis due to fractured vertebrae and bony fragments in the spinal canal (group A; mean age, 79.8 years; YAM, 73%; TRACP-5b, 420.7; P1NP, 47.0; preoperatively) and 8 did not show spinal canal stenosis (group B; mean age, 78.3 years; YAM, 58.3%; TRACP-5b, 496.3; P1NP, 61.8; preoperatively). The number of morphometric vertebral fractures was 2.4 in group A and 0.9 in group B. In this study, we focused on the Group A, VCF with adjacent stenosis. The area of the spinal canal was 162.3 mm² preoperatively and 186.3 mm² at the last visit (P=0.162). No additional surgery was performed. Both TRACP-5b and P1NP were inhibited, however the %YAM decreased at the last visit.

Discussion: Osteoporosis with subsequent VCFs constitute an increasingly important health care problem in western countries, also due to its direct and indirect negative consequences for patient health-related quality of life, its significant economic impact and to the increasing age of our population. This study had a very short follow-up (minimum 1 year); however, the progression of posterior wall damage was inhibited after BKP. The findings indicated that stabilizing the unstable OVF may be critical for preventing the progression of spinal canal stenosis due to fractured vertebrae. The findings indicated that stabilizing the unstable OVF may be critical for preventing the progression of spinal canal stenosis due to fractured vertebrae. Therefore, further studies are needed to evaluate BKP, especially in elderly patients or comorbid patients. The indications for BKP may be wider with appropriate surgical techniques. In elderly osteoporotic or comorbid patients, bone quality is poor. Treatment of osteoporosis is the most important factor in the management of OVF.

Depression and Anxiety Influence Patient Reported Outcomes after Lumbar Fusion

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Introduction: Depression and anxiety are common mental health comorbidities in patients undergoing spine surgery, however the relationship between mental health and patient outcomes following lumbar surgery is not well established. The aim of this study was to determine whether preexisting depression and anxiety affect patient outcomes measurements following lumbar decompression and fusion.

Methods: Patients who underwent lumbar fusion between one to three levels for degenerative lumbar pathology were retrospectively identified at single center, academic institution. Exclusion criteria consisted of patients under the age of 18, less than at 10 months of follow-up, history of previous infection, tumor, trauma, or revision. Patients were divided into groups based on existing mental health comorbidities: no mental health diagnoses (N), depression alone (D), anxiety alone (A), or depression and anxiety (DA). Outcome measures collected include the Short Form-12 survey Physical Component Score (PCS-12), SF-12 Mental Component Score (MCS-12), Oswestry Disability Index (ODI), Visual Analogue Scale (VAS) back pain (VAS Back) and leg pain (VAS Leg) scores. Kruskal-Wallis H test was performed to compare baseline and postoperative PROMs between groups with Dunn multiple pairwise analysis for post-hoc testing. Multivariate analysis with multiple linear regression was performed, controlling for age, sex, BMI, smoking status, preoperative diagnosis, number of levels decompressed, number of levels fused, follow-up (months), duration of preoperative symptoms.

Results: A total of 404 patients were included, 334 (82.7%) in the N group, 25 (6.2%) in the D group, 13 (3.2%) in the A group, and 32 (7.9%) in the DA group. There was a significant difference between all four groups in MCS-12 and ODI scores both pre- and postoperatively ($p = 0.001$, Table 1). Dunn post-hoc testing revealed that the DA group had more disability than the N group in each of these domains. Multiple linear regression analysis found that having one or more mental health conditions was a significant predictor of increased change in ODI ($p < 0.001$), but a significant predictor of decreased change in MCS-12 ($p = 0.006$) perioperatively.

Discussion: In this study, we examined preexisting diagnoses of mental health and their effects on patient outcomes following lumbar surgery. As expected, MCS-12 was significantly lower in the DA group. ODI was also significantly different in this group, indicating a higher level of disability. However, on multivariate analysis, presence of one or more mental health diagnoses was a predictor of greater change in disability. This study highlights the significance of mental health on outcomes for patients undergoing routine lumbar surgery, with the potential for preoperative screening and counseling for patients.

Table 1: Patient Reported Outcome Measurement (PROM) Comparisons Between Mental Health Groups

	Overall (n = 404)	No Depression or Anxiety (n = 334)	Depression only (n = 25)	Anxiety only (n = 13)	Depression and Anxiety (n = 32)	p-value
PCS-12 Pre	31.1 [30.2, 32.0]	31.4 [30.4, 32.4]	28.9 [25.9, 32.0]	33.4 [26.3, 40.6]	28.6 [26.1, 31.1]	$p = 0.338$
PCS-12 Post	40.0 [39.0, 41.0]	40.4 [39.2, 41.6]	39.4 [35.3, 43.6]	41.6 [38.0, 45.2]	35.5 [32.0, 39.0]	$p = 0.072$
MCS-12 Pre	49.8 [48.7, 51.0]	50.8 [49.6, 52.1]	46.1 [40.9, 51.2]	50.1 [42.9, 57.2]	42.3 [38.0, 46.7]	* $p = 0.001$
MCS-12 Post	53.4 [52.4, 54.3]	54.3 [53.4, 55.3]	49.8 [45.1, 54.5]	50.7 [43.0, 58.4]	47.1 [42.8, 51.4]	* $p = 0.001$
ODI Pre	41.7 [39.9, 43.4]	40.1 [38.2, 42.0]	50.7 [43.8, 57.5]	44.6 [33.7, 55.5]	50.0 [44.0, 56.1]	* $p = 0.001$
ODI Post	21.6 [19.8, 23.4]	20.0 [18.1, 22.0]	27.6 [19.2, 36.0]	22.7 [12.4, 33.1]	32.5 [26.0, 39.0]	* $p = 0.001$
VAS Back Pre	5.9 [5.5, 6.2]	5.7 [5.4, 6.1]	6.5 [5.1, 7.9]	5.4 [3.1, 7.7]	6.7 [5.8, 7.7]	$p = 0.323$
VAS Back Post	2.9 [2.7, 3.2]	2.9 [2.6, 3.2]	3.0 [1.9, 4.0]	1.8 [0.8, 2.8]	3.6 [2.5, 4.7]	$p = 0.278$
VAS Leg Pre	6.1 [5.8, 6.4]	6.0 [5.7, 6.4]	7.4 [6.2, 8.6]	5.0 [2.4, 7.7]	6.4 [5.2, 7.6]	$p = 0.147$
VAS Leg Post	2.4 [2.2, 2.7]	2.4 [2.1, 2.7]	2.6 [1.5, 3.6]	1.4 [0.5, 2.2]	3.1 [2.0, 4.3]	$p = 0.437$
PCS-12 Delta	9.1 [7.9, 10.2]	9.1 [7.8, 10.4]	10.9 [6.6, 15.3]	8.6 [3.2, 14.1]	7.7 [4.4, 11.0]	$p = 0.751$
MCS-12 Delta	3.5 [2.3, 4.6]	3.4 [2.1, 4.6]	5.6 [-1.2, 12.3]	-0.6 [-9.6, 8.3]	4.6 [0.5, 8.7]	* $p = 0.006$
ODI Delta	-20.1 [-22.3, -17.8]	-20.4 [-22.8, -17.9]	-23.4 [-32.3, -14.6]	-17.4 [-34.2, -0.6]	-15.5 [-24.4, -6.5]	* $p < 0.001$
VAS Back Delta	-3.0 [-3.4, -2.7]	-3.0 [-3.4, -2.6]	-3.7 [-5.4, -2.1]	-3.3 [-5.9, -0.6]	-2.9 [-4.4, -1.4]	$p = 0.888$
VAS Leg Delta	-3.7 [-4.0, -3.3]	-3.6 [-4.0, -3.2]	-4.7 [-6.2, -3.2]	-3.3 [-6.0, -0.6]	-3.3 [-5.1, -1.5]	$p = 0.423$

An anatomical analysis of the lumbar segmental artery in the oblique lateral corridor in lumbar spine: Existence of “L5 segmental artery”

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Introduction: Lateral interbody fusion (LIF) restores disc height and enables indirect decompression of narrowed spinal canals in patients with lumbar disease such as spondylolisthesis causing decreased disc height and foraminal narrowing. Some mini-open retroperitoneal LIF approaches, such as oblique lateral interbody fusion (OLIF), are safer and less invasive for achieving LIF and show sufficient efficacy by accessing oblique lateral corridor in front of the psoas muscle. The mini-open OLIF approach can provide a small surgical field around the anterolateral portion of an IVD, which can include segmental arteries branched from the aorta. Insulting these arteries can cause massive hemorrhage, rendering the procedure unachievable. Previously we reported the lumbar segmental arteries can be involved in the surgical field for OLIF, especially the L4 and L5 arteries, which can directly run across IVDs using magnetic resonance (MR) imaging. Regarding L5 segmental artery, previous studies have reported its absence, while we reported its existence rate as 38.8%. Resolving and investigating this controversy can provide important clinical suggestions to spine surgeons who are included in OLIF surgery. The present study aimed to analyze the existence rate and the anatomical features of lumbar segmental arteries focused on L5 level using cadavers.

Methods: We prepared twenty formalin—fixed cadavers to investigate the anatomical features of “L5 segmental arteries”, the definition of those is: 1) arteries directly branching from descending aorta, 2) running on lateral portion of vertebrae, and 3) with no mobility or floating; arteries just as like other segmental arteries. We investigated the features of L5 segmental arteries focusing on: 1) existence rate of L5 segmental arteries (directly confirmed by macroscopic evidence of branches from aorta), and 2) their location in related to the L4-5 IVD.

Results: In the 20 cadavers, L5 segmental arteries were confirmed in 8 bodies (40%), 5 of which were closely located ($\leq 3\text{mm}$) from the rim of annulus fibrosus of L4-5 IVD with 3 (37.5% of L5 segmental arteries) of them directly ran across the IVD, indicating possible accidental intraoperative interference and injury.

Discussion and Conclusion: Segmental arteries can be involved in the surgical field for OLIF, with existence rate of 40% in L5 segmental arteries. The existence rate was coincidence with the previous report using MR imaging. Additionally, 37.5% of them (15% of all bodies) directly ran across L4-5 IVD. The “L5 segmental artery” can be regarded as segmental artery-like running iliolumbar artery, which is known to have variety in its existence and location. Surgeons should keep this anatomical evidence regarding L5 segmental arteries keep in mind.

1. Orita S, Inage K, Sainoh T, Fujimoto K, Sato J, Shiga Y, Kanamoto H, Abe K, Yamauchi K, Aoki Y, Nakamura J, Matsuura Y, Suzuki T, Kubota G, Eguchi Y, Terakado A, Takahashi K, Ohtori S. Lower Lumbar Segmental Arteries Can Intersect Over the Intervertebral Disc in the Oblique Lateral Interbody Fusion Approach With a Risk for Arterial Injury: Radiological Analysis of Lumbar Segmental Arteries by Using Magnetic Resonance Imaging. *Spine (Phila Pa 1976)* 2017;42:135-42.

Factors Leading to Postoperative Pain in Adolescent Idiopathic Scoliosis Patients Including Sagittal Alignment and Lumbar Disc Degeneration

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Introduction: Although back pain in adolescent idiopathic scoliosis (AIS) has received increased attention in recent years, its relationship with sagittal alignment and lumbar disc degeneration is poorly documented. This study examined for factors contributing to postoperative pain in AIS, including those of sagittal alignment and lumbar disc degeneration.

Methods: A total of 101 consecutive patients (93 female and 8 male) who underwent posterior spinal fusion for AIS and who were followed for a minimum of 2 years were included in this investigation. Mean \pm standard deviation (SD) age was 14.8 ± 2.3 years (range: 11-24 years). Forty-nine subjects had a Lenke 1 curve, 13 had a Lenke 2 curve, 1 had a Lenke 3 curve, 4 had a Lenke 4 curve, 24 had a Lenke 5 curve, and 10 had a Lenke 6 curve. We assessed Lenke curve type, age, Risser grade, body mass index (BMI), radiographic parameters, lumbar disc degeneration, correction rate, number of fused vertebrae, lowest instrumented vertebra, preoperative Scoliosis Research Society (SRS)-22r survey mental health score, and pre- and postoperative SRS-22r survey pain scores. Lumbar disc degeneration was evaluated from sagittal plane T2-weighted preoperative MR images according to the Pfirrmann classification system. Univariate and multivariate general linear models were employed to identify factors associated with pain 2 years after AIS surgery. Factors associated with pain before surgery were also identified using preoperative SRS-22r pain scores.

Results: Compared with preoperative scores, SRS-22r pain scores were significantly improved at 2 years postoperatively (4.3 to 4.5, $P < 0.001$). In multivariate analysis, patients with a lower preoperative pain score (i.e., more pain) ($P = 0.001$) or lower postoperative T5-12 kyphotic angle ($P = 0.027$) had a worsened pain score 2 years after surgery. There were no remarkable relationships with postoperative pain for Lenke curve type, age, BMI, coronal radiographic parameters, lumbar disc degeneration, correction rate, number of fused vertebrae, or lowest instrumented vertebra. Higher preoperative Risser grade ($P = 0.010$) and lower preoperative SRS-22r mental health score ($P < 0.001$) were significantly related to a diminished preoperative SRS-22r pain score.

Discussion: While preoperative lumbar disc degeneration was not associated with pre- or postoperative pain in AIS, higher preoperative pain and lower postoperative T5-12 kyphotic angle had significant associations with augmented postoperative pain. Higher preoperative pain was related to increased Risser grade and lower mental health score. The formation of kyphosis is important to prevent postoperative pain.

Does the duration to the surgery affect the reduction of fractured vertebra in posterior short-segment fixation for thoracolumbar burst fractures?

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Introduction: Short-segment fixation for thoracolumbar burst fracture has been accepted in the point of fracture reduction and maintenance. We have patients who were delayed to surgery due to associated injury and/or delay of diagnosis. For these patients, we wonder if we can manage with this procedure. The purpose of this study was to investigate the relationship between duration from injury to surgery and reduction of fractured vertebra.

Patients and Methods: A total of 68 consecutive patients with single thoracolumbar burst fracture (T11-L3) who underwent surgery by ligamentotaxis procedure using Schanz screws were included in this study. There were 44 men and 24 women, with an average of 40 years (range 13-68). We have measured local vertebral body angle before and after surgery, and calculated recovery rate of fractured vertebra according to the following formula: $\{ \text{preoperative angle} - \text{postoperative angle} / \text{preoperative angle} * 100 \}$. Load-sharing score was also evaluated.

The patients were divided into three groups (group A: operated within 48 hours from injury, group B: operated on 3 to 5th day from injury, group C: operated on 6th day or later), and compared correction angle among these three groups. Statistical analysis was performed by Kruskal-Wallis test.

Results: We had 31 patients in group A with mean duration to surgery: 0.9 day (22 hour), 24 patients in group B with 3.3 day, and 13 patients in group C with 8.5 day (range 6 to 18).

Age at surgery was 38 years in group A, 39 in group B, and 48 in group C. Mean preoperative vertebral body angle and load-sharing score were 18.7°, 7.2 points in group A, 17.4°, 7 points in group B, and 15.6°, 6.4 points in group C respectively. There was no statistical difference in each parameter.

Recovery rate was 73.7% in group A, 70.1% in group B, 68.6% in group C, and there was no statistical difference in in each group.

Discussion: In reduction of fractured vertebral body by posterior ligamentotaxis procedure, it is assumed that the earlier the timing, the better. However, this type of fracture often includes associated injury, which interrupts early surgical intervention and there was no study which focused on relationship between surgical timing and reduction of fractured vertebra. From the results of this study, we can wait for recovery of systemic status, if patients had severe associated injury in the point of reduction of fractured vertebra. In conclusion, fractured vertebral body was well reduced after interval of at least approximately one week from injury by posterior ligamentotaxis procedure.

The long and short of it: outcome assessment using the SRS-instrument in patients with adult spinal deformity

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Introduction: Designed for patients with adolescent idiopathic scoliosis, the SRS-22 is also widely used as an outcome instrument in patients with adult spinal deformity (ASD), although its structural and cross-cultural validity has not been adequately evaluated [1]. A recent confirmatory factor analyses of its 20 non-management items in ASD patients revealed some consistently weak item-loadings [2]. It was suggested that 4 items (questions 3,14,15,17) be removed, to provide an improved, shorter version of the instrument. This study aims to evaluate the responsiveness of the 16-item version compared with the original 20-item instrument.

Methods: The analysis involved the data of 214 patients with ASD (45±20 years; 168 F, 46 M; 58 degenerative, 156 idiopathic; 130 surgical, 84 conservative) who had completed the following questionnaires within the European Spine Study Group's (ESSG) multicentre prospective study: the SRS-22 and the Core Outcome Measures Index (COMI) upon inclusion and at 12 mo follow-up (FU); and a transition question indicating how the back problem had changed relative to 1 year ago. The latter used a Likert-scale (-7 to +7) and was the external criterion for treatment success in a Receiver Operating Characteristics (ROC) curve analysis, with $\geq +4$ (i.e., at least "moderately better") being a "good" outcome.

Results: The SRS 16-item and SRS 20-item scores showed similarly strong correlations with the COMI scores ($r=-0.79$ and $r=0.78$, respectively), indicating good construct validity for both. The correlations between the external criterion of success (improvement in the back problem) and SRS change scores (baseline to 12mo FU) were $r=0.57$ for the 16-item SRS and $r=0.55$ for the 20-item SRS. The standardized response means (change score/SD) for patients with a "good" outcome were 1.13 and 1.11 for the 16-item and 20-item instruments, respectively (= large effect sizes); the areas under the ROC curve were 0.85 and 0.83 respectively (16vs20, $p=0.053$). The 16-item version discriminated slightly better between good and poor outcomes for the SRS sub-domains (Fig).

Discussion: With the "change in back problem" serving as external criterion, the 16-item instrument showed as good if not better external responsiveness compared with the 20-item. The 16-item instrument seems to be well able to detect important change in adult spinal deformity. Since it is shorter, more responsive, and has already been shown to have better structural validity [2] than the 20-item version, we recommend its use in future studies of patients with ASD. Together with the 2 management items, this should form a new SRS-18 instrument.

(1) Monticone M et al Measurement properties of translated versions of the Scoliosis Research Society-22 Patient Questionnaire, SRS-22: a systematic review. *Qual Life Res* 24: 1981-1998, 2015

(2) Mannion AF et al. Factor analysis of the SRS22 outcome instrument in patients with adult spinal deformity. *Eur Spine J* 25 (Suppl 3):S289-190, 2016

Impact of Age on Outcomes Following Degenerative Scoliosis Surgery

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Introduction: Seniors make up 16.9% of the Canadian population. The number of Canadians who are 65 years or older is increasing at an average rate of 20% every 5 years. In 2017, Sing et al. reported that there is an increasing number of patients undergoing degenerative scoliosis surgery with the largest increase attributed to patients 65-69 years old, followed by those 70-74 years old.(1) The purpose of this study was to assess effectiveness of undergoing spinal surgery to correct degenerative spinal scoliosis in elderly vs non-elderly patients. We hypothesized no significant difference in outcomes between age groups followings degenerative scoliosis surgery.

Methods: A retrospective review of prospectively collected data within the Canadian Spine Outcomes and Research Network (CSORN) database was conducted. ANOVA was used to analyze continuous variables while Chi Square test was used to analyze categorical variables. Significance level was $p < 0.05$.

Results: There were 165 patients identified from the registry who had undergone surgery to treat degenerative scoliosis; 94 patients (57 %) were female, 102 (61.8 %) patients were 65 years or older. The overall average age was 66.6 years (range 35-84, SD 8.6). There were 27 intra-operative complications, 44 peri-operative complications and 18 post operative complications. There was no statistically significant difference between the two age groups with regards to risk of developing intra-operative, perioperative and post operative complications. Elderly patients who underwent degenerative scoliosis surgery reported an average improvement of 2.90 ± 3.23 , 4.01 ± 3.58 , 15.19 ± 20.85 compared to an average improvement for patients younger than 65 years of 3.04 ± 3.50 , 3.00 ± 3.30 , 19.55 ± 19.66 points on the back-pain scale, leg pain scale and the Oswestry Disability Index respectively. There were no statistically significant differences in these measures between the two age groups.

Discussion: As the number of patients undergoing degenerative scoliosis surgery increases, clinicians will need to determine which factors will significantly affect patients' outcomes. This study shows that outcomes following degenerative scoliosis surgery are not associated with age.

1. Sing DC, Berven SH, Burch S, Metz LN. Increase in spinal deformity surgery in patients age 60 and older is not associated with increased complications. The spine journal : official journal of the North American Spine Society. 2017;17(5):627-35.

Clinical impact of sarcopenia for the outcome of minimally invasive lumbar decompression surgery

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Introduction: Although the importance of sarcopenia is underscored recently, little is known about the effect of sarcopenia for the clinical outcome of spine surgery. The purpose of this study was to identify the clinical impact of sarcopenia for the outcome of minimally invasive lumbar decompression surgery.

Methods: The records of 137 patients who were >65 years and underwent minimally invasive lumbar decompression surgery were retrospectively reviewed. We collected the Japanese Orthopaedic Association (JOA) score before surgery and at the final follow-up and measured hand-grip strength, gait speed, appendicular and trunk skeletal muscle mass using bioimpedance analysis. We classified the subjects to sarcopenia, dynapenia and normal stage according to the guidelines set by the European Working Group on Sarcopenia in Older People and used the cutoff values according to the guidelines set by the Asian Working Group for Sarcopenia.

Results: The mean age of patients at the time of surgery was 68.7 years old (65-92 yrs). There are 74 men and 63 women. The JOA score improved 12.8 points preoperatively to 23.9 points at final follow up. The prevalence of sarcopenia, dynapenia and normal stage was 19.7%, 37.2% and 43.1%. The improvement ratio of the JOA score was not significantly different among sarcopenia, dynapenia and normal stage, however the JOA score at final follow up of sarcopenia stage was significantly lower than the other stages. Multiple regression analysis showed that preoperative JOA score ($r=1.11$, $p=0.085$) and low physical performance (low gait speed <0.8 m/s) ($r = 5.15$; $p=0.005$) were independently associated with poor clinical outcomes (The JOA score at final follow up < 21 point).

Discussion: The JOA score improved after minimally decompression surgery even though the patients in sarcopenia stage. Low physical performance (low gait speed <0.8 m/s) has the greater clinical impact for the clinical outcome of lumbar surgery than low skeletal muscle index (< 7.0 kg/m² for men and < 5.7 kg/m² for women).

Correlation between ODI, PROMIS and SF-12 in Minimally Invasive Transforaminal Lumbar Interbody Fusion (MI-TLIF)

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Introduction: As the focus in spine surgery shifts from radiographic to patient-centric outcomes, patient-reported outcomes measures (PROMs) are becoming increasingly important. They are linked to patient satisfaction, and are thus being used to assess healthcare expenditure, determine compensation and evaluate cost-effectiveness. It is evident that PROMs are important to various stakeholders, including patients, physicians, payers and healthcare institutions. Thus, it is vital to establish methods to interpret and evaluate these outcomes. The purpose of this study is to evaluate the correlation between ODI, PROMIS Physical Function (PROMIS-PF) and Short Form-12 Physical Health Score (SF-12 PHS) in patients undergoing minimally invasive transforaminal lumbar interbody fusion (MI-TLIF).

Methods: PROMs collected pre-operatively and 6 weeks, 3 months and 6 months post-operatively were analyzed using Pearson product-moment correlation.

Results: Sixty-one patients, with 54 one-level and 7 two-level fusions were included. The most common operative level was L4-L5 with 62% of procedures being at this level. The ODI decreased from 38.85±21.47 pre-operatively to 18.19±14.84 at 6-months. Similarly PROMIS-PF and SF-12 PHS improved from 36.04±9.38 to 45.93±7.06 and 33.84±10.46 to 40.83±10.07, respectively at 6-months. A statistically significant strong negative correlation was seen between ODI and PROMIS at all time points (Pre-operatively: $r=-0.631, n=52, p<0.0001$; 6-week: $r=-0.640, n=41, p<0.0001$; 3-month: $r=-0.714, n=27, p<0.0001$; 6-month: $r=-0.744, n=9, p=0.021$). Similarly, a statistically significant negative correlation was seen between ODI and SF-12 PHS at all post-operative time-points, which was moderate at 6-weeks ($r=-0.543, n=49, p<0.0001$), strong at 3-months ($r=-0.669, n=40, p<0.0001$) and very strong at 6-months ($r=-0.832, n=20, p<0.0001$). Pre-operatively, the correlation was very weak and statistically non-significant ($r=-0.086, n=58, p=0.522$).

A statistically significant positive correlation was seen between SF-12 PHS and PROMIS at all post-operative time-points, which was moderate at 6-weeks ($r=0.414, n=40, p=0.008$), strong at 3-months ($r=0.744, n=25, p<0.0001$) and very strong at 6-months ($r=0.870, n=8, p=0.005$). Pre-operatively, the correlation was weak and statistically non-significant ($r=0.267, n=52, p=0.055$).

Discussion: While ODI has been used to evaluate outcomes in lumbar spine patients for several years, PROMIS is a relatively new outcome measure that is increasingly being implemented. PROMIS has been shown to decrease patient burden and be more efficient, flexible and precise than other PROMs. The results of our study show a strong negative correlation between ODI and PROMIS at all time-points. In contrast, the correlation between ODI and SF-12, and SF-12 and PROMIS was statistically significant in the post-operative period, ranging from moderate at 6-weeks to strong at 3-months and very-strong at 6-months. Thus, PROMIS-PF is a good surrogate for ODI at all time-points and a good surrogate for SF-12 at 3 months or longer follow-up.

Table 1: Mean ODI, PROMIS and SF-12 PF Scores

	ODI	PROMIS-PF	SF-12 PHS
Pre-operatively	38.85 ± 21.47	36.04 ± 9.38	33.84 ± 10.46
6 weeks	31.30 ± 21.17	39.05 ± 7.13	35.06 ± 10.43
3 months	23.57 ± 19.91	43.35 ± 6.52	40.12 ± 10.61
6 months	18.19 ± 14.84	45.93 ± 7.06	40.83 ± 10.07

Table 2: Correlation between ODI, PROMIS and SF-12 PF Scores

	Number of observations (n)	Pearson Correlation Co-efficient (r)	Strength of Correlation	p - value
Correlation between ODI and PROMIS-PF				
Pre-operatively	52	-0.631	Strong	<0.0001
6 weeks	41	-0.640	Strong	<0.0001
3 months	27	-0.714	Strong	<0.0001
6 months	9	-0.744	Strong	0.021
Correlation between ODI and SF-12 PHS				
Pre-operatively	58	-0.086	Very weak	0.522
6 weeks	49	-0.543	Moderate	<0.0001
3 months	40	-0.669	Strong	<0.0001
6 months	20	-0.832	Very Strong	<0.0001
Correlation between SF-12 PHS and PROMIS-PF				
Pre-operatively	52	0.267	Weak	0.055
6 weeks	40	0.414	Moderate	0.008
3 months	25	0.744	Strong	<0.0001
6 months	8	0.870	Very Strong	0.005

Aneurysmal bone cyst of the spine: treatment by concentrated bone marrow injection

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Introduction: Aneurysmal bone cyst (ABC) is a cystic lytic lesion of bone, consisting of blood lacunae separated by connective septa. In 30% of cases ABC is found inside other bone diseases (giant cell tumour, osteoblastoma, chondroblastoma, telangiectatic osteosarcoma), while in 70% of cases it occurs as a primary lesion (1).

Excellent results have been obtained in the treatment of aneurysmal bone cyst (ABC) of the spine by repeated arterial embolizations (SAE) (2-4). Alternative treatments have been proposed when SAE is ineffective or inadequate (5, 6).

This study presents the results of our experience in the treatment of vertebral ABC through the use of concentrated autologous mesenchymal stem cells (MSCs).

Methods: The treatment is performed by direct injection of autologous MSCs harvested from patient's iliac crest and concentrated using the concentration system Res-Q™ 60 BMC. The treatment can be repeated for two or three times at distance of about 4 months.

We successfully treated two teenagers who came to our attention both with histologically confirmed diagnosis of ABC in C2 vertebra (Figures 1 and 2).

After these attempts, other nine patients have been treated with MSCs until now (mean age: 18 years, range: 12-33; FU range: 52- 5 months).

Results: In two cases it was necessary to perform an alternative treatment with Denosumab as no healing was observed after MSCs injection. The other cases presented an improvement of the disease at clinical and radiological follow-up, after two or three MSCs injections. The presence of newly formed bone within the ABC appeared as a clear sign of recovery and increased gradually, until the cyst appeared completely ossified about one year after the treatment, with associated disappearance of the pain. In the last case after 5 months follow up the lesion has no signs of healing and selective arterial embolization can't be performed because of the absence of pathological blood circulation, reaching the lesion. We propose to perform another treatment with MSCs injection, trying to stimulate bone regeneration.

Discussion: Promising results in the treatment of vertebral ABC have been achieved by injection of autologous mononuclear cells derived from bone marrow concentration. The goal of this treatment is to interrupt the destructive osteoclastic process of the disease and promote spontaneous bone regeneration.

References:

1. Mascalda E, et al. *Orthop Traumatol Surg Res.* 2015; 101(1 Suppl):S119-27.
2. Boriani S, et al. *Spine* 2001; 26:27- 35.
3. Boriani S, et al. *J Neurooncol.* 2014;120:171- 8.
4. Amendola L, et al. *Eur Spine J.* 2013;22:533-41.
5. Terzi S, et al. *Spine (Phila Pa 1976).* 2017 Aug 1;42(15):1130-1138.
6. Barbanti-Brodano G, et al. *Eur Spine J.* 2017 Feb 6. doi: 10.1007/s00586-017-4978-x.

Figure 1: Imaging concerning a case of C2 aneurysmal bone cyst before the treatment with concentrated bone marrow. Sagittal MRI view (A); sagittal CT scan views (B, C); axial CT scan view (D).

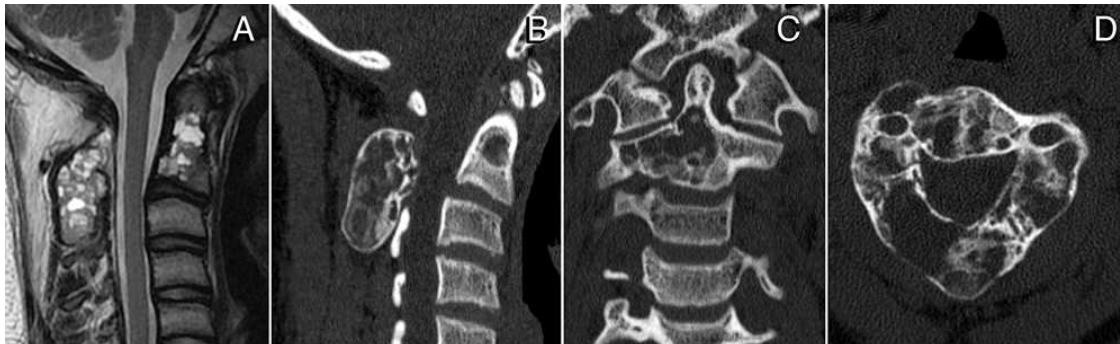
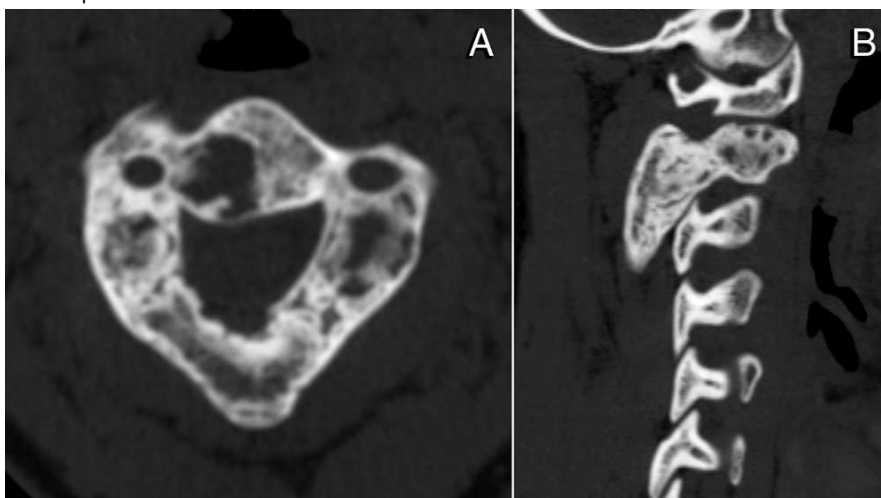


Figure 2: Axial (A) and sagittal (B) CT scan views performed one year after the treatment with concentrated bone marrow, showing the complete ossification of ABC.



Comparison of Perioperative Complications between Anterior Fusion and Posterior Fusion for Thoracolumbar Vertebral Fractures in Elderly Patients: Propensity Score Matching Analysis using Diagnosis Procedure Combination Database

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Introduction: Thoracolumbar vertebral fractures (TL-VF) often occur because of osteoporosis and low-energy trauma in the elderly patients. While anterior fusion (AF) and posterior fusion (PF) are two representative major surgical method, only a few papers have compared perioperative outcomes between anterior and posterior procedures. We conducted perioperative complication rates between AF and PF using a large national inpatient database in Japan, Diagnosis Procedure Combination (DPC) database and propensity score (PS) matching analysis.

Methods: All data in this study were collected from the Japanese DPC database for patients diagnosed with thoracic or lumbar vertebral fracture over 65 years old patients from 2012 to 2016. We adjusted for known confounding biases with PS matching. One-to-one matched pairs between each surgical procedure were analyzed for the purposes of comparing systemic complication rates, local complication rates, reoperation rates, medical costs, and mortality.

Results: Overall, there were 8366 (AF/PF; 1021/7345) patients who underwent surgery for TL-VF. After PS matching, 972 pairs of patients undergoing AF and PF were made. More perioperative systemic complications were observed in the AF group, such as pneumonia (AF/PF=2.2%/1.0%, $P=0.046$), pulmonary embolism (0.6%/0%, $P=0.014$), urinary tract infection (3.2%/1.1%, $P=0.002$), chylothorax (0.4%/0%, $P=0.045$) and pleurisy (2.5%/0.5%, $P<0.001$). No significant difference in the local complication rates, reoperation rates for systemic and local complications, and mortality were found between the two groups. The costs ($P<0.001$) were higher in the AF group.

Discussion: More systemic complications, especially, such as pneumonia, pulmonary embolism, chylothorax and pleurisy were observed in the AF group. As the reason, we guessed that anterior approach for thoracolumbar spine generally has invasion to the respiratory system. The medical costs were also higher in the AF group. The findings in this study will contribute to each TL-VF patient by allowing suitable adaptation of thoracolumbar surgeries.

Risk factors of pulmonary embolism after lumbar spine surgery

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Introduction: The lumbar spine surgery is commonly performed for the treatment of advanced stage of lumbar spine pathologies. The complication of pulmonary embolism (PE) which was always secondary to deep venous thrombosis (DVT) was rare but fatal. Knowing the risk factors of PE after lumbar spine surgery is of great significance for its prevention, especially for high-risk patients. The purpose of this study was to conduct a systematic review of literatures published in the last five years to determine risk factors and preventative measures of PE after lumbar spine surgery.

Methods: On March 2018, we searched the database Pub-Med, Medline, EMBASE, the Cochrane library, Clinical key, Springer link and Wiley Online Library with time restriction from March 2013 to March 2018 using the term 'pulmonary embolism', 'thrombosis', and 'lumbar spine surgery'. Selected papers were examined for the level of evidence by published guidelines as level I, level II, level III, level IV studies. We investigated risk factors and preventative measures of PE after lumbar spine surgery from these papers.

Results: The initial search yielded 128 citations. Twenty-seven of these studies met the inclusion and exclusion criteria. 11 were level II evidence studies, 7 were level III evidence studies, and 9 were level IV evidence studies. The incidence of PE after lumbar spine surgery has previously been reported from 0.022% to 7.5%. And the mortality varied from 8.5% to 17.5%. The risk factors included BMI, age, intraoperative positioning, teaching hospital, length of hospital stay, male sex, operative time over 261 min, anterior/posterior combined approach and fusion levels. Fibrin monomer complexes (FMC) and d-dimer can be used as early monitoring indicators. Keeping a neutral position of the neck during the operation, applying subclavian vein catheterization and using low molecular heparin after the operation can prevent the occurrence of pulmonary embolism after lumbar operation.

Discussion: The incidence of pulmonary embolism after lumbar spine surgery is low but fatal. It is not only related to patients' own factors, but also related to surgical factors. Preventative measures should be taken perioperatively.

Predictors of clinical outcome following surgery for lumbar spinal stenosis: a study of postoperative pain and disability trajectories

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Introduction: On average, patients experience important reductions in pain and disability following surgery for degenerative lumbar spinal stenosis (LSS). However, variability in the postoperative course of symptoms suggests that many patients do not fit the average symptom trajectory. If subgroups of patients with LSS can be identified by their trajectories of pain and disability following surgery, these groups will represent useful patient phenotypes. Once identified, the ability to predict which patients are at risk for poor outcomes would be a valuable tool for surgical decision making. **Objectives:** 1) Identify patient subgroups defined by trajectories of pain and disability following surgery for LSS. 2) Identify predictors of belonging to the poor outcomes subgroup for disability, leg pain and back pain.

Methods: A retrospective analysis of prospectively collected data. Patients (N=548) with LSS were recruited from 13 surgical spine centers participating in the Canadian Spine Outcomes and Research Network database. Study outcomes (leg and back pain numeric rating scales, modified Oswestry disability index) were measured before surgery and after 3, 12, and 24 months. Patients were fit to pain and disability trajectory subgroups with group-based trajectory modeling. Generalized linear mixed models, adjusted for age and sex, were used to identify associations between postoperative clinical outcome and preoperative demographic, clinical history, health status, and surgical factors. The subgroup with excellent outcomes was used as the reference group; associations were reported with relative risk ratios (RR).

Results: The group-based trajectory models identified 4 unique leg pain trajectories, and 3 trajectories each for back pain and disability. Depending on outcome 29% to 42% of patients were classified as members of an outcome trajectory subgroup that experienced little to no benefit from surgery. The construct validity of the trajectory subgroups was supported by differences in the proportion of patients meeting thresholds for minimum clinically important change and clinical success ($p < 0.001$).

Factors predicting membership in postoperative trajectories indicating poor outcomes for disability, leg and back pain were comorbid depression (RR[95%CI]=3.70[1.53-8.90]; RR[95%CI]=3.79[1.11-12.94]; RR[95%CI]=3.78[1.11-12.88], respectively), scoring moderate to severe on the Patient Health Questionnaire (RR[95%CI]=4.02[1.99-8.15]; RR[95%CI]= 2.40[1.09-5.63]; RR[95%CI]=2.60[1.04-6.98], respectively) and previous drug use. Preoperative opioid use was associated with 2.51 (95%CI 1.22-5.20) times the risk of belonging to the poor outcome subgroup for disability and 3.77 (95%CI 1.40-10.18) times the risk for poor back pain outcome. Preoperative neuroleptic use was associated with 3.78 (95%CI 1.02-6.93) times the risk of poor leg pain outcome.

Patients with higher Mental Health Component Summary Scores (MCS-12) had 48% less risk of belonging to the subgroup with poor disability (RR[95%CI]=.52[.40-.68]) and leg pain (RR[95%CI]=.52[.37-.72]) outcomes, and 32% less risk of poor back pain outcomes (RR[95%CI]=.68[.50-.93]).

Discussion: Subgroups of patients with LSS can be identified by their trajectories of pain and disability following surgery. The predictors of having poor outcomes suggests it is time to look beyond pathology/surgical factors only and include mental health variables as an integral part of the surgical decision making process in an effort to avoid patients at increased risk for surgical failure.

How does minimally invasive lumbar decompression surgery impact lumbar muscle health?

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Introduction: One of the benefits of minimally invasive spine (MIS) surgery is the muscle sparing nature of the approach. There has been little evidence quantifying the amount that paralumbar muscle changes during minimally invasive spine surgery. The goal of this study was to quantify the change in muscle health before and after MIS lumbar decompression surgery.

Methods: We performed a retrospective review of patients that eventually went on to undergo a lumbar decompressive surgery for lumbar radiculopathy. We analyzed magnetic resonance imaging (MRI) to quantify muscle health using validated measures of cross sectional area using the lumbar indentation value (LIV) and lumbar muscle fatty atrophy using the Goutallier classification. T2 axial slices from the disc space at the operative level were analyzed. We graded fatty atrophy on a 0-4 scale and the LIV was calculated using standard techniques of measuring the distance between the tip of a spinous process and a line tangential to the muscular fascia. Goutallier classifications were performed on both the combined multifidus and erector spinae muscles as well as individually for the multifidus muscle. We performed a linear regression analysis to determine the relationship of pre-operative LIV and post-operative LIV. We also compared the average pre and post-operative Goutallier classifications and LIV's using a student's t-test.

Results: A total of 19 patients had pre and post-operative MRI scans for lumbar radiculopathy. There were 21 disc spaces involved in these operations. The average age was 59.8+/-15.6 years old and there were 10 men and 9 women. The average gap between post-operative MRI and the primary surgery was 21.5+/-0.3 weeks. There was no significant difference in Goutallier classification of the combined multifidus/erector spinae muscles and the multifidus muscle alone between pre-operative and post-operative MRI's (2+/-0.84 vs 1.95+/-0.79 p = 0.86 and 2.05+/-0.68 vs 2.2 +/- 0.70 p = 0.57 respectively). We found that the average pre-operative LIV was 15.7+/-7.2mm and the average post-operative LIV was 13.1+/-6.3mm which was not statistically difference (p = 0.22). The correlation between pre and post-operative LIV was significant ($r^2 = 0.91$, p = 0.96) and did indicate a proportionate decrease in LIV of 16.9% before and after surgery.

Discussion: Our findings demonstrate the minimal changes in fat atrophy after MIS lumbar decompression surgery. There is evidence of a decrease in muscle cross sectional area of paralumbar muscle after MIS decompressive surgeries as measured by LIV. Further research is required to compare changes of musculature before and after open versus MIS lumbar surgeries.

Results of a novel percutaneous pedicle screw insertion technique for patients with diffuse idiopathic skeletal hyperostosis -double endplates penetrating screw (DEPS) technique –

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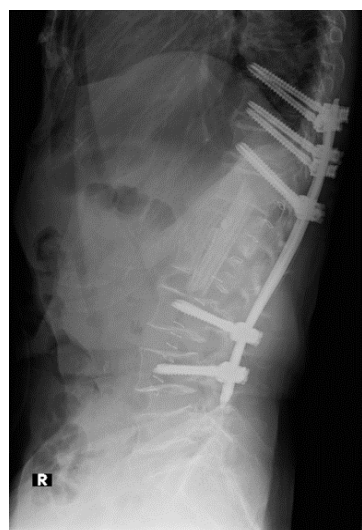
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Introduction: Vertebral instability caused by the pseudoarthrosis after vertebral fracture or pyogenic spondylitis may have difficulty in bone healing in patients with diffuse idiopathic skeletal hyperostosis (DISH) due to long lever arms cranial and caudal to affected vertebra. Surgical treatment is required in these patients such as minimally invasive spine stabilization (MIS) using a percutaneous pedicle screw (PPS). However, rigid fixation is not easily accomplished due to concomitant bone fragility. We have developed a double endplate penetrating screw (DEPS) technique, a novel PPS insertion technique suitable for with DISH. The purpose of this study is to evaluate the effectiveness of the DEPS technique.

Methods: The DEPS technique is a modification of the penetrating S1 endplate screw (PES) technique by Matsukawa et al. The screw is inserted upwards from outer caudal side of the pedicle toward the inner cranial side, penetrating the upper endplate of the vertebral body and the lower endplate of the cranial adjacent vertebral body. Twelve patients were treated with DEPS: 10 with osteoporotic vertebral body fracture and 2 with pyogenic spondylitis (5 males and 7 females). The average age was 82.3 years old (61 to 94 years old), and the average follow-up period was 10.8 months (4 to 18 months). As screws of DEPS technique extend to adjacent vertebral body, this technique was applied only to vertebral bodies that have fused due to DISH, whereas the conventional PPS technique was applied to unfused vertebral bodies to maintain the mobility. Radiological parameters, such as the level of affected vertebral body, range of DISH, and implant failures. The rate of implant failure was compared between DEPS technique and the PPS technique, were evaluated. using the χ^2 test.

Results: The affected bodies were found in Th11; 2 patients, Th12; 2 patients, L1; 6 patients, L1 2; 1patient, L4 5; 1patient. DISH was extended from cervical spine to lumbar spine in all patients. In all of the patients, screws were inserted 2 to 3 vertebral bodies both at cranial and caudal sides with either methods as affected vertebra had severe instability due to long lever arm associate with DISH. 68 screws were inserted with DEPS and 62 screws were inserted with conventional method. No implant failure was confirmed with screws inserted with DEPS technique and 4 screws showed loosening in the conventional method (6.5%) with marginal significance ($p=0.08$). Revision surgery was required due to loosening in a patient in conventional group whereas none required in DEPS groups.

Discussion: As no implant failure was observed with the DEPS technique in the patients with DISH, this novel techniques may have stronger fixation force compared to conventional technique. Future studies focusing on the biomechanical aspect of the technique are required to confirm our clinical results.



Comparing baseline characteristics of a prospective cohort of patients stratified by the degenerative spondylolisthesis instability classification (DSIC): are all slips the same?

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Introduction: Recent randomized control trials have questioned whether spinal fusion surgery confers a significant therapeutic advantage to laminectomy alone in patients with degenerative spondylolisthesis. Many have challenged that patients are unique and that more of an individualized approach to surgical decision making is indicated. An instability classification (DSIC) was proposed to help guide this decision making. The purpose of this project was to determine whether the baseline characteristics of patients varied dependent DSIC classification.

Methods: A prospective cohort of patients were enrolled from 16 different sites across Canada. Baseline demographic, patient reported outcome measures (PROMs), radiographic data were collected and global stability ratings were assessed based on the DSIC. The DSIC stratifies patients into three groups, type 1 (stable), type 2 (potentially unstable) and type 3 (unstable) degenerative spondylolisthesis. Baseline data was then compared using SPSS software.

Results: There were 307 patients available for review. Type 1 patients were significantly older than type 2 or 3 patients (68 years versus 65 and 63 years, $p=0.018$). There were also a higher proportion of females in the type 3 cohort (74% vs 28%). Type 3 patients had significantly different/inferior SF-12 MCS, EQ-5D, PHQ-9 and ODI scores. There were no differences in SF-12 PCS, NDI leg or back pain scores. There were no significant differences in radiographic parameters between groups.

Conclusions: The results of this prospective cohort study suggest that there are potentially significant baseline clinical differences in patients with degenerative spondylolisthesis. Although the post-operative surgical outcomes were beyond the scope of this study, there is some early evidence that trials should account for these unique patient characteristics by appropriate stratification based on stability.

Does degenerative adult lumbar deformity be necessarily fused to L5 or S1

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Introduction: Current surgical treatment options for degenerative adult scoliosis mainly include long-segment and short-segment decompression and fusion. One of the goals of surgical intervention is the restoration of the coronal and sagittal balance, which make the long-segment decompression and fusion very appealing. However, a high incidence of complications, such as proximal junctional kyphosis (PJK), has been reported in most series. Recently, a few of researchers took decompression as the primary goal, and suggested short-segment decompression and fusion surgery for degenerative scoliosis. In this study, we evaluated the clinical results of decompression combined with limited fusion surgery on the degenerative lumbar scoliosis combined with lumbar stenosis.

Methods: A retrospective review on 96 degenerative adult lumbar scoliosis combined with lumbar stenosis cases who received decompression combined with short-segmental fusion surgery alone from July, 2010 to June, 2017 was carried out, including 32 single segment decompression and fusion, 21 double segments decompression and fusion, 16 double segments decompression while single segment fusion, 12 triple segment decompression and fusion, and 15 triple segment decompression while double segment fusion. For all of the above cases, 38 fused above L4, 37 fused to L5, and 21 fused to S1. The operation time, blood loss, the surgical complications, the lumbar scoliosis angle and lumbar lordosis angle, visual analog scale score (VAS), Oswestry disability index (ODI), and the adjacent segment degeneration (ASD) were observed and compared among different surgical treatments.

Results: The mean follow-up time was (3.5±2.4) years. The mean operation time in single segment fusion, double segment fusion and triple segment fusion were 86min, 115min, and 136min, respectively. The mean intraoperative blood loss in single segment fusion, double segment fusion and triple segment fusion were 135ml, 230ml, and 350ml, respectively. The lumbar scoliosis angle correction and lumbar lordosis angle correction at the end of postoperative follow-up in single segment fusion were all significantly lower than in triple segment fusion ($P < 0.05$). The VAS score and ODI score improved significantly postoperatively in all of the three groups. However, the VAS score and ODI score of the cases who fused to L5 or S1 were significantly higher than that who fused above L4 ($P < 0.05$). 26 cases exhibited obvious radiologic ASD. However, no revision surgery was needed among these cases.

Discussion: The strategy of decompression combined with limited fusion surgery on the degenerative lumbar scoliosis combined with lumbar stenosis could achieve good clinical results. The lumbar scoliosis and lordosis angle correction increased following increased fusion segments. However, no significant clinical benefit was observed. The surgery should be focused on decompression instead of reshaping. To get better clinical results, the terminal fusion segment selection should be avoided on L5 or S1, if not necessary.

Temporal Profile of Serum Bone Metabolic Markers after Posterior/Transforaminal Lumbar Interbody Fusion

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Introduction: Posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF) are common surgical procedures for degenerative lumbar diseases. Bone turnover markers, which are widely used for assessment of osteoporosis treatment, might be utilized to assess the healing process of spinal fusion and to predict fusion status. However, it remains unclear how bone turnover markers fluctuate after lumbar spinal fusion surgery. The purpose of this study is to demonstrate the dynamics of bone turnover markers after lumbar spinal fusion surgery in patients without osteoporosis.

Methods: The current prospective study included non-osteoporosis patients aged from 30 to 79 years who underwent a standard one- or two-level PLIF/TLIF with pedicle screw fixation for degenerative lumbar diseases. Those with a history of previous spinal surgery, fracture within one year, collagen disease and chronic kidney disease (eGFR<30mL/min/1.73m²) were excluded. Using computed tomography (CT) at six months after surgery, patients with pseudarthrosis were excluded from the analysis. Bone specific alkaline phosphatase (BAP) and intact procollagen type 1 amino-terminal propeptide (P1NP) were measured to assess bone formation, and tartrate-resistant acid phosphatase 5b (TRACP-5b) to assess bone resorption. Blood samples were collected before surgery and at 1, 2, 4, 8, 12 and 24 weeks after surgery. Longitudinal data were presented as mean percentage changes from the baseline.

Results: A total of 44 patients (25 males and 19 females, mean age of 66.0 years) met the inclusion criteria. Temporal changes of bone formation markers at 1, 2, 4, 8, 12 and 24 weeks were -20.4%, +8.7%, +34.6%, +27.4%, +24.4% and +19.5% in BAP; -3.4%, +70.1%, +112.2%, +95.6%, +80.7% and +49.3% in PINP. Bone formation markers once decreased at one postoperative week, but increased to the peak level at four weeks; the high level was kept until 24 weeks. Changes in TRACP-5b at 1, 2, 4, 8, 12 and 24 weeks were -17.1%, +23.8%, +38.0%, +40.9%, +34.3% and +21.1%, respectively; bone resorption marker reached the peak level at eight weeks after surgery. The peak of bone formation markers preceded bone resorption marker by four weeks.

Discussion: To our knowledge, this is the first study to reveal temporal profile of bone turnover markers after lumbar spinal fusion surgery. The present result suggested that bone metabolism temporarily decreases by surgical invasion. Bone formation increased to the peak in one-month after surgery, and bone resorption caught up in two months, and thereafter both gradually returned to the baseline. In this study, we demonstrated the temporal profiles of bone formation and resorption markers in non-osteoporosis patients. The current findings might be utilized to assess the fusion status, and have a potential to diagnose non-union earlier than radiographic assessment. In addition, it might provide a basis for future means to monitor pharmacological intervention promoting bone healing.

Surgical outcomes of segmental posterior lumbar interbody fusion for chronic low back pain associated with vertebral bone marrow edema

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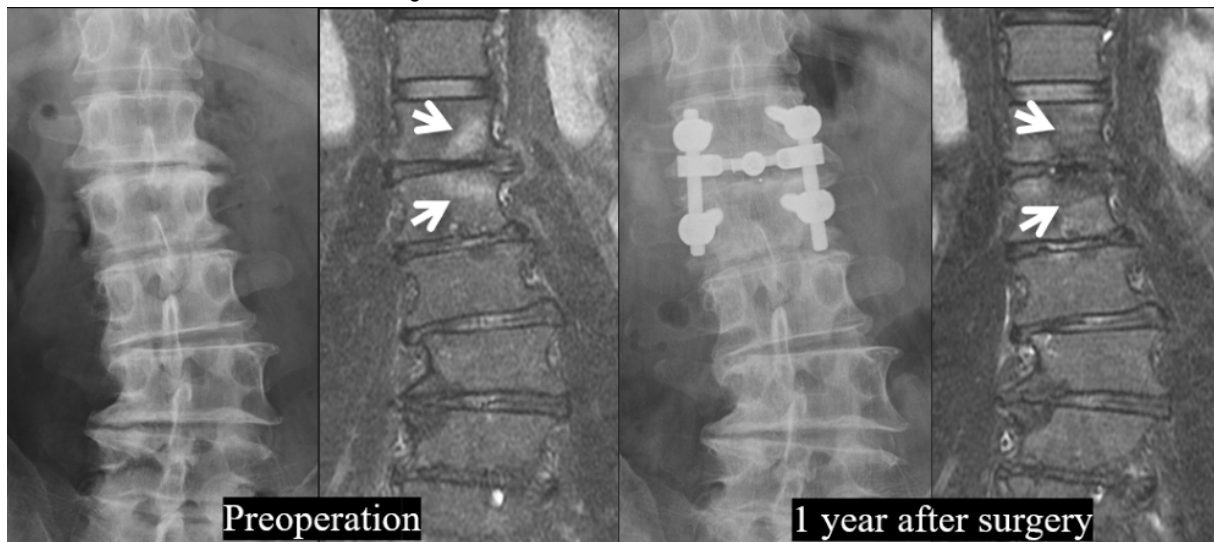
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Introduction: The cause of low back pain (LBP) in lumbar degenerative disorders is controversial. Various factors have been reported such as fatigue of the paravertebral muscle, instability of the spine, spinal malalignment, and degenerated facet joints. We had reported that bone marrow edema (BME) frequently found in adjacent to the endplates on fat saturated T2-weighted magnetic resonance imaging is strongly associated with LBP. The aim of this study is to investigate surgical outcomes of segmental posterior lumbar interbody fusion (PLIF) for chronic LBP associated with BME.

Methods: We enrolled consecutive 29 patients (13 males, 16 females) who underwent PLIF for chronic LBP associated with BME for March 2012 to September 2017. We included lumbar degenerative disorders patients who had LBP (VAS >50) at least 6 months with BME on T2-weighted fat saturated images. Patients with a previous history of lumbar surgery, isthmic spondylolisthesis were excluded. We defined LBP as axial pain in the area from the lower margin of the thorax to the iliac crest. LBP was assessed with visual analog scale (VAS; 0-100mm) and Oswestry Disability Index (ODI; 0-100%). To evaluate the objective changes, we scored the size of BME as follows: score 0 (no findings of BME), score 1 (BME affecting less than half of the height of the vertebral body), and score 2 (BME affecting more than half of the height of the vertebral body)

Results: Seven patients with lumbar degenerative spondylolisthesis, 22 patients with *de novo* degenerative lumbar scoliosis underwent PLIF. The mean age was 60.6 years (range 39-78 years), and mean follow-up period was 24.1 months (range 12-67 months). Mean duration of LBP was 48.8 months (range 13-123 months). PLIF were performed at L1-2 on 1, L2-3 on 1, L3-4 on 4, L4-5 on 19, and L5-S1 on 4 patients. The mean VAS and ODI scores were 70.1±14.6 and 44.6±13.4 at baseline. These scores were significantly improved at 1 month after PLIF (34.5±19.0, 29.4±11.9, P<0.001), and maintained until final follow up (35.8±20.6, 26.9±13.5, P<0.001). BME scores were 1.78±0.42 at baseline, and significantly decreased to 0.93±0.61 at 1 year after PLIF (P<0.001). During the final follow up, LBP was recurred in 5 patients (17.2%) due to adjacent segment disease. Of these patients, 1 patient required additional PLIF in adjacent segment 2 years after first surgery.

Discussion: LBP was significantly improved by segmental PLIF that was targeted to BME. Furthermore, in lumbar degenerative scoliosis patients, satisfactory clinical outcomes were obtained by segmental fusion targeted to BME without long fusion for spinal alignment correction. BME adjacent to the endplates is one of the important factors of chronic LBP. Segmental PLIF targeted to BME is an effective treatment in lumbar degenerative disorders.



Case. A 63 years old male. Segmental fusion was performed for L1-2 BME.

VAS score of LBP was improved 80 to 30, and BME was reduced after surgery.

Medical complications and risk factors after long level spinal fusion for adult degeneration scoliosis

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Instruction: A retrospective review comparative database was used to evaluate long level internal fixation surgical adult degenerative scoliosis (ADS) patients. This study aims to identify the patient- and surgical- related risk factors for various types of medical complications after long level spinal fusion for ADS patients. ADS surgery is known for its high incidence of complications. The purpose of this study was to determine current complication rates and the predictors of medical complications in surgical ADS patients.

Methods: The patient- and surgical- related risk factors of each individual medical complication were identified by using univariate testing. Patients were separated into groups of with and without medical complication, the complication group was further classified as major or minor medical complications and stratified as infection, neurological and cardiopulmonary. And patients were divided into groups of with and without infection, groups with and without neurological complications and groups with and without cardiopulmonary complications. Potential risk factors were identified using univariate testing. Multivariate Logistic regression was used to evaluate independent predictors of medical complications.

Results: One hundred and fifty-three ADS patients who underwent long level spinal fusion were included. Total medical complications incidence was 26.1%, which included infection (13.1%), neurological (12.4%), cardiopulmonary (10.5%), gastrointestinal (5.2%) and renal (1.3%) complications. Patient-related independent risk factors for development of medical complications included diabetes (OR 2.87, P = 0.038), smoking (OR 4.44, P = 0.001); for infection were diabetes (OR 4.74, P = 0.006) and smoking (OR 3.17, P = 0.033); for neurological complications were BMI (OR 1.16, P = 0.010) and diabetes (OR 4.12, P = 0.014); for cardiopulmonary complications were hypertension (OR 4.35, P = 0.039), smoking (OR 4.23, P = 0.035) and cardiac comorbidity (OR 6.14, P = 0.015). fusion level (OR 2.79 P = 0.000), length of hospital stay (OR 1.88 P = 0.016) and symptom duration (OR 2.57, P = 0.001). Surgical-related independent risk factors for development of major medical complications were fusion level (OR 3.57, P = 0.000), operative time (OR 0.99, P = 0.041), osteotomy (OR 9.33, P = 0.004), blood transfusion (OR 4.37, P = 0.043) and LOS (OR 1.68, P = 0.001); for infection were fusion level (OR 2.55, P = 0.006), blood transfusion (OR 23.06, P = 0.001) and LOS (OR 1.36, P = 0.010); for neurological complication were fusion level (OR 2.54, P = 0.009), osteotomy (OR 9.35, P = 0.012) and blood transfusion (OR 6.90, P = 0.033); for cardiopulmonary complication were fusion level (OR 2.17, P = 0.001).

Discussion: Diabetes and smoking were the most common patient-related independent risk factors increase the development of each individual medical complication. On the other hand, fusion levels and blood transfusion were the most common surgical-related independent risk factors increase the development of each individual medical complication. Prevention of these risk factors can reduce the incidence of complications in Chinese patients with ADS surgery.

1. Hawasli AH, Chang J, Yarbrough CK, Steger-May K, Lenke LG, Dorward IG. Interpedicular height as a predictor of radicular pain in adult degenerative scoliosis. *Spine J.* 2016;16:1070-8.
2. Schwab FJ, Smith VA, Biserni M, Gamez L, Farcy JP, Pagala M. Adult scoliosis: a quantitative radiographic and clinical analysis. *Spine (Phila Pa 1976).* 2002;27:387-92
3. Glassman SD, Hamill CL, Bridwell KH, Schwab FJ, Dimar JR, Lowe TG. The impact of perioperative complications on clinical outcome in adult deformity surgery. *Spine (Phila Pa 1976).* 2007;32:2764-70.
4. Cho KJ, Suk SI, Park SR, Kim JH, Kim SS, Choi WK, et al. Complications in posterior fusion and instrumentation for degenerative lumbar scoliosis. *Spine (Phila Pa 1976).* 2007;32:2232-7
5. Simpson JMS, Christopher P.; Balderston, Richard A.; Simeone, Frederick A.; An, Howard S. The Results of Operations on the Lumbar Spine in Patients Who Have Diabetes Mellitus. *The Journal of Bone & Joint Surgery.* 1993;75:1823-9.

Tight Filum Terminale as a differential diagnosis of criptogenic symptoms and its experiences

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Purpose: Tight Filum Terminale (TFT) is a disorder in which the conus medullaris is retracted to the caudal side due to abnormal tension of the filum terminale, causing various symptoms. Although TFT is usually recognized by the finding that the filum terminale is observed with a diameter of 2 mm or more by MRI and the conical part moves to the back side in the textbook, it is difficult to diagnose the disease by capturing the lesions in the image in the clinical cases. Diagnosis criteria of Komagata et al. are used in addition to exclusion of other possible diseases. The purpose of the present study was to clarify the clinical features, which were helpful for the diagnosis, by observing the patients who underwent a dissection of the filum terminale.

Patients: The cases were 26-year-old male, 42-year-old male, 36-year-old male, and 17-year-old female. They had low back and/or lower limb pain. Although MRI examination was performed in orthopedic clinic in the past, their diagnosis were not determined. All of the patients underwent a dissection of the filum terminale, and showed symptomatic disappearance. Their clinical findings were investigated.

Results: There were mutual characteristics for all cases: frequent urination more than 10 times per day was noticed; pain was only developed in the bending both of the neck and trunk; the pain was reduced immediately by releasing the flexion of the neck. All cases showed numbness of hands and lower limb paralysis. In addition, findings suggesting a pyramidal tract disorder such as clonus of Achilles tendon reflex and positive Hoffman or Wartenberg signs were observed in 3 out of 4 cases. The specificity for examination named as TFT provocation test at the sitting position was helpfully higher than standing examination.

Discussion: We performed the filum terminale dissection for the 4 cases of TFT. As Komagata et al. pointed out, TFT has a characteristic finding that its symptoms are exacerbated by flexion of the neck and trunk, and relieved by releasing the cervical anterior bending. Even if the patients visited several medical institutions complaining of various pain by TFT, they were not lead to a diagnosis in many cases. There would be potentially many patients just drifting along, with their pains remain untreated. The TFT provocation test at the sitting position was a valuable inspection method for detecting TFT. In this case group, 3 out of 4 cases showed a neurological abnormality suggestive of pyramidal tract disorder, and abnormality was not recognized in their cervical / thoracic MRI. Pyramidal tract disorder may be useful to remind the possibility of TFT.

Determinants of Postoperative Spinal Height Change among Adult Spinal Deformity Patients with Long Construct Circumferential Fusion

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Introduction: Spinal corrective surgeries can affect body height and this height change can be a potential concern of patients. Previous studies have only focused on young patients with adolescent idiopathic scoliosis (AIS). Whereas recent advances of surgical technique and implants allow surgeons to treat more challenging adult spinal deformity (ASD) cases surgically, it is still unknown whether AIS height change results can be applied to ASD cases. The aim of this study was to examine predictive factors of spinal height among ASD patients who underwent circumferential lumbar fusion with instrumentation.

Methods: We retrospectively reviewed clinical and imaging data of ASD patients who underwent lumbar corrective circumferential fusion (combined anterior and posterior approaches) of three or more levels between 2007-2018 at a single academic institution (n=106). Spinal height (SH) was defined as the vertical distance between the midpoint of the C2 endplate and the horizontal line from the posterosuperior aspect of the S1 endplate on a standing lateral image (Figure 1). Height change was calculated as the difference between preoperative and postoperative spinal height measurements from whole spine lateral radiographs. As potential predictors of height change, the number of lateral lumbar interbody fusion (LLIF) levels, change in spino-pelvic parameters, total number of levels fused, and pedicle subtraction osteotomies (PSO) were documented. Univariate and multivariate linear regression analyses were performed to identify predictors of postoperative height change.

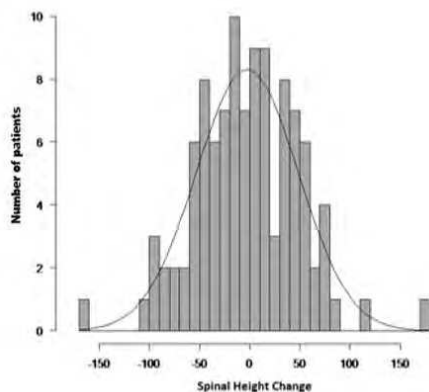
Results: The mean age (\pm standard deviation (SD)) of the 106 patients was 64.9 ± 9.6 (range 33 to 82). The mean spinal height change was $-2.39 \text{ mm} \pm 50.8 \text{ mm}$ (range, -160 to 172) (Figure 2). The univariate analyses showed that the number of LLIF levels (coefficient 10.9, $p=0.03$), the absolute coronal vertical axis (CVA) change (coefficient 0.6, $p=0.01$) and the absolute Cobb angle change (coefficient -0.9, $p=0.03$) were significant predictors for height change. Patients with PSO (n=14) tended to have a shorter height postoperatively (coefficient -26.1), but this was not statistically significant ($p=0.07$). Multivariate analyses conducted variables with $p<0.20$ (sex, absolute amounts of CVA and Cobb change, PT change, LLIF levels, and PSO) showed that PT change is an independent contributor to SH change (coefficient -0.99, $p=0.04$, R-squared 0.11).

Discussion: In this study, we utilized a modified definition of SH used in previous ASI studies to include characteristics of ASD. The results of our study demonstrated that patients with ASD can lose SH postoperatively, which is less likely to occur in AIS patients. We found that PT change was an independent contributor of SH change. Further investigations with greater numbers are needed to identify the impact of SH change on patients' clinical outcomes and satisfaction of the treatment.

Figure 1. Schematic representation of spinal height measurement (in mm)



Figure 2. Spinal height change (in mm) showing an approximately normally distributed bell-shaped curve.



Correction surgery for adult spinal deformity improves the 3D alignment of lower extremities

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Introduction: Spinopelvic alignment improves following correction surgery for adult spinal deformity (ASD). Alteration of 3-D alignment of lower extremities is, however, yet to be clarified. Relationship between the lower extremity alignment change and severity of osteoarthritis (OA) of the knee is also unknown.

Purpose: To clarify how the alignment of lower extremities changes through the correction surgery for ASD.

Methods: Forty patients with ASD (mean age: 66.5 years, range 63-77 years; 36 women) were enrolled. All patients had a single stage primary posterior correction surgery since October 2014. We excluded patients with lumbosacral transitional vertebrae or with previous surgery of lower extremities (LE). The subjects who could not complete slot-scanning three-dimensional X-ray imager (EOS) due to severe deformity were also excluded. We retrospectively evaluated spinopelvic alignment, hip knee ankle angle (HKA) in the coronal plane, knee flexion angle (KF) and severity of knee OA by Kellgren Lawrence (KL) grading using EOS before and three months after the surgery. We classified KL grade 0, 1, and 2 into mild OA group, and KL grade 3 and 4 into severe OA group. HRQOL was evaluated by ODI scores. All the values before and after surgery were compared by paired *t* test or Wilcoxon signed rank test with significant *P* value of <0.05.

Results: Not only spinopelvic alignment (TPA, TK, LL, PT), but also LE alignment (bilateral HKA, KF) were significantly improved following the surgery, and ODI did improve concurrently (Table 1). Regarding the OA subgroups, HKA in mild OA side (53 knees) was more normalized (175.9 to 177.1) compared to that in severe OA side (27 knees) (172.4 to 174.5). KF of bilateral mild OA (n=24) and bilateral severe OA (n=11) groups also improved after surgery with more normal in mild OA group (mild OA: 9.3 to 4.5, severe OA: 11.5 to 8.2).

Discussion and Conclusions: With a progressive loss of spinal lordosis, increase of PT permits keeping C7 plumb line behind the femoral heads to maintain standing posture. In case of severe kyphosis, however, hip extension limits the pelvis retroversion, thus it is compensated by flexion of the knees (1). In ASD patients, KF positively correlates with PI-LL, SVA and TPA (2) and ODI deteriorates with increase of knee flexion (3, 4). Therefore KF can be an indicator of HRQOL. The alignment of lower extremities improved not only in sagittal plane, but also in coronal plane following spinopelvic correction surgery, suggesting that the surgery contributes to improve decompensated posture into compensated posture with better HRQOL. In severe OA group, however, improvement of HKA and KF is inferior to that in mild OA group. These imply that there is a limitation in spinopelvic correction surgery in the patients with varus deformity and flexion contracture of the knee to improve whole body alignment and HRQOL.

Table 1. Spinopelvic and lower extremity parameters (°) and ODI before and after the correction surgery			
	Pre operation	Post operation	<i>p</i>
T1 pelvic angle (TPA)	38.4±13.6	22.2±8.4	<0.0001*
Thoracic kyphosis (TK)	21.6±13.3	40.1±10.5	<0.0001*
Lumbar lordosis (LL)	7.9±22.5	36.8±11.7	<0.0001*
Pelvic Incidence (PI)	54.3±11.4	53.9±10.8	0.45
Pelvic tilt (PT)	33.8±9.6	26.7±7.8	<0.0001*
Right HKA	175.2±3.4	176.5±2.6	0.0002*
Left HKA	174.2±3.6	176.0±2.7	<0.0001*
KF	10.1±7.6	5.4±6.5	<0.0001*
ODI	44.9±13.6	27.8±12.1	<0.0001*
<i>Means and standard deviations</i>			
<i>*Statistically significant</i>			

1. Roussouly P, Pinheiro-Franco JL. Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. *Eur Spine J* 2011;20:S609-618.
2. Jalai CM, et al. Full-Body Analysis of Age-Adjusted Alignment in Adult Spinal Deformity Patients and Lower-Limb Compensation. *Spine* 2017;42:653-661
3. Ferrero E, et al. Role of pelvic translation and lower-extremity compensation to maintain gravity line position in spinal deformity. *J Neurosurg Spine* 2016;24:436-446
4. Yoshihara H, et al. Relationship between sagittal radiographic parameters and disability in patients with spinal disease using 3D standing analysis. *Orthop Traumatol Surg Res* 2018 (in press), <https://doi.org/10.1016/j.otsr.2018.07.009>.

An anatomical evaluation of the superior hypogastric neural plexus at the lumbosacral junction

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Introduction: Recently mini-open retroperitoneal oblique lateral interbody fusion technique is applied to the junction with less complication as OLIF51 technique (Woods KR, Billys JB, Hynes RA. The Spine J. 2017). The technique is based on the traditional anterior lumbar interbody fusion (ALIF), which remains to be still one of the effective surgical methods to acquire effective lumbosacral fusion. The mini-open OLIF51 approach can provide a small surgical field around the bifurcations of great vessels with specially-designed retractors. One of the well-known perioperative complication of L5-S1 ALIF is retrograde ejaculation. Although its incidence is around 0.5-1%, it can lead to reproductive disorder in man whether it is temporal or eternal, and should be cared about. The disorder occurs due to the injury of nerve plexus on the lumbosacral junction, superior hypogastric nerve plexus (SHP). The present study aimed to investigate the feature of SHP using cadavers.

Methods: We prepared fifteen formalin-fixed cadavers (6 males, and 9 females) to investigate the anatomical features of SHP. The SHP was confirmed as follows: the retroperitoneal space was transperitoneally exposed to recognize great vessels in front of the lumbar spine. SHP was observed as nerve plexus that spreads on the surface of the aorta via lumbosacral junction (L5-S1 intervertebral disc [IVD]) to descend to the anterior portion of the sacrum. The major interested area of ALIF, the anterior portion of the L5-S1 IVD between the bifurcation, was regarded as the region of interest (ROI) where the anatomical features of SHP were investigated. The anatomical investigation was done using a loupe.

Results: In the 15 cadavers, 12 bodies showed cord-like structure. Within the L5-S1 ROI, the ways how SHPs run are divided into three patterns: 1) net-like pattern (3 ≤ branches on the L5-S1 IVD): 8 bodies (53.3%), 2) bi-branch (1-2 branches): 4 bodies (26.7%). The rest 3 cadavers showed only very few and thin nerve fibers, which spread upon the vessel surface and hard to recognize.

Discussion and Conclusion: SHP showed anatomical varieties from cord-like to net-like pattern, and sometimes hard to recognize. SHP descends to the intrapelvic region to provide innervation of intrapelvic organs, thus the possibility for deficiency can be considered as low. This suggests the cases with these thin and unrecognizable SHP can cause SHP injury during the surgery, while single cord-like SHP can also lead to postoperative SHP injury-related neurological disorder such as retrograde ejaculation. Surgeons should keep in mind this anatomical evidence regarding the possible existence of SHP and should treat it as such to avoid neural injury.

Low back pain in standing position significantly improves in patients treated with bilateral decompression via unilateral approach for lumbar spinal stenosis: analyzing the detailed visual analogue scale

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Introduction: Bilateral decompression via unilateral approach (BDUA) for lumbar spinal stenosis (LSS) is a less invasive technique compared to conventional laminectomy. Recently, several authors have reported favorable results of low back pain in patients of LSS treated with BDUA. However, the transitions of detailed low back pain and lower extremity symptoms before and after surgery remain unclear. Furthermore, unsymmetrical invasion to para-spinal muscle and facet joint may result in the residual unsymmetrical symptoms. To answer these questions, we conducted a retrospective study to evaluate the low back pain and lower extremity symptoms using detailed visual analogue scale.

Methods: From April 2010 to March 2016, fifty patients with LSS who were treated with BDUA and followed up until 1 years were included. Firstly, we measured detailed visual analogue scale (VAS; 100mm) of low back pain (LBP) in three different postural situations; motion, standing, and sitting (Pain Res Treat 680496, 2012). Secondly, we evaluated localization (left side versus right side) of LBP, lower extremity pain (LEP), and lower extremity numbness (LEN) measuring separated VAS in approached side and opposite side. All VAS values were measured until the final follow-up at 1 year. Oswestry Disability Index (ODI) was also measured to check the clinical improvement. X-ray findings (change of local angulation in the decompression segment) were evaluated before surgery and 1 year follow-up.

Results: Detailed LBP VAS before surgery was 53.1±31.1 in motion, 39.8±31.7 in sitting, and 62.9±28.8 in standing; the result showed LBP in standing was significantly stronger than LBP in sitting ($p<0.01$). After surgery, the strong LBP in standing was improved and the detailed LBP VAS at 1 year was 26.1±30.4 in motion, 23.4±25.6 in sitting, 26.2±27.3 in standing. The three postural LBP significantly improved ($p<0.01$) and became almost the same level. Separated LBP, LEP, and LEN VAS showed equally significant improvement in both sides and there were no significant differences between approached and opposite side (LBP: 43.3±33.3 to 25.7±29.0 in approached side, 38.2±31.9 to 25.2±29.7 in opposite side; LEP: 59.3±30.6 to 25.9±28.2 in approached side, 42.3±35.4 to 22.7±28.8 in opposite side; LEN: 63.1±27.7 to 28.8±31.9 in approached side, 50.1±35.1 to 27.5±32.8 in opposite side) ($p<0.01$). ODI scores were also improved (42.9±16.9 to 23.7±19.6) ($p<0.01$). In the X-ray evaluation, the negative correlation was observed between the residual LBP in motion and the change of local angulation in the decompression segment ($R: -0.3856, p<0.01$).

Discussion: This study first evaluated the characteristics and localization of LBP in LSS patients before and after BDUA. LBP in LSS before surgery was significantly strong in standing and the pain reduced by BDUA surgery. Moreover, LBP and lower extremity symptoms improved equally between the approached and opposite side. This result suggests that the possibility of existence of radicular LBP improved by decompression surgery. Furthermore, the BDUA surgery did not worsen the residual LBP in approached side and instability in spite of unsymmetrical invasion to para-spinal muscle and facet joint. X-ray findings showed the loss of angulation was seen in cases of residual LBP in motion.

Total Disc Replacement in the Treatment of recurrent lumbar disc herniation

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Introduction: To evaluate Biomechanical benefits of Total Disc Replacement (TDR) including both the restoration of normal segmental range of motion and the prevention of physiological lumbar lordosis encourage spine surgeons to perform TDR for recurrent lumbar disc herniation.

Methods: A total of twenty first patients (mean age: 44) who had recurrent lumbar disc herniation were operated on between 2000 and 2008. Anterior lumbar discectomy with TDR placement via an extraperitoneal approach were performed. Each patient was evaluated using a VAS and the Oswestry index. Clinical and radiographic results of these patients were evaluated at each follow-up time (1, 3, 6, 12, 24 months after operation and the latest).

Results: The average visual analogue scales score for pain was 9.40 before operation, changed to 4.30 one month after operation, further declined to 2.70 two years after operation and finally to 1.90 at the latest follow-up evaluation ($P < 0.001$). Meanwhile, the average Oswestry Disability Index was 50.8 before operation, 29.6 one month after operation, 13.5 two years after operation and 9.2 at the latest follow-up evaluation ($P < 0.001$). All operated levels maintained mobile and there was no significant loss of range of motion observed. Complications such as implant dislocation or significant subsidence of the prosthesis occurred in none case of this group. 96% patients were satisfied with the surgery at the latest follow-up evaluation

Discussion: Results from this series are promising and indicate that placement of TDR for recurrent lumbar disc herniation is a valuable alternative to conventional techniques. The main advantages of this application are preservation of spinal stability, early mobilization, restoration of normal segmental range of motion and elimination of problems related to intervertebral disc tissue such as discogenic pain and recurrence of disc herniation.

Risk factors for residual low back pain after posterior lumbar interbody fusion

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Introduction: The residual low back pain after lumbar posterior interbody fusion surgery affects the clinical outcomes of the patients with lumbar degenerative disease. However, the mechanism of the residual low back pain after surgery remains unclear. The purpose of this study was to clarify the risk factors of postoperative residual low back pain in lumbar spondylolisthesis.

Methods: Thirty patients (males 14, females 16) who underwent posterior interbody fusion surgery for lumbar spondylolisthesis at our institute from January 2016 to March 2017 were included in this study. The residual low back pain was defined as a visual analog scale over 20mm at 3 months after surgery. The patients were divided into two groups based on the presence or absence of postoperative residual low back pain. The patients with low back pain were included in pain group (L group: n=8) and the patients without pain were included in the control group (C group: n=22). Age, sex, height, body mass index, operation time and estimated blood loss, preoperative low back pain, hip joint range of motion, the cross sectional areas of the multifidus muscle and the psoas muscle at L4/5 level, spinopelvic parameters on standing lateral radiographs (lumbar lordosis, pelvic incidence, sagittal vertical axis) were compared between the two groups. Fisher's exact test and student t-test were used for statistical analysis.

Results: Hip joint extension (L group: 5.3 ± 3.4 degrees, C group: 10.5 ± 5.0 degrees), the cross sectional area of the multifidus muscle (L group: 583.1 ± 177.8 mm², C group: 944.5 ± 264.6 mm²), and preoperative lumbar lordosis (L group: 27.2 ± 10.8 degrees, C group: 38.2 ± 12.9 degrees) were significantly smaller in L group than those in C group. There were no significant differences between two groups in age (L group: 64.3 ± 11.2 years, C group: 61.5 ± 11.3 years), sex (L group: males 4, females 4, C group: males 10, females 12), height (L group: 161.1 ± 13.0 cm, C group: 161.3 ± 9.5 cm), body mass index (L group: 23.6 ± 1.9 kg/mm², C group: 24.0 ± 1.8 kg/mm²), operation time (L group: 209.5 ± 24.9 min, C group: 212.1 ± 61.1 min) and estimated blood loss (L group: 315.1 ± 83.2 ml, C group: 287.4 ± 166.6 ml), preoperative visual analog scale of low back pain (L group: 47 ± 24 mm, C group: 38 ± 29 mm), the cross sectional area of the psoas muscle (L group: 1336.5 ± 772.8 mm², C group: 1712.7 ± 950.7 mm²), pelvic incidence (L group: 50.4 ± 7.3 degrees, C group: 56.8 ± 11.5 degrees), sagittal vertical axis (L group: 81.9 ± 56.0 mm, C group: 45.9 ± 41.1 mm).

Conclusion: Preoperative hip contracture, denervation of the multifidus muscle and loss of lumbar lordosis were detected as risk factors of the residual low back pain after lumbar posterior interbody fusion surgery. Preoperative excursion training of hip joint and back muscle strength training might affect the residual low back pain.

Good clinical outcomes and fusion rate after facet fusion with cortical bone trajectory screws for degenerative lumbar spondylolisthesis

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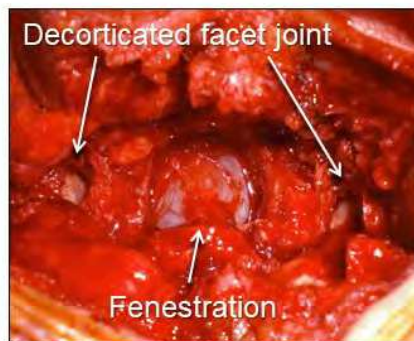
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Introduction: In a long-term clinical and radiological follow-up study of posterolateral fusion (PLF) for degenerative lumbar spondylolisthesis (DLS), we observed good clinical outcomes after PLF in terms of *in situ* fusion, low incidence of adjacent segment disease, and the lack of need for slippage reduction. Furthermore, we previously found that facet fusion (FF) using a percutaneous pedicle screw (PPS) system (PPS-FF) as a minimally invasive evolution of PLF also resulted in good clinical outcomes. We started performing the much less invasive FF technique using cortical bone trajectory (CBT) screws (CBT-FF) in 2013. Here, we assessed the fusion rate and clinical outcomes of this procedure.

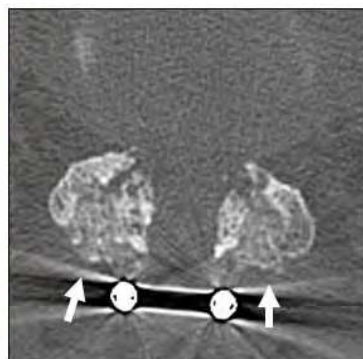
Methods: The indications for lumbar fusion were: 1) sagittal translation $\geq 8\%$ on a flexion-extension lateral radiograph or 2) anterior wedging ≥ 5 degrees on a flexion radiograph and a disc range of motion (ROM) ≥ 10 degrees. Forty-two patients (24 women, 18 men; mean age, 71.3 years) who underwent CBT-FF for single-level DLS were retrospectively reviewed after a minimum follow-up of 1 year. The surgical method involved making a 4-cm skin incision, bilateral laminar fenestration, and FF with autologous bone harvested from the spinous process. CBT screws were then inserted. We evaluated the FF rate using computed tomography (CT) and range of motion (ROM) at the fused level on a flexion-extension lateral X-ray film preoperatively and at the final follow-up and analysed the therapeutic effectiveness of FF using the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), Roland-Morris Disability Questionnaire (RMDQ), and visual analogue scale (VAS).

Results: The FF rate was 85.7% (36/42 cases). At the final follow-up, all patients with an adequate FF on CT had no recognizable motion at the fused level. In six nonunion cases, the mean ROM significantly decreased from 12.4 degrees preoperatively to 2.7 degrees postoperatively. The therapeutic effectiveness on the JOABPEQ was demonstrated in the Walking Ability score in 75.6% of the patients and in the Low Back Pain score in 71.9%. The postoperative mean RMDQ value and VAS scores were significantly decreased.

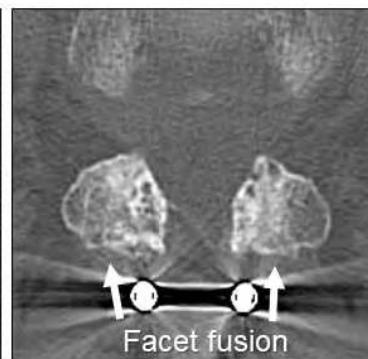
Discussion: CBT screw insertion is less invasive than PPS insertion because the former is performed directly through the exposed laminae, thus avoiding subcutaneous tissue exposure and paraspinal muscle damage by PPS insertion through the fascia. Although the CBT-FF fusion rate was lower than the previously reported PPS-FF fusion rate of 88.6%, good clinical outcomes were noted even in nonunion cases, likely because the ROM significantly decreased postoperatively, indicating stabilization of previously unstable spondylolisthesis. Moreover, preserving the intervertebral disc is very important and surgery with intervertebral disc preservation is the least invasive. There are potential revision surgery options, such as PLF and lumbar interbody fusion, in cases of FF failure. Thus, CBT-FF has several advantages for spinal fusion and is minimally invasive and useful in the management of DLS.



Operative image



CT immediately after op



CT 6mo post-op

Prospective Case Series on Clinical & Radiological Outcomes of Single Level Oblique Lateral Interbody Fusion

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Introduction: Indirect decompression using oblique lateral interbody fusion (OLIF) is known to increase spinal canal dimensions by restoring intervertebral disc height in degenerative lumbar diseases. However, the clinical significance of these radiological improvements has not been fully elucidated. The purpose of this study is to evaluate clinical and radiological outcomes after single level OLIF, and the relationship between the clinical and radiologic outcomes.

Methods: Among patients who were planned to receive single level OLIF for lumbar degenerative disease, those consented to take MRI and CT at postoperative 1 year were included in the current study. Clinical outcomes were assessed using ODI, JOABPEQ, SF-36, VAS for back pain and radiating pain before and 3, 6, 12 months after the operation. Regarding the radiological parameters, change in disc height, segmental and lumbar lordosis angle and cage subsidence were evaluated from the simple radiograph. Changes in diameter and cross-sectional area of the central canal and intervertebral foramen were measured from MRI, and completion of fusion was evaluated using CT. The outcomes were compared between three different diagnostic groups: 1) degenerative spondylolisthesis, 2) spondylolytic spondylolisthesis, and 3) spinal stenosis without dynamic instability. For statistical analysis, paired t-test was used to analyze interval changes in clinical scores and radiological parameters. Correlation and regression analysis were used to evaluate the relationship between these parameters.

Results: Total of 44 patients were included in the current study. All categories of clinical scores showed statistically significant improvement until 6 months postoperatively. All radiological parameters from simple radiography, including the disc heights and segmental and lumbar lordotic angles were improved immediately after the operation. Subsidence of interbody cage was observed in 6 (13.6%) and 11 (25.0%) patients at postoperative 1 week and 1 month, respectively. The average ODI and SF-36 physical component score were lower in patients with cage subsidence, compared to the patients without cage subsidence. Complete interbody fusion was observed on CT at postoperative 1 year in 32(72.7%) patients, while other 12(27.3%) showed intermediate fusion status. However, there was no statistically significant difference between the patients with complete and intermediate fusion. Postoperative 1 year MRI showed improvement of all spinal canal dimensions following OLIF, except for the foraminal width. The elevation of foraminal height on the MRI was associated with the improvement of lower extremity radiating pain. All clinical and radiological outcomes showed no statistically significant difference between the three diagnostic groups.

Discussion: In the current study, favorable clinical outcomes were observed following OLIF, most of the clinical improvement occurring within the three months following OLIF. All radiologic parameters that were assessed from the simple radiography and MRI showed significant improvement after OLIF. When the relationship between the clinical and radiologic outcomes was evaluated, the elevation of foraminal height was associated with the improvement of lower extremity radiating pain and cage subsidence was associated with poor clinical scores. Therefore, the sufficient restoration of the foraminal height while preserving the endplates can be considered important for satisfactory clinical results following the OLIF procedure.

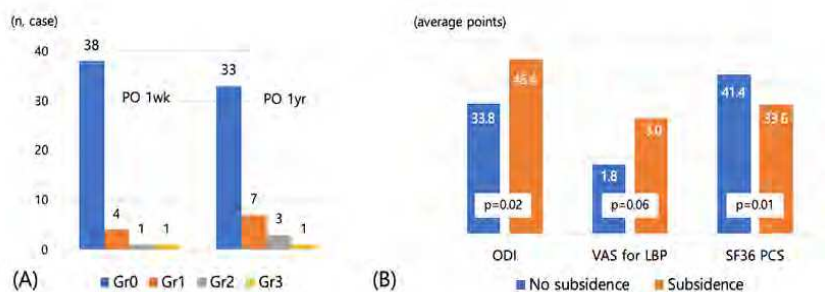


Figure 1. Cage subsidence following oblique lateral interbody fusion. (A) Grade of cage subsidence at postoperative 1 week and 1 year. (B) Clinical scores stratified by the presence of the cage subsidence.

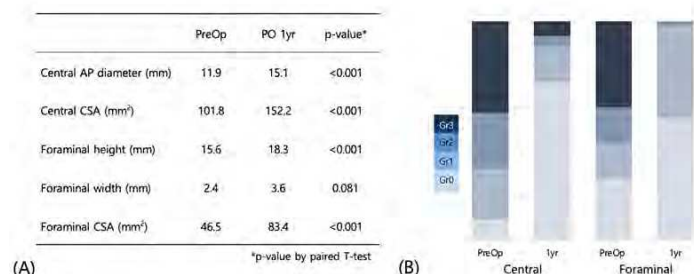


Figure 2. Radiological improvement following OLIF. (A) Change of central and foraminal dimensions. (B) Change of central and foraminal stenosis grading.

The rate of fusion for stand-alone anterior lumbar interbody fusion: a systematic review

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Introduction: Anterior lumbar interbody fusion (ALIF) has been used for treatment of several spinal conditions including degenerative disc disease and low-grade spondylolisthesis. Expected fusion rate of stand-alone ALIF constructs is currently unclear. The aim of this study was to examine fusion rate for stand-alone ALIF surgery.

Methods: We queried the MEDLINE, COCHRANE, and EMBASE databases for all literature related to spine fusion rates using a stand-alone ALIF procedure with a publication cutoff date of July 19, 2018. Supplementary combinations of search terms included spine, fusion, fixation, rate(s), and arthrodesis. ALIF surgery was considered stand-alone when not paired with pedicle screw fixation. Cohort fusion rate differences were calculated using Student t-tests with significance assigned if p-value was less than 0.05.

Results: Title and abstract level review required assessing 840 unique publications. Across the 55 studies that met inclusion criteria of this systematic review, 5517 patients and 6303 levels were fused. The included studies spanned 31 years from 1988 through 2018. Stand-alone ALIF with interbody cage placement was the most frequently utilized approach (73%, Table 1). The overall weighted average patient fusion rate following stand-alone ALIF was 88.2% (range: 16.6% - 100%). In the 31 studies with at least 50 subjects, the weighted average fusion rate following stand-alone ALIF was 88.6% (range: 57.5% - 99.0%). Nearly 55% of included studies reported $\geq 90.0\%$ fusion rates. Across all included studies, fusion was assessed using radiographs in 65% of the included studies and 35% using CT scans. Mean radiological follow-up period was 27.4 months. Fusion rates were lower in studies with 50% or more subjects having positive smoking and worker's compensation status, however these results were found to be insignificant ($p > .05$). Fusion rate for subjects in the eight rhBMP-2 study groups was 94.4% ($n = 889$) compared to 84.8% ($n = 3102$) in 38 study groups without rhBMP-2 utilized. Utilization of rhBMP-2 did not lead to a statistically significant improvement in fusion rate ($p > 0.05$).

Discussion: Over the last thirty years, there has been a shift in stand-alone ALIF surgery with allogenic bone dowels towards utilizing zero-profile interbody cage implants integrated with anterior spacers for placement of screws. Based on the available data, stand-alone ALIF procedures yield high fusion rates overall within 12 to 24 months. Fusion rate is more likely to be over-reported in studies with a single radiologist assessing radiographs when compared to multiple independent radiologists reviewing CT scans. Fusion failure and pseudoarthroses rates are higher in study populations involving a high percentage of smokers or positive workers compensation status. Utilization of rhBMP-2 during ALIF surgery may ensure high rates of fusion when treating patients at elevated risk for poor outcomes including smokers, WC patients, and those with chronic comorbidities.

Table 1: Pooled Mean Fusion Rate by Stand-Alone ALIF Definition

Stand-Alone ALIF Definition	Studies	Subjects	Fusion Rate
Bone Dowels	5	239	88.5%
Bone Dowels + Cortical Blocks	2	172	73.7%
Cages	18	2693	86.7%
Cages + Anterior Plate	7	813	95.2%
Cage (Zero-Profile)	14	867	88.7%
Cage (Zero-Profile) + Anterior Plate	1	115	93.0%
Cortical Blocks	1	67	95.5%
Cortical Blocks + Anterior Plate	1	113	88.0%
Cortical Blocks + Wire	3	128	81.1%
Other	3	310	87.8%
Total	55	5517	88.2%

5-year results of a double-blind RCT on comparing interspinous implant without bony decompression to conventional decompression for lumbar spinal stenosis

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Introduction: Short-term results comparing interspinous process devices (IPD) to conventional decompression in patients with intermittent neurogenic claudication (INC) due to lumbar spinal stenosis provide evidence that clinical outcomes are comparable¹. This study focuses on the long-term, 5-year results of this comparison.

Methods: Patients with neurogenic claudication due to lumbar spinal stenosis at one or two levels who had failed to respond to conservative treatment, were randomized to receive either standard bony decompression or stand alone implantation of an IPD (Coflex). A total of 159 patients were randomized at the five participating neurosurgical centers. Patients and research nurses remained blinded for the allocated treatment throughout the study period of 5 years. The primary outcome at long-term (5-year) follow-up was the score for the Zurich Claudication Questionnaire (ZCQ), secondary outcome measures included Visual Analogue Scores (VAS) for back pain and leg pain. Repeated-measurement analyses were applied to compare outcomes over time.

Results: 80 participants received an IPD and 79 participants underwent spinal bony decompression. At five years, the success rate according to the Zurich Claudication Questionnaire for the IPD group [68 % (95 % CI 56-78)] did not show a significant difference compared to standard bony decompression [56 % (95 % CI 44-68) p-value 0.422]. Reoperations, because of absence of recovery, remained significantly higher in the IPD group compared to standard decompression with comparable reoperation rates at 2 and 5 years (p=0.04). Long-term back pain was lower [26 mm on a 100 mm scale (95% CI 20-32)] in the IPD group compared to the bony decompression group [38 mm (95% CI 30-46) p-value 0.02]. This is in contrast to the 2-year results where the VAS back pain was higher in the IPD group compared to standard bony decompression (36 vs. 28 mm, p-value 0.04).

Discussion: Long-term results demonstrate that implanting a stand-alone interspinous device is equally successful compared to standard decompression in treating neurogenic claudication. The VAS back pain seems to improve over time in the IPD group. However, the difference in VAS back pain between both treatment group at 5-years might be statistically significant, but is clinically probably non-relevant. Reoperation rate in the IPD group remains significantly higher but does not increase after 2 years follow-up. Implanting an IPD appears to be an acceptable, though more expensive, alternative for decompressive surgery.

1. Moojen WA, Arts MP, Jacobs WC, van Zwet EW, van den Akker-van Marle ME, Koes BW, Vleggeert-Lankamp CL, Peul WC. IPD without bony decompression versus conventional surgical decompression for lumbar spinal stenosis: 2-year results of a double-blind randomized controlled trial. *Eur Spine J* 2015, Oct;24(10):2295-305.

Does Improvement in Static Balance Alignment Truly Enhance Dynamic Body Balance?

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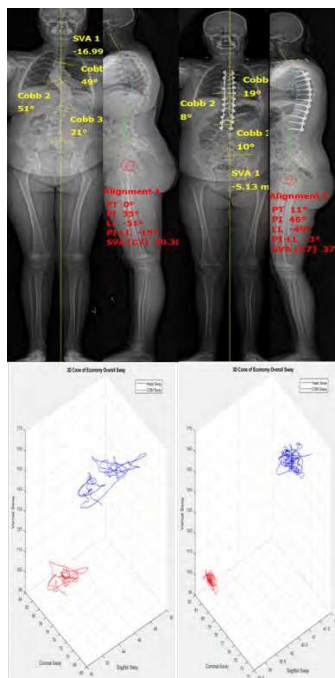
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Introduction: Spinal deformities comprise a variety of conditions that affect the normal spinopelvic alignment in the coronal and or sagittal planes.[1] The location of the center of balance in the sagittal plane in deformity patients is most commonly estimated using full-length spinal radiographs (Figure 1).[2-3] Recently, Haddas et al. developed a new method to quantify the cone of economy(CoE) dimensions and balance parameters in spinal disorder patients.[5] The recent appreciation of the relationship between the spine and the pelvis has fostered a more precise pre-planned surgical intervention to restore the native alignment.[6] With the aforementioned in mind, the importance of the sagittal alignment based on static imaging is recognized and well documented,[2-4] however, to our best knowledge, no one has yet attempted to correlate static balance alignment parameters with a dynamic overall body balance in a group of adult degenerative scoliosis(ADS) patients before and after surgery.

Methods: Twenty-nine ADS patients performed a series of functional balance test a week before (Preoperative) and 3 months after the surgery (Postoperative) Furthermore, each patient underwent a full-length head to toe micro-dose x-rays on the same days of testing. Outcome measurements were center of mass(CoM) and head overall sway along with CoE dimensions for the dynamic balance test and pelvic incidence, sacral slope, sagittal pelvic tilt, lateral pelvic tilt, kyphosis, lordosis,SVA,CVA, spinosacral angle, full body index, knee-flexion, and Cobb-angle. For each parameter, the change (Δ) in value was calculated by subtracting the post-surgery value from the pre-surgery one.

Results: At 3 months postoperatively, these patients showed improvement in their balance, specifically the Cobb angle was reduced (Pre: 41.85 vs Post: 11.97°, p=0.001) and kyphosis angle was increased (Pre:38.99 vs Post:46.62°, p=0.005). Furthermore, these patients presented with lower magnitude CoM (Pre:40.69 vs Post:28.00 cm, p=0.002) and head (Pre: 64.93 vs Post: 49.96 cm, p=0.004) total sway, as well as lower magnitude CoE dimensions (CoM: Sagittal: Pre: 2.51 vs Post: 1.33 cm, p=0.035; Coronal: Pre: 3.59 vs Post: 2.92 cm, p=0.049; Head: CoM: Sagittal: Pre: 3.98 vs Post: 2.30 cm, p=0.028). The Δ Cobb angle was correlated with Δ CoM total sway (r=0.499, p=0.025), and Δ CoM (r=0.446, p=0.033) and Δ Head (r=0.442, p=0.035) vertical sway. The Δ Kyphosis was correlated with Δ Stance width (r=0.494, p=0.017), and Δ CoM (r=0.476, p=0.037) and Δ Head (r=0.472, p=0.023) coronal sway. The Δ Lordosis was correlated with Δ Head coronal sway (r=0.464, p=0.041). The Δ Sagittal pelvic tilt was correlated with Δ Stance width (r=0.422, p=0.024). The Δ Lateral pelvic tilt was correlated with Δ Head coronal sway (r=0.416, p=0.049).

Discussion: Surgical realignment improved static and dynamic balance in ADS patients. Three months after surgical intervention, ADS patients reduced their CoM and head total sway along with lower magnitude CoE dimensions. Furthermore, 3 months after surgical intervention, ADS patients presented with a reduced coronal Cobb angles and improved thoracic kyphosis angles. Changes in static balance alignment were highly correlated with overall dynamic balance. In specific, changes in Cobb angle, kyphosis, lordosis and sagittal pelvic tilt were highly correlated with changes in CoM and head total sway along with changes in CoE dimensions.



1. Aebi M. The adult scoliosis. *Eur Spine J* 2005;14:925-48
2. Diebo BG, Varghese JJ, Lafage R, et al. Sagittal alignment of the spine: What do you need to know? *Clin Neurol Neurosurg* 2015;139:295-301.
3. Amabile C, et al. *Eur Spine J*, 27(2): 458-66, 2018.
4. Dubousset J. Three-dimensional analysis of the scoliotic deformity. *The pediatric spine: principles and practice*. New York: Raven Press Ltd, 1994.
5. Haddas R, Lieberman IH. A method to quantify the "cone of economy". *European Spine Journal* 27:1178–87, 2018.
6. Metha VA, et al. *Neurosurgery*, 70(3):707-21, 2012.

Impact of Range of Motion on Progression of Adjacent Segment Disease: Disc vs. Disc

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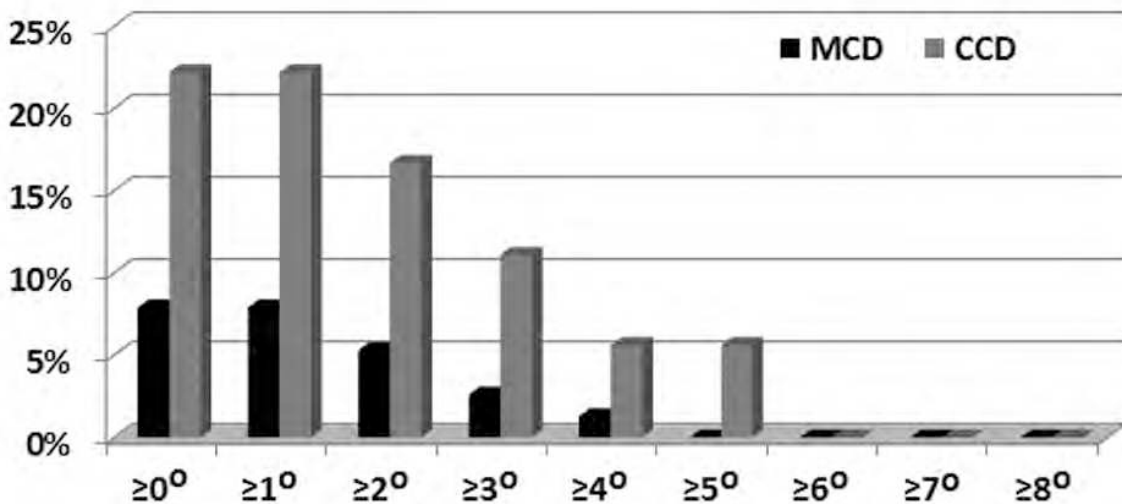
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Introduction: Previously, long term outcomes investigating range of motion (ROM) preservation over time between an investigational arm mobile core device (MCD) and control arm controlled core device (CCD) have been reported. No studies have looked at the relationship of ROM to the progression of adjacent segment disease (ASD) between disc prostheses. The primary purpose of this study was to compare changes in ROM between two lumbar TDRs. Secondly the relationship between incremental degrees of motion maintained to progression of ASD was investigated.

Methods: This is a post-hoc analysis of data collected from a large, prospective, multicenter clinical trial. As part of the clinical trial, 175 patients received either the investigational MCD or the CCD control device. All patients were treated for symptomatic disc degeneration unresponsive to minimum 6 months non-operative care. The primary outcome measures were ROM and the progression of ASD. ROM was evaluated through radiographs at the index level at baseline (preoperative) and at 5-years postoperative. At 5-years, a change in adjacent ASD was defined as an increase of at least one grade based on the Kellgren-Lawrence scale.

Results: At baseline both MCD and CCD patients had similar index level ROM of 6.6° and 6.2° respectively (p>0.5). At 5-years postoperative, patients with a CCD had an average ROM of 4.2° which represented a statistically significant reduction from baseline (p<0.02). Patients with a MCD had an average ROM of 6.1° at 5-years which was similar to the baseline ROM (p>0.4). In a comparison between groups, patients with a CCD had 31% less ROM at 5-years postoperative than patients with a MCD (p<0.025). Patients receiving an MCD were less likely to have progression of ASD at 5-years than patients who received a CCD (8.8% vs. 19%, p<0.05). As seen in the figure, for each additional degree of motion at the TDR level, there was a decline in the rate of ASD with a trend for lower rates in MCD group, compared with CCD. Among patients with at least 6° of motion there was no ASD in either TDR group.

Discussion: These data show that there may be a relationship between the maintenance of motion over time and the progression of ASD. While additional analysis is warranted, a novel MCD may be more effective in maintaining ROM and thus better at delaying ASD than the earlier generation CCD.



Early Reduction of Ligamentum Flavum 2 Weeks after Posterior Fusion in situ without Direct Posterior Decompression for Unstable Degenerative Lumbar Spondylolisthesis

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Introduction: Radicular symptoms (e.g., leg pain, claudication) caused by degenerative lumbar spondylolisthesis (DLS) are a result of segmental instability and nerve root compression by hypertrophied ligamentum flavum (LF) at the lateral recesses. Mechanical instability has been considered a possible cause of LF hypertrophy. Thus, we hypothesized that spinal stabilization in situ alone may reduce the hypertrophied LF and alleviate radicular symptoms. The purpose of the present study was to evaluate radiologically the early morphological changes of the LF after posterior fusion in situ without direct posterior decompression (e.g., laminectomy, removal of the LF) for unstable DLS.

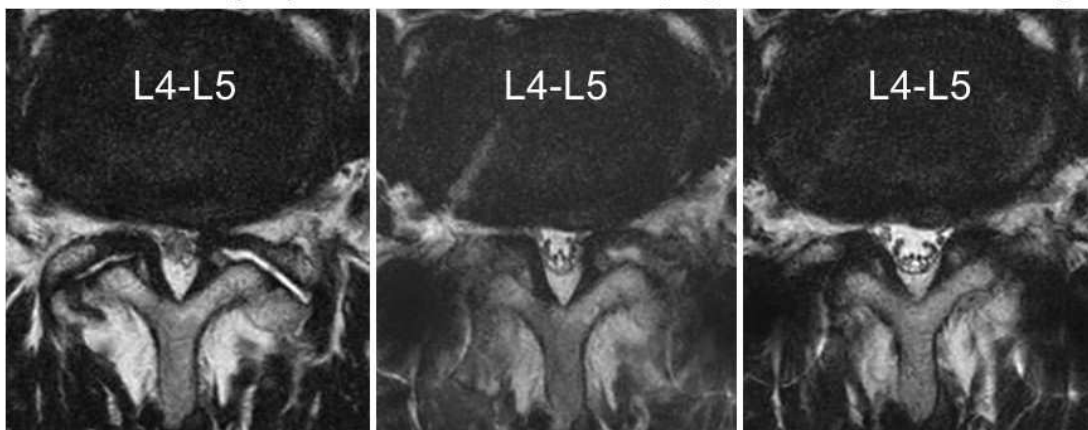
Methods: We included 25 consecutive patients with persistent radicular symptoms caused by single-level unstable DLS who underwent instrumented facet fusion in situ using autologous iliac bone without posterior laminectomy. Cross-sectional area of the LF (LFA), thickness of the LF at the lateral recesses (LFT), and cross-sectional area of the thecal sac (TSA) were measured on MR images. Disc height (DH), disc angle (DA), slipping of upper vertebra (% slip), and disc range of motion (ROM) were measured on lateral radiographs. All measures were obtained at 2 weeks and at 6 months postoperatively and compared with preoperative values. Clinical symptoms, including leg pain and walking disability were evaluated using a visual analogue scale (VAS) and the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ).

Results: Significant decreases ($p < 0.0001$) in LFA and LFT (29% and 37%) were observed 2 weeks after surgery, and had continued to decrease by up to 59% and 68%, respectively at the 6-month follow-up. TSA increased by 34% at 2 weeks and by 84% at 6 months postoperatively ($p < 0.0001$). DH and DA did not show significant changes postoperatively. Although % slip was decreased, patients had upper vertebral slipping of 5.0% at 2 weeks and 5.9% at 6 months after surgery. The fusion rate was 88%. All patients with adequate fusion had no recognized motion at the fused level. In three patients with inadequate fusion, ROM decreased from 16.7° to 3.3° postoperatively. Radicular symptoms resolved immediately after surgery in all patients. VAS scores for leg pain were significantly reduced ($p < 0.01$) to 21% of preoperative values at 2 weeks, and 15% at 6-months' follow-up. JOABPEQ category scores for walking ability demonstrated therapeutic effectiveness in 88% of the patients at 2 weeks and 100% at 6-months' follow-up.

Discussion: Significant decreases in the LFA and LFT, and an increase in TSA were observed at 2 weeks postoperatively, and lasted 6 months after posterior fusion in situ without decompression, despite a lack of restoration of disc height or correction of spinal alignment. Stabilization of the unstable segment and a decrease of mechanical stress may have induced the reduction of LF accompanied by the spinal canal enlargement at the lateral recesses, leading to good clinical outcomes. Thus, posterior fusion in situ without decompression may be sufficient and appropriate for managing radicular symptoms caused by unstable DLS, questioning the need for both direct decompression and indirect decompression by interbody distraction.

Case example

Before surgery 2 weeks after surgery 6 months after surgery



LFA (mm ²) :	113.7	→	88.5	→	33.4
LFT (mm) :	7.2	→	3.2	→	1.9
TSA (mm ²) :	65.3	→	86.4	→	121.4

Do patients that catastrophize back and leg pain prior to lumbar decompression do worse after surgery?

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Introduction: Recent studies have illustrated the role of catastrophization and somatization in patients suffering from lumbar spinal stenosis. There is evidence that VAS back and VAS leg pain scores correlate with pain catastrophizing scale in patients suffering from lumbar spinal stenosis. No study to date, however, has examined the role that pre-operative pain catastrophizing might have on post-operative outcomes for these patients.

Methods: We performed a retrospective review of patients that eventually went on to undergo a lumbar decompressive surgery. We defined patients catastrophizing pain as having pre-operative VAS leg/back scores of 9 or above. These pain catastrophizing (PC) patients were then divided into a cohort with VAS leg scores above 9 (VL-PC) and a cohort with VAS back scores above 9 (VB-PC). Health related quality of life (HRQOL) scores were collected on these patients in the pre-operative period and the post-operative period up to 1 year out from surgery. These scores included the Oswestry Disability Index (ODI), Short Form 12 (SF-12) mental health scores (MHS) and physical health scores (PHS) and PROMIS scores. We performed a student's T-test to analyze if there was a difference in outcomes after surgery between VL-PC patients and those that did not catastrophize leg pain (non-VL-PC).

Results: 139 patients were included within our analysis. There were 21 patients in the VB-PC cohort (14 female, mean age - 48.0 +/- 17.6 years old) and 31 patients in the VL-PC cohort (22 female, mean age - 49.4 +/- 18.2 years old). The pre-operative SF-12 MHS (42.0 vs. 47.5, $p = 0.02$), SF-12 PHS (28.1 vs 32.2, $p = 0.003$), ODI (59.7 vs 38.0, $p < 0.001$) and PROMIS (29.3 vs 35.7, $p < 0.001$) scores were worse for the VL-PC cohort versus non-VL-PC. The pre-operative SF-12 MHS (40.6 vs. 47.9, $p = 0.02$), SF-12 PHS (28.6 vs 32.1, $p = 0.02$), ODI (59.5 vs 39.7, $p = 0.01$) and PROMIS (29.5 vs 35.7, $p < 0.001$) scores were worse for the VL-BC cohort versus non-VL-BC. In the post-operative period, the VL-PC cohort had worse HRQOL scores at the 2 week time point in terms of SF-12 PHS (28.1 vs 47.5, $p = 0.02$) and SF-12 MHS (42.0 vs 47.5, $p = 0.02$). At all other time points post-operatively there was no statistically significant difference between SF-12 MHS, SF-12 PHS, ODI and PROMIS scores in the VL-PC cohort vs non-VL-PC cohort. For the VB-PC cohort, post-operative outcome scores were only worse at 6 weeks out from surgery in terms of SF-12 MHS (42.5 vs 52.8, $p = 0.003$) and SF-12 PHS (27.7 vs 38.0, $p = 0.003$) as compared to the non-VB-PC cohort.

Discussion: These results show that patients that catastrophize back or leg pain may have short term worse outcomes after lumbar decompressive surgery. This difference in outcomes between those that catastrophize pain and those that do not catastrophize pain appears to disappear after 6 weeks out from surgery.

Minimally Invasive Sacroiliac Joint Fusion Using a Novel Hydroxyapatite-Coated Screw System Improves Functional Outcomes in Patients with Sacroiliitis at One-Year Follow-up

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Introduction: The sacroiliac joint (SIJ) has been implicated as a source of chronic low back pain in 15 to 30% of patients. The mainstay of therapy for disorders of the SIJ has been non-operative treatment, including activity modification, non-steroidal anti-inflammatory drugs, and physical therapy. SIJ injections provide diagnostic information and occasional durable therapeutic benefit. When these modalities fail, sacroiliac joint fusion may be recommended. This study describes the clinical outcomes of a novel hydroxyapatite-coated titanium screw for surgical treatment of SIJ dysfunction.

Methods: This study is a retrospective, Institutional Review Board-exempt chart review on 45 consecutive patients who underwent minimally invasive SIJ fusion with a novel hydroxyapatite-coated screw system. Patients were diagnosed based on North American Spine Society guidelines and evidence-based criteria. Clinical assessments were collected, evaluated, and compared pre-operatively and at 12 months post-operatively.

Results: Mean patient age was 69.4±9.6 years, and 60.0% of patients were female. Mean preoperative visual analog scale sacroiliac (VAS SI) pain scores decreased significantly by a mean of 6.1 points at 12 months postoperatively ($p<0.001$). Oswestry Disability Index (ODI) scores significantly decreased by a mean of 41.4 points at 12 months postoperatively ($p<0.001$). Twenty percent (9/45) of patients underwent bilateral SIJ fusion, while the remaining were unilateral. Screw size ranged from 10x35 mm to 10x50 mm.

Discussion: The clinical outcomes of SIJ fusion using a hydroxyapatite-coated screw system to treat sacroiliitis significantly decreased VAS SI and ODI scores at 1 year.

Obesity and High Fasting Blood Glucose as Independent Risk Factors for Reoperation after Endoscopic Discectomy

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Purpose: Recently, minimally invasive surgery has undergone remarkable technical evolution. However, recurrent lumbar disc herniation (rLDH) is still the main reason for reoperation following primary percutaneous endoscopic lumbar discectomy (PELD). This retrospective study aimed to investigate the risk factors for rLDH and the reoperation rate following single level PELD.

Methods: A total of 205 consecutive patients who underwent PELD for single-level lumbar disk herniation (LDH) between 2013 and 2015 were retrospectively analyzed to identify causes of reoperation and associated risk factors. Reoperation was defined as postoperative radiographic findings of recurrent symptomatic disc herniation at the same level requiring subsequent surgery. Chart review was done, and preoperative and postoperative radiographic and demographic reviews were performed. Besides, patients with recurrent LDH were further assessed for the time of recurrence, length of pain-free period, and history of trauma.

Result: From February 2013 to December 2015, 205 patients had undergone PELD; 21 (10.2%) cases required subsequent revision surgery due to rLDH. Multivariate analyses showed that obesity and high fasting blood glucose (FBG) levels were independent risk factors with significant predicted value for reoperation following single level PELD after adjusting for other potential risk factors. Body mass index (BMI) of 25.775kg/m² and FBG level of 5.155 mmol/L were defined as cut-off points for PELD based on the results of receiver operating characteristic (ROC) curves.

Conclusion: The study demonstrated that obesity (BMI >25.775), and high FBG levels (>5.155 mmol/L) were independent risk factors for PELD reoperation. Keywords: Percutaneous endoscopic lumbar discectomy ; Lumbar disc herniation; Reoperation; Risk factors; Minimally invasive

In Which Cases Do Surgeons Specializing in Total Disc Replacement Perform Fusion in Patients with Symptomatic Lumbar Disc Degeneration?

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Introduction: Results of lumbar total disc replacement (TDR) have consistently been reported to be similar or superior to lumbar interbody fusion in appropriately selected patients. The purpose of this study was to investigate the reasons and their frequency for why TDR specialty surgeons performed lumbar fusion rather than TDR.

Methods: A consecutive series of 515 patients undergoing lumbar TDR or fusion during a 5-year period by three surgeons specializing in TDR were reviewed. For each fusion, the reason for not performing TDR (including hybrids) was recorded. After recording a description of the primary reason for performing fusion, these were classified into categories. A category of “combined” was used for patients with multiple related problems such as severe stenosis, disc space collapsed, Grade 1 spondylolisthesis, and/or segmental instability.

Results: During the study period, 65.4% (n=337) of patients underwent TDR and the remaining 34.6% (n=178) underwent lumbar interbody fusion (stand-alone ALIF or ALIF combined with posterior instrumentation +/- fusion). Of the 178 fusion patients, the most common reason for fusion vs. TDR was combined factors which occurred in 59 patients (11.5%). The second most common reason was greater than Grade 1 spondylolisthesis (n=32, 6.2%), followed by insurance noncoverage (n=24, 4.7%) and 13 did not receive TDR due to osteopenia/osteoporosis (2.5%). There were pars defects in 11 patients (2.1%), degenerative deformity in 9 patients (1.7%) and pseudoarthrosis repair led to fusion in 6 patients (1.2%). Other reasons for fusion included significant facet joint degeneration and/or painful facets (n=4, 0.8%), bridging osteophytes (0.4%), and significant scarring from prior discectomy (n=2, 0.4%). There was one case (0.2%) each of: possible metal allergy, pedicle fracture, apophyseal ring defect, intraspinal extradural mass, annular cyst, TDR removal, TLIF cage removal, ankylosing spondylitis, rheumatoid arthritis, high sacral slope, possible post-stem cell injection discitis (performed remote), and one patient opted for fusion instead of TDR. In 4 patients (0.8%) the reason for fusion vs. TDR could not be clearly determined from the chart review.

Fusion patients' mean age was significantly greater than TDR patients (52.5 vs. 41.6 years; $p < 0.01$). There was no significant difference between the two groups with respect to gender (both approximately 42% female) or the percentage of patients with single-level surgery (61.2% vs. 56.7%).

Discussion: The most common reason for not performing lumbar TDR was related to factors that may compromise the stability of the operated segment and/or functionality of the TDR. The older age may be related to these factors as well as segmental degenerative deformity leading to fusion. The results of this study found that many patients are good candidates for lumbar TDR. However, even among TDR specialists, fusion may be preferred in some patients where it is prudent to not take undue risks.

Same-day Discharge versus Inpatient Lumbar Fusion: A Matched Cohort Comparison of Four Surgical Approaches

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Introduction: Discharge from the hospital on the day of (outpatient) lumbar spinal fusion procedures is becoming more common. However few studies have compared the morbidity between inpatient and same-day lumbar spinal fusion surgeries. The purpose of this study is to compare an unmatched and matched cohort of patients who underwent inpatient and outpatient lumbar fusion procedures and report outcomes in terms of patient characteristics and a comparison 30-day readmissions and post-operative complications.

Methods: Patients who underwent lumbar fusion procedures including postero-lateral fusion without inter-body (PLF), postero-lateral fusion with inter-body (PLF-IB), anterior stand-alone fusion (ALF) and combined anterior and posterior fusions (A-PSF) were identified from the National Surgical Quality Improvement Program registry (2012-2016). Using propensity scores, patient who underwent outpatient lumbar fusion procedures were matched 1:1 with patients who underwent the same procedures but were admitted for an inpatient stay. The rates for post-operative complications and 30-day readmissions were compared between matched cohorts using the student's t test.

Results: The average age for outpatient surgery was 57.41 (56.41 – 58.42), with 83.4% of patients being < 70 years of age. The cohort included 53.4% males and 46.6% females and mean BMI was 27.40 kg/m², with 28% of patients being obese (BMI > 30 kg/m²). 23.7% were smokers, 14.6% had diabetes, and 50.4% had hypertension, 64.8% were ASA Class of II or below. The mean number of levels operated was 1.28 (1.24 – 1.33). The rates of major/minor complications were less than 1% while 2.6 % of patients were re-admitted within 30-days and 1.4 % had return to OR.

After matching, outpatient lumbar fusion had lower rates of blood transfusions (PLF-IB, ALF p<0.001), need for ventilation >48hrs (PLF, PLF-IB p=0.04), cardiac arrest (PLF, PLF-IB; p=0.004), thromboembolic events (PLF-IB, ALF; p=0.045), urinary tract infection, myocardial infarction (PLF, PLF-IB; p=0.045), pneumonia (PLF; p=0.044). PLF and PLF-IB had lower rates of return to the OR (p=0.048) and 30-day readmissions (p=0.035). These lower rates were not seen in the ALF group. Moreover there were no differences in the complications, return to OR and 30-day readmissions after matching in A-PLF group.

Discussion: Outpatient lumbar fusion surgery is safe in appropriately selected patients such as those who are younger, with lower BMI and have an ASA classification of I or II. Selection of patients should be on a case by case basis with careful attention individual comorbidities. Patients with multiple comorbidities or indicated for longer fusion constructs should remain as inpatients.

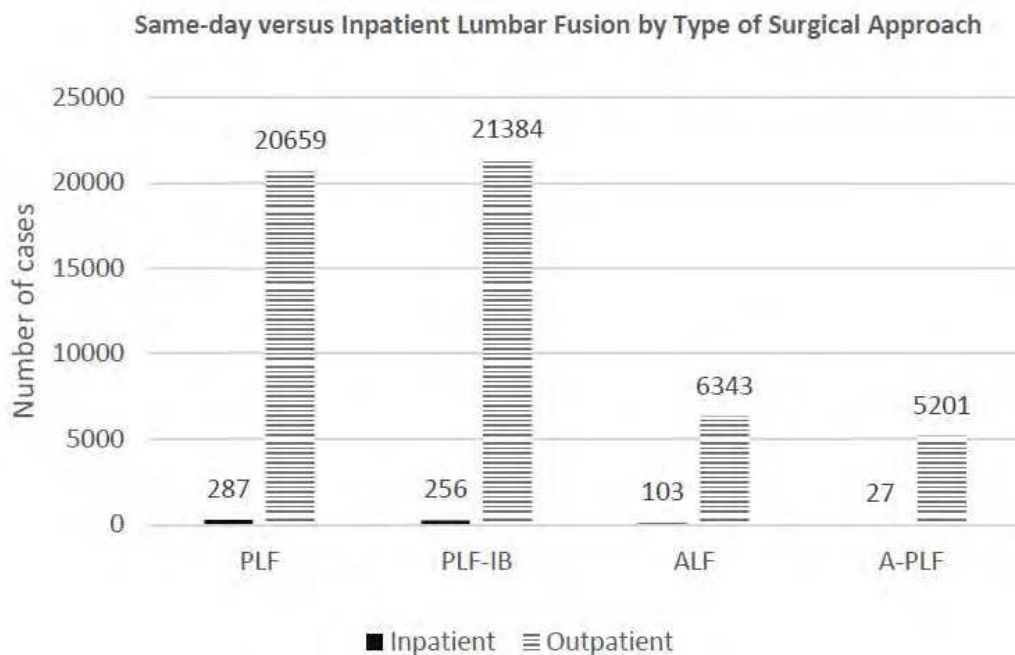


Figure: Number of cases of same-day versus inpatient lumbar fusion

Extension of distal fusion at L4 improves radiologic results for rigid curves in major thoracolumbar and lumbar adolescent idiopathic scoliosis

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Introduction: There is little information regarding surgical outcomes for different distal fusion levels (L3 versus L4) in a rigid curve with major thoracolumbar and lumbar (TL/L) adolescent idiopathic scoliosis (AIS). This study is to compare the surgical outcomes for different distal fusion levels in a rigid curve with major TL/L AIS using rod derotation (RD) with direct vertebral rotation (DVR) following pedicle screw instrumentation (PSI)

Methods: AIS patients in rigid curve with major TL/L curves (n=28) treated by PSI with RD and DVR and with a minimum 2-year follow-up were divided into L3 and L4 groups according to the lowest instrumented vertebra (LIV).

Results: Operative time, blood loss, and follow-up period did not significantly differ between groups. There was no significant difference in TL/L curve between the L3 and L4 groups either postoperatively ($P = 0.162$) or at the last follow-up ($P = 0.952$). Additionally, there were no significant differences in thoracic (minor) and compensatory (caudal) curves postoperatively (thoracic curve: $P = 0.426$, compensatory curve: $P = 0.762$) or at the last follow-up (thoracic curve: $P = 0.620$, compensatory curve: $P = 0.562$). The overall prevalence of unsatisfactory results was 42.9% (12/28 patients); the prevalence of unsatisfactory results was 61.1% (11/18) in the L3 group and 10% (1/10) in the L4 group, which was significantly different ($P < 0.05$).

Discussion: Unsatisfactory results occurred more often in the L3 group than in the L4 group, and unsatisfactory results had significant influence on progression of TL/L and distal compensatory curves. Such progression was closely correlated with deteriorating LIV disc angle in the L3 group. Therefore, if the curve is rigid, LIV should be extended to L4 to avoid the adding-on phenomenon in the treatment of major TL/L AIS using RD with DVR following PSI.

Ballon kyphoplasty combined with Minimally invasive percutaneous pedicle screw fixation in the surgical treatment of osteoporotic vertebral fracture.

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Purpose: Percutaneous vertebroplasty (Ballon Kyphoplasty; BKP) for osteoporotic vertebral fracture (OVF) accompanied with a vertebral endplate injury or a large intravertebral cleft occasionally allows early adjacent vertebral body fractures and cement migration may be occurred. It may have caused a poor clinical result. The purpose of this study is to investigate its usefulness by simultaneously using BKP and percutaneous pedicle screw (PPS) for cases where there is concern about adjacent vertebral fracture and cement migration after BKP.

Methods: The subjects were eleven cases in which BKP and PPS were concurrently used for the thoracolumbar OVF from July 2017 to October 2018. All women have a mean age of 78.9 years, and the mean postoperative observation period is 30.7 weeks. In preoperative diagnostic imaging, all cases had large clefts or end plate injury in fractured vertebral bodies. For these cases, BKP and PPS were performed for the first period. After surgical treatment, a Damen corset or rigid corset was used until bone fusion was obtained, and in principle PTH preparation was administered as a treatment for osteoporosis. The following variables were examined in this study: the period from injury to surgery, operation time, intraoperative blood loss, cement injection volume, fracture vertebral body wedge angle before and after surgery, preoperative Bone mineral density (BMD), and complications.

Result: The mean period from injury to operation was 9.7 weeks, the mean operation time was 71.1 minutes, the mean intraoperative blood loss was 28.8 g, and the mean cement injection volume was 6.7 mL. The preoperative fracture vertebral body wedge angle was 18.9 ° on average at forward bending, 8.2 ° on average at backward bending, and 10.7 ° on average of difference in front-back bending. Postoperative fractured vertebral body wedge angle was found to be 4.5 ° on average immediately after surgery and 5 ° on average at final follow-up observation, and almost no correction loss was observed. Complications were confirmed in two cases with inferior endplate injury adjacent to BKP level, and PPS backout in 1 case, but follow-up observation was possible without additional surgery.

Discussion: The concept of this method (BKP + PPS) is to reduce the stress on adjacent vertebral bodies. In addition, this method also has the effect of preventing the migration of cement within the vertebral body by the stabilization of upper and lower vertebral bodies with PPS. The operation time, the amount of bleeding is small, it is minimally invasive to the elderly, the short term outcome is good. BKP + PPS is considered to be a useful surgical option.

Does the Number of Surgically Decompressed Levels in Lumbar Spinal Stenosis Patients “Predict” Postoperative Clinical Outcomes?

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Introduction: Stability following multi-level decompressive laminectomy without fusion has been debated using *in vitro* biomechanical and radiographic models. However, there is a lack of information regarding *clinical* outcomes for these patients. Assessing patients with lumbar spinal stenosis, the goal of this study was to determine if clinical outcomes varied between those patients who underwent single-level decompression surgery to those with three or more decompressed levels.

Methods: We performed a retrospective cohort analysis of consecutive patients who underwent a primary lumbar laminectomy between 2009 and 2015 by one of two senior orthopaedic spine surgeons for lumbar spinal stenosis. Patients were divided into two groups based on the number of decompression levels: single-level or three or more levels. Patients received either a single-level or multiple levels of decompression based on the distribution of their symptoms and the degree of stenosis on advanced imaging. Patients were excluded from analysis if they were under 18 years of age at the time of surgery, had unstable or high-grade spondylolisthesis, if they had undergone a previous lumbar surgical procedure, or presented with an isolated herniated nucleus pulposus without underlying stenosis. Demographic information was collected for all patients, including: age, sex, body mass index, diabetes, smoking status, and American Society of Anesthesiologists (ASA) score. Patient reported outcomes were obtained in the form of Oswestry Disability Index (ODI) scores, Visual Analog Scales (VAS) scores for the back and leg, 12-Item Short Form Mental and Physical Survey (SF-12) scores, and the Veterans Rand 12-Item Health Mental and Physical Survey (VR-12) scores.

Results: Overall, 138 consecutive patients were assessed, of which 106 underwent a single-level, and 32 underwent a three or more level laminectomy. The average age of all patients was 54.3 ± 16.3 years. Mean follow-up was 24.2 months. There were no significant differences in the pre-operative VAS-back, VAS-leg or ODI scores between the single-level laminectomy and three or more level laminectomy groups (Table 1). Both groups of patients experienced significant improvements in these clinical outcomes post-operatively with no clinically significant difference in the degree of improvement. There was no difference in the likelihood for reoperation following three or more levels of decompression (6.45% multilevel vs. 9.43% for single level, OR=4.46, $p=0.234$). Specifically, four single-level patients (3.8%) and two of the three or more level (6.2%) patients underwent a revision to a posterior spinal fusion at the levels that were originally decompressed at an average of 24 months (single-level 22.1 months; 3+ levels 25.4 months) after the original surgery.

Discussion: Despite the concern for instability, patients undergoing decompression of three or more levels present with similar post-operative outcomes to those who undergo a single-level decompression for lumbar spinal stenosis. Under specific clinical and radiographic criteria, a multi-level decompression of three or more levels may be a safe and effective procedure with acceptable outcomes at two years after surgery.

Table 1. Comparing clinical outcomes

	One level	3+ Levels	All patients	Multivariate Analysis	
				Beta	p-value
Preoperative					
VAS back	7.3 ± 2.9	6.9 ± 2.6	6.7 ± 3.0	-0.54	0.590
VAS leg	7.0 ± 2.8	5.1 ± 3.4	6.1 ± 3.3	-2.02	0.066
ODI	49.6 ± 17.6	40.7 ± 8.0	45.4 ± 18.1	-8.03	0.117
SF-12 mental	53.4 ± 10.2	54.2 ± 4.6	53.7 ± 8.9	2.56	0.664
SF-12 physical	33.4 ± 11.4	30.4 ± 14.7	34.8 ± 11.5	5.97	0.411
VR-12 mental	53.9 ± 10.6	53.7 ± 0.9	55.1 ± 9.1	0.83	0.906
VR-12 physical	34.9 ± 12.6	29.4 ± 18.4	36.5 ± 12.4	4.05	0.678
Final					
VAS back	2.7 ± 2.6	3.2 ± 2.7	3.2 ± 2.8	0.75	0.390
VAS leg	2.2 ± 2.5	2.9 ± 3.5	2.7 ± 3.0	0.18	0.849
ODI	22.3 ± 19.1	23.0 ± 19.8	24.6 ± 19.7	-2.21	0.689
SF-12 mental	52.5 ± 11.1	53.9 ± 8.2	53.1 ± 9.6	1.99	0.700
SF-12 physical	38.7 ± 13.8	33.5 ± 12.3	38.6 ± 13.0	-1.48	0.807
VR-12 mental	55.1 ± 11.7	54.6 ± 7.6	55.5 ± 10.4	1.28	0.830
VR-12 physical	41.8 ± 14.5	35.7 ± 14.3	41.1 ± 13.6	-4.28	0.531
Change preoperative to final					
VAS back	5.1 ± 3.4	4.3 ± 2.8	4.4 ± 3.6	-1.60	0.197
VAS leg	5.2 ± 3.8	3.2 ± 4.0	3.9 ± 4.5	-1.95	0.226
ODI	31.4 ± 21.5	22.6 ± 15.4	25.9 ± 21.8	-6.56	0.346
SF-12 mental	2.1 ± 9.8	7.58	1.2 ± 8.6	8.08	0.491
SF-12 physical	-8.3 ± 13.6	-6.95	-7.9 ± 13.0	-2.94	0.867
VR-12 mental	0.5 ± 11.1	6.58	0.2 ± 9.1	5.52	0.660
VR-12 physical	-10.5 ± 14.4	-8.82	-8.8 ± 13.6	-2.46	0.890
Reoperation	9.43%	6.45%	7.62%	4.46	0.234

Clinical result of kyphoscoliosis comparison between degenerative kyphoscoliosis and kyphoscoliosis with osteoporotic vertebral fracture

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Introduction: Despite the increase in number of surgery for kyphoscoliosis, some cases are difficult to treat. The purpose of this study is to compare degenerative kyphoscoliosis without osteoporotic vertebral fracture (OVF) and kyphoscoliosis with OVF and to clarify features and problems.

Materials and Methods: This study involved 54 patients who underwent surgery for kyphoscoliosis with a minimum 6-month follow-up. Patients were divided to OVF group or degenerative without OVF (D group). The analysis of age, blood loss, operation time, X-ray parameters, JOABPEQ, comorbidity, surgical methods, and complications were performed.

Results: There were no significant differences between D and OVF group in age, blood loss, operation time, JOABPEQ and X-ray parameters. CCI (Charlson Comorbidity Index) of group D and OVF were 0.6 ± 0.7 and 1.3 ± 1.4 respectively, indicating significantly poor condition in OVF group. Delirium was significantly more evident with 7% in D group and 41% in OVF group and significantly higher number of patients underwent more than grade 3 osteotomy in OVF group (45%) than in D group (9%). PJK occurred in 21% of D group and 55% of OVF group. Additionally rod breakage and screw-back out occurred in 9% of D group and 30% of OVF group.

Discussion: Perioperative and implant complication rates were significantly higher in OVF group than D group. Although the limitation is that the osteoporosis can not be evaluated since bone mineral density measurement was not performed in all cases in our study, it was considered that complications were caused by high CCI and severe surgical intervention is critical in operations of kyphoscoliosis with OVF.

An Analysis for safety insertion of sacral alar-iliac screw on the fluoroscopy, using three-dimensional analyzing software

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Introduction: S2 alar-iliac (SAI) screws have been common anchor recently in cases of lumbosacral fixation. The screw deviation to anterior or caudal direction has potential risk for major vessel injury, internal iliac artery or superior gluteal artery. Therefore, use of navigation system or intraoperative CT is recommended to avoid such injuries. On the fluoroscopy, the tear-drop-view has been recommended to confirm adequate screw insertion. The flaw of tear-drop-view is difficult to set the screws and review the fluoroscopy simultaneously due to the setting of the fluoroscopy unless special surgical table. The pelvic inlet view is another recommended methods, however, no study have investigated how the beam should be tilted. The purpose of this study was to investigate the condition of the fluoroscopy which could provide accurate information of SAI screw deviation under anteroposterior or lateral view using three-dimensional analyzing software.

Methods: A total of 50 patients who were over 40 years old and taken abdominal thin-slice CT in the outpatient clinic of internal medicine were included in this study. The obtained CT images were reconstructed using 3D analyzing software for simulation of spinal screws. Ideal SAI screws (7.0mm *80mm) were individually set on three-dimensional analyzing software from entry point of 1 mm inferior and 1 mm lateral to the S1 dorsal foramen. Anterior or caudal deviated screws were defined as deviated half thread of screw by rotation anteriorly or caudally from the entry point of the ideal screw. The conditions which provide proper recognition for the screw deviation were investigated on lateral view and anteroposterior view with beam tilted caudally using the raysum methods in order to virtualize fluoroscopic images.

Results: The anterior deviated screws were not recognized on lateral view in all cases, but recognized on pelvic inlet view (Figure: arrow) in all cases. The anterior deviated screw were recognized in specific range of beam tilted angle from S1 slope: $32.8 \pm 12.1 - 101.8 \pm 15.0^\circ$. If the beam tilt angle set by 60° , all anterior deviated screw, except one case, were recognized. The recognizable beam tilt angle ranges for caudal deviated screw were $15.9 \pm 12.0 - 46.6 \pm 11.4^\circ$. However, 21% of screws were not able to be recognized in any inlet angle.

Discussion: The safety margins of SAI screws were typically smaller in anterior direction than in caudal direction. Intraoperative fluoroscopic setting was recommended 60° inlet from S1 slope to avoid anterior screw deviation in cases which fail to obtain clear images by the tear-drop-view. The lateral view was recommended to make sure that SAI screw was not deviated caudally.



Risk factors for reoperation after decompression for lumbar spinal stenosis in patients with diffuse idiopathic skeletal hyperostosis extended to lumbar segment

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Introduction: Diffuse idiopathic skeletal hyperostosis (DISH) begins most frequently in the lower thoracic spinal segments and extends to the upper thoracic segments and lumbar spine.

DISH which extended to lumbar segment (L-DISH) has been reported as an independent risk factor for reoperation after surgery for lumbar spinal stenosis (LSS) (Yamada K. Spine 2018). The increased mechanical loading to lower non-ossified segments in patients with L-DISH might be the cause of increasing revision surgery, however, it is still unclear about characteristics of poor surgical outcome in patients with L-DISH. The purpose of this study was to investigate risk factor for reoperation in patients with L-DISH in detail by the minimum 5 years follow-up of the decompression surgery.

Methods: We have performed conventional medial facetectomy as decompression-alone procedure for LSS. We investigated 489 responders to a postoperative postal survey out of 1150 consecutive patients who underwent decompression-alone procedure for LSS between 2002 and 2010. The survey included questions about reoperations performed at another hospital and the patient-reported outcomes. This study included 57 patients with L-DISH (male 48 cases, mean age 69.5 years). DISH was evaluated by preoperative standing whole-spine radiographs. Reoperations were defined as revision surgery at same level of the index procedures, and excluded revision surgery for postoperative hematomas or infections. Univariate and multiple logistic regression analysis were performed to investigate predictor of reoperation. Explanatory variables were investigated by demographics, parameters by preoperative plain radiographs, segmental intervertebral cleft and ≥ 2 mm of facet opening by preoperative CT, and disc degeneration (Pfirman grade) and endplate change (Modic type) from preoperative MRI. Influences of DISH were evaluated by the number of vertebrae involved by DISH and sum of Mata's grade of lumbar level as the evaluation for ossification in segments even without complete ossification.

Results: The mean number of vertebrae involved by DISH was 8.8. The sum of Mata's grade of lumbar segment was mean 4.7. A total of 10 patients (17.5%) and 11 segments underwent reoperation at the index levels during mean 9.2 years follow-up. Univariate analysis indicated significant association with reoperation in surgical period (surgery ≥ 10 years ago, $p=0.012$), ≥ 10 degrees of segmental sagittal ROM by dynamic radiograph ($p=0.014$), and facet opening by CT ($p=0.009$). Independent risk factors for reoperation by multivariate analysis were surgical period and facet opening (adjusted odds ratio 17.4, $p=0.013$).

Discussion: Morphologic assessments of DISH were not associated with reoperation, but facet opening by CT was associated. Facet opening was reported as a predictor of segmental lumbar instability (Hasegawa K. JNS 2010). Patients with L-DISH frequently have some ossification in lower lumbar segments, and difficult to assess segmental instability by dynamic radiographs. Facet opening might be useful parameter to assess instability which leads reoperation especially in rigid lumbar spine like L-DISH. In conclusions, facet opening by CT was the independent risk factor for reoperation at index levels after decompression for LSS in patients with L-DISH.

A CSORN study of spinopelvic sagittal alignment after operative treatment for lumbar degenerative spondylolisthesis

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Introduction: The object of this study was to evaluate the change in lumbar lordosis (LL) and sagittal vertical axis (SVA) from the operative treatment of patients with lumbar degenerative spondylolisthesis.

Methods: Consecutive patients at nine spinal centres were prospectively enrolled in a study evaluating the assessment and management of lumbar degenerative spondylolisthesis patients using the Canadian Spine Outcomes and Research Network (CSORN) database. Pelvic parameters included sacral slope, pelvic tilt, pelvic incidence (PI), sagittal vertical axis (SVA), lumbar lordosis (LL), and thoracic kyphosis. Primary outcome was change in LL and SVA at 6-18 weeks after surgery. Secondary objectives evaluated the effects of preoperative imbalance (SVA \geq 50mm and LL < PI-9°) and surgery type (decompression, fusion or interbody fusion) on postoperative spinopelvic alignment.

Results: A total of 341 patients were enrolled between January 2015 and September 2018. Cases not yet receiving surgery or with no radiographic measures were excluded leaving 195 patients. The average age was 65.7 years; most were female (60.0%); had grade I spondylolisthesis (73%) and had a single operated level (83%). Missing data ranged from 22% to 36%. Mean preoperative LL was 46.1 \pm 13.5°, PI was 56.7 \pm 13.1°, PT was 23.9 \pm 9.5°, and SVA was 31.8 \pm 40.5 mm (mean \pm SD). At 6-18 weeks, the mean LL increased by 2.3 \pm 10.9° (n=176; P<0.001) and SVA decreased by -8.5 \pm 33.5 mm (n=117; P=0.003). All other measures did not differ after surgery. Preoperatively, 52% had PI to LL mismatch (LL < PI-9°) and 26% had significant sagittal imbalance (SVA \geq 50mm). Postoperatively, 41% had LL < PI-9° and 19% had SVA \geq 50mm. Of the total cohort, 7.3% developed denovo PI to LL mismatch (LL < PI-9°), 33.9% had persistence of a LL < PI-9°. Mal-alignment developed in 3.4% (SVA \geq 50mm) and 15.4% with SVA \geq 50mm pre-operatively remained imbalanced. Surgery type had a similar effect on spinopelvic alignment (P<0.05 for all parameters).

Discussion: Mean SVA and LL improved after surgery. Most patients that had spinopelvic sagittal balance prior to surgery maintained balance.

Surgical outcomes of percutaneous endoscopic discectomy for adolescent lumbar disc herniation

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Introduction: Most lumbar disc herniation in adolescent patients with persistent low back and neurological symptoms do not respond to noninvasive treatment and require operative treatment. The disc herniation in adolescents should be treated with minimally invasive procedures, because long-term results of disc surgery depend not only on the disc disease itself but also on the degree of surgical trauma. The aim of this study is to evaluate the efficacy and safety of percutaneous endoscopic discectomy (PED) in the treatment of adolescent lumbar disc herniation.

Methods: We analyzed the surgical outcomes in 17 consecutive adolescent patients between 13 and 18 years of age (mean age, 16.4 years) who underwent PED for single level lumbar disc herniation at our institute from January 2012 to May 2017. PED was performed with transforaminal approach under local anesthesia and sedation. The primary outcomes were evaluated using visual analog scale (VAS) for both of the low back pain and leg pain, and the Oswestry Disability Index (ODI). As the secondary outcomes, finger to floor distance (FTFD), perioperative complication, recurrence of disc herniation, and duration of the return to sports were evaluated.

Results: Preoperative clinical symptoms were both low back pain and leg pain in 13 patients, leg pain only in 3 patients, and low back pain only in 1 patient. On MRI, all patients had contained type disc herniation. Central location of herniation was found in 11 patients, paracentral location of herniation was found in 4 patients. Mean duration of clinical symptoms was 9.4 months (range: 2-30 months). PED was performed at L4-5 on all patients. Mean follow-up duration was 7.0 months (range: 3-12 months). The mean VAS scores of low back pain and leg pain were significantly improved from 70.1mm and 55.0mm to 12.4mm and 5.3mm at 1 month, and 8.0mm and 3.1mm at 3 months follow-up ($P<0.01$). The mean ODI were significantly improved from 31.1% to 15.4% at 1 month, and 7.5% at 3 months follow-up ($P<0.01$). The mean FTFD was 33.5cm at baseline, 23.3cm at 1month, and significantly improved to 13.1cm at 3 months follow-up ($P<0.01$). No patients had durotomies, infections, vascular or nerve injuries. One patient had a recurrent disc herniation at 5 months after surgery, and improved by conservative treatment. In 10 patients who had sporting activities, all patients could return to sports mean 2.4months (range: 2-3 months) after surgery.

Discussion: Transforaminal PED achieved satisfactory results for adolescent LDH that were comparable to the results of open discectomy. The advantage of transforaminal PED, a minimal disruption of paraspinal muscular and osseo-tendinous structures, is suitable for adolescent patients. In conclusion, transforaminal PED appears to be a safe and effective intervention for adolescent LDH.

What is the role of surgery for spinal metastasis of lung cancer? - Propensity score matched analysis between surgery with radiotherapy and radiotherapy alone -

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Introduction: Although metastatic spine disease is increasing, the debate on therapeutic modality still remains due to heterogeneous primary sites and different patient's condition. In addition, molecular targeted therapy has been introduced and reported to be effective. The aim of this study is to evaluate the efficacies of surgery as well as molecular targeted therapy for spinal metastasis of lung adenocarcinoma.

Methods: Twenty-two patients treated with surgery and radiotherapy (surgery group) for lung adenocarcinoma were matched in a 1-to-1 format with 94 patients undergoing radiotherapy alone (only RT group) by age, sex, Tokuhashi score, spinal instability neoplastic score (SINS) using propensity score. Eastern Cooperative Oncology Group (ECOG) - performance status (PS), Frankel grade and the possibility of ambulation were compared. In subgroup analysis, clinical outcomes and survival were evaluated along with molecular targeted therapy for mutations of epidermal growth factor receptor (EGFR) or anaplastic lymphoma kinase (ALK).

Results: The patients with better ECOG-PS (0, 1, 2) and Frankel grade (D, E) before treatment were significantly greater in the only RT group (95.5% vs. 72.7%, $p=0.039$, respectively). However, the number of the patients unable to ambulate was significantly greater in the surgery group (27.3% vs. 4.5%, $p=0.039$). Although significant improvements of Frankel grade (22.7% vs. 0%, $p=0.018$) and ambulation (18.2% vs. 0%, $p=0.036$) were observed in the surgery group, survival was not significantly different between the two groups ($p=0.790$). Longer survival and significant improvement of ECOG-PS were observed in patients with mutations of EGFR or ALK (21.0 ± 2.8 vs. 5.0 ± 1.5 months, $p=0.042$ for survival; 35.3% vs. 7.4%, $p=0.02$ for ECOG-PS).

Discussion: Surgery combined with radiotherapy significantly improved ambulation and Frankel grade compared with radiotherapy alone, while molecular targeted therapy significantly improved the performance status and survival rate. In metastatic lung adenocarcinoma, patients with neurologic deterioration should be considered for surgery combined with radiotherapy, especially in patients with mutations of EGFR or ALK expected to have longer life expectancy.

Stepwise local anesthesia for percutaneous endoscopic interlaminar discectomy: technique strategy and clinical outcomes

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Introduction: Different from percutaneous endoscopic transforaminal discectomy, endoscopic interlaminar discectomy is typically performed under general anesthesia. This is mainly due to suboptimal pain control under the conventional local anesthesia. While local anesthesia has natural advantages in endoscopic surgery, the strategy of local anesthesia deserves to be improved to have better intraoperative pain control in interlaminar endoscopy. The purpose of this study is to develop a stepwise approach of local anesthesia for percutaneous endoscopic interlaminar discectomy and evaluate its efficacy and adverse events.

Methods: A stepwise technique of local anesthesia was used to perform local anesthesia in interlaminar endoscopic discectomy, which includes 3 steps: conventional local anesthesia from the skin to the laminae, epidural injection and nerve root block. From June 2015 to May 2017, consecutive patients diagnosed with L5-S1 disc herniation and treated with interlaminar endoscopic discectomy were enrolled into the current study. Local anesthesia or general anesthesia was used mainly based on the patient's preference. The anesthetic effectiveness of stepwise local anesthesia was assessed using intraoperative visual rating scores (VRS) and adverse events were recorded. The operation time, hospital stay, anesthesia cost and surgical outcomes were compared between local anesthesia and general anesthesia.

Results: Among 98 patients included in the current study, 48 patients received stepwise local anesthesia and the other 50 received general anesthesia. Among those used stepwise local anesthesia, 40 (83.3%) patients rated anesthetic effectiveness as excellent, 7 (14.6%) as good, and 1 (2.1%) as poor. Nine patients had minor complications that may associate with local anesthesia, including dyspnea, temporary paresis of the legs, and worsened dysesthesia and numbness in the legs. After interlaminar endoscopic discectomy, the patient's leg pain significantly relieved in both groups. The operation time, hospital stay and anesthesia cost were statistically significantly less in patients who used local anesthesia than those underwent general anesthesia: The stepwise local anesthesia obtained satisfactory pain control in interlaminar endoscopic lumbar discectomy. **Discussion :** Such a modified local anesthesia is safe, cost-efficient, easy to perform, and can avoid disadvantages of general anesthesia and therefore, can be used as an alternative anesthesia in interlaminar endoscopic discectomy.

Return to Activities and Discontinuation of Narcotics after Minimally Invasive Spine Surgery

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Introduction: As chronic low back pain incurs high costs for both patients and the society as a whole, it is imperative that expectations are appropriately established in regards to results and recovery after spine surgery. Recent studies have shown that utilizing minimally invasive techniques may potentially be more cost-effective than utilizing open techniques. This study compares the time to return to activities, namely return to work and return to driving, and time to discontinuation of narcotics, between MI single-level lumbar decompression and MI single-level lumbar fusion.

Methods: This is a retrospective, single academic center, single surgeon cohort study. The present analyses included patients who had undergone elective MI single-level lumbar decompression or fusion between April 2017 and August 2018. Patients who had undergone non-elective lumbar spine surgeries, or surgeries for traumas, tumors or fractures were excluded. To be included, patients had to have been driving or working pre-operatively, or had to have been administered narcotics post-operatively. Patient demographics, including age, sex, BMI, race, ASA class, and insurance type, were collected pre-operatively and were obtained from electronic medical records. The number of days it took for patients to return to the activity or to discontinue narcotics was calculated. Independent samples median t-tests and independent samples Mann-Whitney U-tests were conducted to assess for differences between the two procedures. The percentage of patients who returned to activities/discontinued narcotics at various time-points (15, 30, 60, 90, 120, and 150 days) were also calculated, and chi2-tests were conducted to compare those percentages between the two surgeries.

Results: In return to driving analysis, 36 patients underwent MI single-level decompression (median days to return to driving = 14 days), and 41 patients underwent MI single-level lumbar fusion (median = 16 days). In return to work analysis, 38 patients underwent decompression (median days to return to work = 16.5 days), and 31 patients underwent fusion (median = 14 days). In discontinuation of narcotics analysis, 41 patients underwent decompression (median days to discontinue narcotics = 7 days), and 44 patients underwent MI fusion (median = 11.5 days). For all three measures, there were no significant differences in demographic variables between those who underwent decompression and those who underwent fusion procedures. There were no statistically significant differences in the median number of days to return to driving, return to work, or discontinuation of narcotics, or in the distributions of those values. Additionally, for all three measures, there were no statistically significant differences in the percentages of patients returning to the activity/discontinuing narcotics at any follow-up time-point between the two procedures.

Discussion: Return to activities and discontinuing narcotics after spine surgery are important aspects of patient expectations for recovery. It is well known that open lumbar fusion patients take significantly longer to return to activities and discontinue narcotics compared to open lumbar decompression patients. This study shows that utilizing minimally invasive methods for fusion may allow fusion patients to recover faster, and hence potentially eliminate the difference seen in open techniques.

Relationship between global sagittal alignment and surgical outcomes after minimally invasive posterior decompression in patients with lumbar spinal stenosis

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Introduction: Patients with lumbar spinal stenosis (LSS) accompanied by intermittent claudication have forward-bending posture during standing and walking because the spinal canal expands. However, little is known about the changes in alignment after decompressive surgery, and the impact of sagittal spinopelvic alignment on clinical outcomes has not been specifically investigated. The purpose of the present study is to evaluate the relationship between spinal sagittal alignment and clinical results after minimally invasive laminotomy for LSS.

Methods: A total of 72 cases was reviewed, and mean age was 69.5 years. The minimum duration of clinical and radiological follow-up was 12 months. All patients underwent a tubular surgery with assistance of endoscopic technique. Radiological parameters and clinical outcomes were compared between patients with a preoperative sagittal vertical axis (SVA) > 50mm (group A: n=49) and patients with a preoperative SVA < 50mm (group B: n=23). Clinical outcomes were assessed according to Japanese Orthopaedic Association (JOA) and visual analog scale (VAS) scores for back and leg pain, and Roland-Morris Disability Questionnaire (RDQ).

Results: SVA and lumbar lordosis (LL) were significantly improved after laminotomy in B group, respectively (SVA: preop 78.6mm, postop 54.2mm, $p < 0.05$, LL: preop 27.8°, postop 35.7°, $p < 0.05$). In 11 cases (48%) of B group, the global sagittal balance improved to normal alignment. At final follow-up evaluation, no significant differences between two groups were found for JOA score and RDQ. The VAS score for low back pain is significantly higher in patients with the presence of anterior translation of SVA after surgery compared with those with the improvement of SVA (4.8 ± 1.8 v.s 3.1 ± 1.9 , $p < 0.05$).

Discussion: Lumbar posterior decompression can induce an improvement in global spinal sagittal alignment in approximately half of the LSS cases with anterior translation. Furthermore, the presence of anterior translation of SVA after decompressive surgery may be caused for low back pain in patients with LSS.

Effect of indirect decompression and influence of adjacent segments after lateral lumbar interbody fusion for lumbar degenerative spondylolisthesis

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Purpose: Recently, lateral lumbar interbody fusion (LLIF) such as XLIF or OLIF with posterior fixation has been performed in patients with lumbar degenerative spondylolisthesis as minimally invasive surgical technique alternative to the conventional posterior procedures. Some investigators reported postoperative good clinical and radiographic results after the procedure without posterior decompression. But the postoperative changes in the dural sac (DS), the ligamentum flavum (LF) and the intervertebral disc at the fusion site and adjacent intervertebral disc level has not been reported. The purpose of this study was to evaluate changes of the DS, the LF and the disc after LLIF with posterior fixation over time.

Materials and Methods: The study group included forty patients (25 female, 15 male) with the mean age of 67.9 years at the time of surgery. All patients underwent fusion surgery using OLIF with posterior percutaneous pedicle screw (PPS) fixation without posterior decompression for lumbar degenerative spondylolisthesis. They were followed for more than two years after surgery. The cross-sectional area (CSA) of the DS, the LF thickness and disc degeneration evaluated using the Pfirrmann grading system at the fusion site, at the first and second cephalad disc level from the fusion disc level were measured over time using T2-weighted magnetic resonance imaging (MRI). Statistical analysis of changes in each parameter was performed using the paired t-test and Spearman's rank correlation coefficient, and $p < 0.05$ was considered statistically significant.

Results: The average CSA of the DS at fusion site was 64.5/100.8/114.7/118.3 cm² (before surgery/three months after surgery/one year after surgery/two years after surgery), and it had significantly increased during two years after surgery. The average LF thickness at fusion site was 4.2/3.3/3.0/2.9 mm, and it had significantly decreased during two years after surgery. The average CSA of the DS at first cephalad adjacent disc level was not a significant change although it had showed a trend toward decreased over time. The average LF thickness at first cephalad adjacent disc level were 3.9/4.0/4.1/4.2 mm, and it had significantly increased during two years after surgery. The average CSA of the DS and the average LF thickness at second cephalad disc level did not change over time. There was no relationship between disc degeneration and LF thickness at first and second cephalad adjacent disc level.

Discussion and Conclusion: In the current study, indirect decompression by correction of spondylolisthesis using ligamentotaxis and acquiring the height of the intervertebral disc by inserting OLIF cage provided significant enlargement of the CSA of the DS and thinning of the LF at fusion site compare before and after surgery, and spinal stability by fusion surgery using OLIF with PPS fixation provided further significant enlargement of the CSA of the DS and further thinning of the LF by continuous atrophy at the fusion site after surgery over time. But it was observed that the LF thickness increased at first cephalad adjacent disc level after surgery over time, and there is a possibility that adjacent segment degeneration may occur over time. Therefore, further evaluation with long follow-ups will be necessary.

Trends in Opioid Usage Two Years Following Thoracolumbar Spine Surgery

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Introduction: Opioid overdose results in 116 deaths per day in the United States (1). It is estimated that 21-29% of patients misused opioids prescribed for chronic pain (2). The Canadian Orthopedic Association released a statement that stressed the importance of timely access to musculoskeletal care in order address the underlying causes of pain and curb the epidemic of opioid misuse. This study aims to evaluate the effect of undergoing surgery on patient opioid usage. We hypothesize that patients who undergo surgery to address their underlying spine pathology will reduce their opioid usage and improve their quality of life.

Methods: We conducted a retrospective review of prospectively collected data within the Canadian Spine Outcomes and Research Network (CSORN) database for patients who underwent thoracolumbar procedures by the McGill Spine group. All adult patients who underwent thoracolumbar procedures and completed their 2 year follow up were included. Fisher exact test was used to analyze categorical variables. ANOVA was used to analyze continuous variable and significance was $p < 0.05$.

Results: Forty-five patients met the inclusion criteria. Twenty-nine patients reported that they did not use opioids on initial assessment. Of the 29 patients who were not using opioids at initial assessment, one patient reported usage at two-year follow-up. Of the 16 patients who were using opioids at initial assessment, seven had completely stopped all usage representing a 37.5 % reduction in the number of patients using opioids ($P 0.0016$). Opioid users reported a reduction of 2.69 ± 2.09 , 2.94 ± 3.42 and 18.50 ± 15.28 points while non-opioid users reported a reduction of 4.17 ± 3.12 , 3.62 ± 3.94 and 17.55 ± 18.91 points on the back-pain scale, leg pain scale and Oswestry Disability Index respectively. There were no statistically significant differences in these measures between the groups.

Discussion: Chronic pain and opioid misuse continue to be significant challenges that are affecting the quality of life of patients. This study highlights the significant impact that addressing patients' underlying pathology can have on quality of life and opioid usage.

- 1) Center for Behavioral Health Statistics and Quality. 2016 National Survey on Drug Use and Health: Detailed Tables. Substance Abuse and Mental Health Services Administration, Rockville, MD; 2017.
- 2) Vowles KE, McEntee ML, Julnes PS, Frohe T, Ney JP, van der Goes DN. Rates of opioid misuse, abuse, and addiction in chronic pain: a systematic review and data synthesis. *Pain*. 2015;156(4):569-576. doi:10.1097/01.j.pain.0000460357.01998.f1.

Impact of Body Mass Index on Adjacent Segment Disease after Lumbar Fusion for Degenerative Spine Disease

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Introduction: Adjacent segment disease (ASD) is an important complication following fusion of degenerative lumbar spines. However, the role of body mass index (BMI) in ASD has been less addressed. We aimed to examine the relationship between BMI and ASD after lumbar fusion for degenerative spine diseases.

Methods: For this retrospective study, we enrolled 190 patients undergoing lumbar fusion surgery for degeneration. BMI at admission was documented. ASD was defined by integration of the clinical presentations and radiographic criteria based on the morphology of the dural sac on magnetic resonance images.

Results: ASD was identified in 13 of the 190 patients, accounting for 6.8%. The interval between surgery and diagnosis as ASD ranged from 21-66 months. Five of the 13 patients required subsequent surgical intervention for clinically relevant ASD. In the logistic regression model, BMI was a risk factor for ASD after lumbar fusion for degenerative spine diseases (odds ratio, 95% confidence interval = 1.68, 1.27-2.21; $p < 0.001$). Any increase of one mean value in BMI would increase the ASD rate by 67.6%. The patients were subdivided into 2 groups based on BMI, and up to 11.9% of patients with $BMI \geq 25 \text{ kg/m}^2$ were diagnosed as ASD at the last follow-up.

Discussion: BMI is a risk factor for ASD in patients undergoing lumbar fusion for degenerative spine diseases. Since BMI is clinically objective and modifiable, controlling body weight before or after operation may provide opportunities to reduce the rate of ASD and improve the outcome of fusion surgery.

Long-term outcomes following lumbar microendoscopic discectomy and microendoscopic decompression: Minimum 10-year follow-up evaluation performed using a patient-based outcome measure

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Introduction: The purpose of this study was to assess the minimum 10-year outcomes following microendoscopic discectomy for lumbar disc herniation (MEDH) and microendoscopic decompression for lumbar spinal stenosis (MEDS).

Methods: Seventy-six patients were classified into three groups: DH group (33 patients underwent MEDH); S group (23 patients underwent MEDS); and DS group (20 degenerative spondylolisthesis [DS] patients underwent MEDS). All 76 operations were performed by the same surgeon. The follow-up rate was 50.3% (76/151). Seventy-five patients were excluded from the study: 40 patients were lost to follow-up within 10 years after their initial operations, 23 patients were interviewed by telephone but did not attend our clinic to confirm other lesions at the most recent follow-up evaluation, and 12 patients had lost their records of preoperative evaluations. Fifteen patients (7 patients in the DH group and 4 patients in the S and DS groups) required reoperations within 10 years after their initial operations, and their clinical outcome evaluations were done just before the reoperations. Paired t-test was used to compare the preoperative and postoperative visual analogue scale (VAS) scores. The results were statistically compared using Scheffé's F test for differences among the DH, S, and DS groups. The degrees of improvement (DOIs) on the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ) and the intensities of improvement (IOIs) on VAS at the first follow-up evaluation (mean, 12 months after operation) and at the most recent follow-up evaluation (mean, 126 months) of the DH group were statistically compared by paired t-test. DOIs and IOIs at the most recent follow-up evaluation of the S group (mean, 126 months) and DS group (mean, 125 months) were statistically compared by unpaired t-test.

Results: The effectiveness rates of pain-related disorders, gait disturbance, and social life disturbance in JOABPEQ were almost equally high in all three groups (Fig. 1). Significant decreases in low back pain, leg pain, and leg numbness, as measured by VAS, were noted at the most recent follow-up evaluation in the DH, S, and DS groups. Statistical comparisons of the DOIs in all five functional scores and IOIs in low back pain, leg pain, and leg numbness showed no significant differences among the DH, S, and DS groups (Figs. 2 and 3). No significant differences were observed between the first follow-up evaluation and the most recent follow-up evaluation concerning the DOIs and IOIs of the DH group, and between the S and DS groups concerning the DOIs and IOIs at the most recent follow-up evaluation (Figs. 2 and 3).

Discussion: Clinical 1-year outcomes of MEDH were thought to be maintained for over 10 years, and MEDS is a useful, minimally invasive surgical procedure that leads to the same clinical long-term outcomes with DS as without DS. Moreover, MEDH and MEDS were almost equally effective for over 10 years not only in improving low back pain, leg pain and numbness, but also especially in improving pain-related disorders, gait disturbance, and social life disturbance by detailed quality of life assessment using JOABPEQ.

Fig. 1. Effectiveness rates in the DH, S, and DS groups

	DH group (n=33)	S group (n=23)	DS group (n=20)
Pain-related disorders	71.0%	77.3%	70.6%
Lumbar spine dysfunction	60.6%	57.1%	60.0%
Gait disturbance	77.4%	73.9%	85.0%
Social life disturbance	78.8%	69.6%	70.0%
Psychological disorders	45.5%	34.8%	45.0%

If either the postoperative score increases by ≥ 20 points compared to the preoperative score or the preoperative score is < 90 and the postoperative score reaches ≥ 90 points, the operation is judged "effective."

The effectiveness rate in each group was calculated by the following formula: (number of patients judged "effective") / [(total number of patients in the group) - (number of patients with both pre- and postoperative scores ≥ 90)]

Fig. 3. Intensities of improvement (IOIs) at first and at most recent follow-up evaluation in the DH group, and IOIs in S and DS groups at most recent follow-up evaluation

	DH group (at first follow-up)	DH group (at most recent follow-up)	S group (at most recent follow-up)	DS group (at most recent follow-up)
Low back pain	14.1 \pm 38.4	21.5 \pm 38.3	20.6 \pm 38.8	30.2 \pm 34.0
Leg pain	41.3 \pm 48.5	43.0 \pm 46.8	43.5 \pm 36.7	50.2 \pm 29.0
Leg numbness	24.6 \pm 47.0	38.0 \pm 39.9	41.4 \pm 36.8	51.2 \pm 32.4

Values are expressed as mean \pm standard deviation.

Intensity of improvement (IOI) was calculated by the following formula:
preoperative score - postoperative score of VAS

Fig. 2. Degrees of improvement (DOIs) at first and at most recent follow-up evaluation in the DH group, and DOIs in S and DS groups at most recent follow-up evaluation

	DH group (at first follow-up)	DH group (at most recent follow-up)	S group (at most recent follow-up)	DS group (at most recent follow-up)
Pain-related disorders	36.4 \pm 48.0	33.8 \pm 53.0	39.1 \pm 41.4	31.4 \pm 39.2
Lumbar spine dysfunction	22.0 \pm 41.9	27.3 \pm 45.9	29.7 \pm 38.8	19.2 \pm 39.0
Gait disturbance	41.6 \pm 42.6	37.0 \pm 45.8	41.6 \pm 36.7	56.8 \pm 34.7
Social life disturbance	39.8 \pm 40.4	39.1 \pm 39.2	36.3 \pm 30.2	39.5 \pm 31.4
Psychological disorders	11.3 \pm 18.6	13.4 \pm 18.8	19.1 \pm 23.1	22.3 \pm 26.0

Values are expressed as mean \pm standard deviation.

Degree of improvement was calculated by the following formula:

postoperative score - preoperative score of JOABPEQ

A Prospective Evaluation of the Results of Bilateral Decompression Alone in Patients with Grade 1 Degenerative Spondylolisthesis

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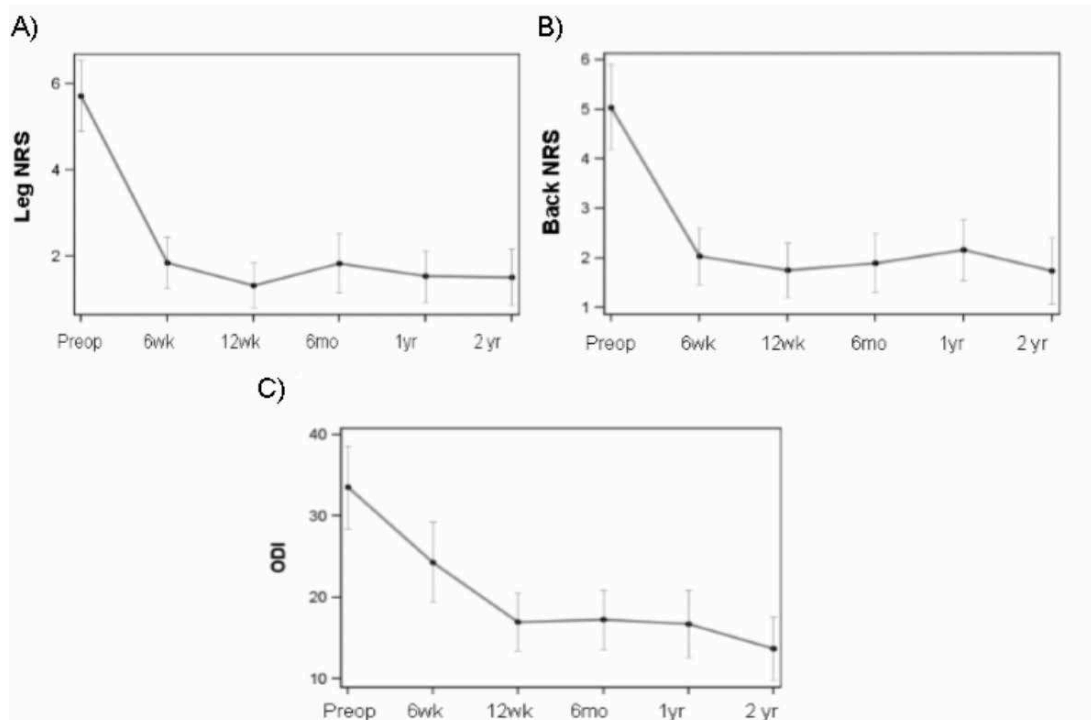
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Introduction: Degenerative spondylolisthesis with stenosis is a common source of disability in older patients. The current gold standard of treatment is decompression with instrumented fusion. However, there is controversy regarding the role of decompression alone, as fusions have been associated with higher morbidity, complication rates, and cost. Conflicting data has been presented in recent randomized controlled trials as to the relative efficacy of fusion compared to decompression alone in this patient population (Ghogawala 2004, Ghogawala 2016, Forst 2016). Previous studies of decompression alone in this clinical setting have demonstrated high rates of revision associated with disc space height, facet angle, and translation on flexion/extension films (Blumenthal 2013). The purpose of this prospective study was to assess the factors that determine post-operative outcomes after bilateral decompression alone in patients with degenerative spondylolisthesis and stenosis.

Methods: A total of 50 patients were prospectively enrolled from a single spine surgery center between September 2013 and May 2015. Patients underwent bilateral decompression without fusion, via either a unilateral approach for a bilateral decompression, or a bilateral laminotomy approach. Pre and post-operative functional outcomes were recorded using the ODI and VAS for leg and back pain. Baseline radiographic variables included facet angle (on preoperative MRI), anterolisthesis, disc height, and translation and angulation on flexion/extension radiographs. Images were assessed by three reviewers. Data was analyzed using means and 95% confidence intervals for descriptive statistics, ICC for intra- and inter-rater reliability of radiographic and MRI measures, and generalized linear models for patient reported outcomes. A “good outcome” was defined as no reoperation and either improvement of at least the minimal clinically important different (MCID) (12.8) on the ODI, or postoperative scores in the normal range (<=20). Differences in preoperative characteristics, ODI/NRS scores, and radiographic measures between “good” and “poor” outcomes were assessed with Chi-Squared, Fisher’s exact, and Mann-Whitney U tests.

50 patients aged 69.9±8.9 years underwent surgery and were followed for 2 years. Three patients were excluded from the analysis: one patient was discovered to have an isthmic, not degenerative spondylolisthesis, and two were noted to not have an anterolisthesis. The reoperation rate was 19% (9/47) at 2 years, and 23% (11/47) at 3 years. Leg and back NRS scores and ODI scores improved significantly after surgery ($p < 0.001$, Figure). There were statistically significant increases in the anterolisthesis, angular motion, and translation on F/e films. No radiographic or demographic variable was predictive of a good outcome.

Discussion/Conclusion: Good clinical outcomes were obtained in this cohort of DS patients treated with decompression alone. The reoperation rate at 2 years was 19%, and 23% at 3 years- similar to what has been found in other recent reports. We were unable to find a significant association between any demographic characteristic or radiographic findings and reoperation or outcome. Significant postoperative increases were noted in segmental translation and angulation. Larger clinical trials with longer periods of follow-up may be necessary to better predict risk factors for reoperation in these patients.



*Error bars indicate 95% confidence intervals.

Psychological factors affect physical activity in patients with lumbar spinal stenosis

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Introduction: Patients with lumbar spinal stenosis (LSS) often avoid walking and may have reduced walking distance and physical activity because of neurogenic claudication. It has been reported that body mass index, pain, female sex, and age predict physical activity in patients with LSS. However, no reports have examined the psychological factors associated with physical activity in patients with LSS. The purpose of this study was to use psychological assessment to identify factors associated with physical activity in patients with LSS.

Methods: This study was a cross-sectional analysis of a randomized clinical trial of patients with LSS. Patients presenting with symptoms of neurogenic claudication caused by LSS, which was confirmed by magnetic resonance imaging (MRI), were enrolled from September 2014 to May 2018. All patients completed the Zurich Claudication Questionnaire (ZCQ), the self-paced walking test (SPWT), a numerical rating scale (NRS) of low back pain, leg pain, and leg numbness, the Hospital Anxiety and Depression Scale (HADS), the Pain Catastrophizing Scale (PCS), the Pain Anxiety Symptoms Scale (PASS-20), and the Tampa Scale for Kinesiophobia (TSK) at baseline. Physical activity was measured by pedometer as the average number of daily steps. In the first week, patients were asked to carry on their normal life while wearing the pedometer. Spearman correlational analyses were used to identify relationships between physical activity and demographic data, MRI findings, and physical and psychological factors. Stepwise multiple regression analysis was performed to analyze the relationships between physical activity and physical and psychological variables at $P < 0.1$. A P -value < 0.05 was considered significant.

Results: Seventy-one patients (35 men and 36 women, average age 71.6 years) were included in this study. Significant correlations were observed between physical activity and age ($r = -0.543$), severity of stenosis at L3/4 ($r = 0.279$), walking distance on the SPWT ($r = 0.338$), HADS depression score ($r = -0.245$), PASS-20 total score ($r = -0.327$), cognitive anxiety ($r = -0.352$), escape/avoidance ($r = -0.235$), fear ($r = -0.284$), and TSK score ($r = -0.246$) ($P < 0.05$). Gender, ZCQ symptom severity, ZCQ physical function, NRS of leg numbness, and PASS-20 physiological anxiety score ($P < 0.1$) were included as dependent variables in the stepwise multiple regression analysis. Multiple regression analysis revealed that age, severity of stenosis at L3/4, walking distance on the SPWT, and PASS-20 fear predicted physical activity ($r^2 = 0.448$).

Discussion: In patients with LSS, anxiety and fear avoidance beliefs about pain, kinesiophobia, and depression are more strongly related to physical activity than back and leg pain. Age, MRI findings, neurogenic claudication, and fear of pain predict physical activity. Fear-avoidance models might provide important information for devising physical therapy programs for patients with LSS. Assessment and treatment of psychological factors may help to increase physical activity in patients with LSS. Further studies should confirm whether psychological interventions can help to increase physical activity in patients with LSS.

Risk factors for vertebral, hip, and femoral fractures among patients with Parkinson disease: A 5-year follow-up in Korea

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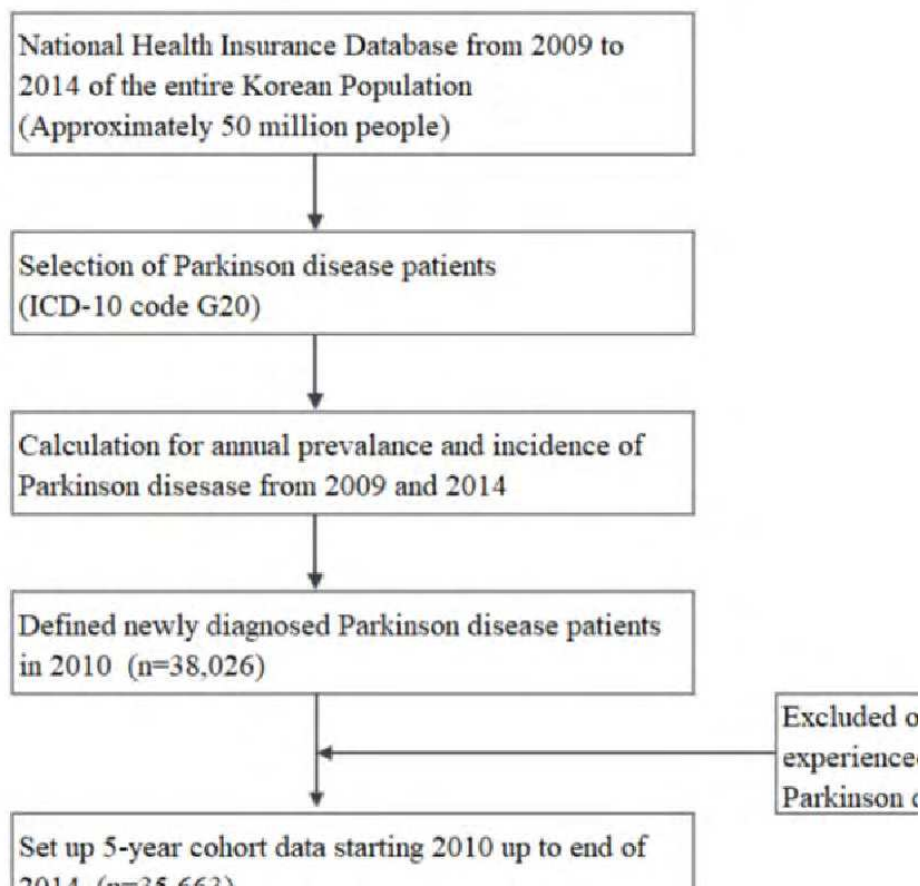
Introduction The number of the elderly population is increasing annually especially in Korea, and a higher proportion of the elderly population has Parkinson's disease (PD). No studies have examined the risk factors related to major fractures, including vertebral fracture (VF), hip fracture (HF), and femur fracture (FF). We investigated the prevalence and incidence of PD and provide evidence for preventive strategy of VF, HF and FF in PD patients.

Methods: This study was designed as a retrospective cohort study and we used a nationwide medical service utility database from 2009 to 2014, we enrolled PD patients with diagnosis of G20 as per ICD-10 who used medical services. Overall, the number of PD patients was 97,311, 106,072, 115,762, 127,647, 137,782, and 144,757 through 2009-2014, respectively. We followed 35,663 patients diagnosed with PD in 2010 without prior fracture. We estimated the annual PD prevalence and incidence and used Cox proportional hazard model to estimate the hazards ratio (HR) for fractures based on demographic characteristics, underlying disease, and socio-economic status according to fracture type (osteoporosis-related fracture, VF, HF/FF). Furthermore, we investigated the cumulative incidence of those fractures by month during the 5-year follow-up.

Results: The standardized PD prevalence increased from 238 to 279 between 2009 and 2014, and its incidence decreased from 86 to 72 between 2010 and 2014 per 105 populations based on 2015 census data. We followed 35,663 PD patients: women, 20,732 (58.1%); aged ≥ 60 years, 29,264 (82.1%); with osteoporosis, 6,542 (18.3%); VF experience, 4,242 (11.9%); and HF/FF experience, 2,112 (5.9%). Osteoporosis was a significant risk factor for VF (HR 1.75, 95% CI 1.64-1.87) and HF/FF (HR 1.37, 95% CI 1.24-1.51). The cumulative incidence of VF and HFF was the highest at 6 months and increased more than half in the coming 2 years after PD diagnosis.

Discussion: This study showed that comparable incidence patterns of VF and HF/FF. The most frequent period of fracture incidence was within 6 months after PD diagnosis. In addition, one third of VF, HF, or FF occurred in 2010 and increased more than half in the next 2 years after PD diagnosis. Those early events for the major fractures including VF and HF/FF after PD diagnosis, are likely to explain the results of poor feeding and musculoskeletal symptoms, making PD patients vulnerable for fragile or accidental fractures and in-hospital falls related major injuries. Therefore, awareness and prevention for falling risk and anti osteoporosis are very critical for patients in early-stage PD. Accordingly, early intervention with physical rehabilitation, gait exercise, psychiatric consultation, and feeding education may be critical to reduce the comorbidities including fractures for PD patients. Moreover, as long as PD patients have difficulty in proper walking and high risk to have fall-associated fractures, they should be given ambulation aids.

Conclusions: VF and HF/FF are common among PD patients. VF and HF/FF risks were high for female PD patients aged ≥ 60 years with osteoporosis. Fracture prevention strategies should be focused on elderly, women, and osteoporosis patients within 3 years of PD diagnosis.



Serum oxidative stress reflects the severity of neurological damage in patients with lumbar canal stenosis: a pilot cross-sectional human study

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Introduction: Oxidative stress occurs when there is an imbalance between the production and elimination of oxidative species. Recently, it was reported that oxidative stress induced by reactive oxygen species is involved in the pathobiology of acute spinal cord injury or neurodegenerative disorders like amyotrophic lateral sclerosis that influence the apoptosis of neuronal cells. However, there are no reports on oxidative stress and lumbar spinal disorders. Here we conducted a pilot cross-sectional study to evaluate serum levels of oxidative stress in lumbar canal stenosis.

Methods: From April 2015 to March 2018, 71 serum samples were collected at our hospital during hematological examinations before surgery from patients who underwent spinal surgery for neurological symptoms due to lumbar canal stenosis. Informed consent was obtained from all patients. The level of oxidative stress was evaluated by measuring reactive oxygen metabolites (ROM) that detect serum hydro-peroxide levels (Diacron-Reactive Oxygen Metabolites test, Italy). Generally, the normal level of ROM in healthy controls is <300 (CARR U) while levels >340 are defined as moderate oxidative stress and >400 as severe oxidative stress. We examined the correlation between ROM values and age, sex, and existence of diabetes. Neurological evaluation including nerve damage patterns (presence of radicular or caudal signs) and the existence or non-existence of motor weakness of the lower extremities were also investigated.

Results: Mean ROM in the 71 patients was increased to 393 ± 93.3 , indicating moderate oxidative stress. There was also no correlation between ROM and age, sex, or existence of diabetes. Analysis of nerve damage patterns showed ROM was 382 ± 79.1 in the cauda sign group (n=29) and 401 ± 102.2 in the radicular sign group (n=42). A slight elevation in the radicular sign was detected although this was not significantly different. On the other hand, analysis of the presence of motor weakness showed ROM was 418 ± 101.1 in the 36 cases with motor weakness and 368 ± 78.0 in the 35 cases with no motor weakness. This indicated there was a significant increase in ROM in patients with motor weakness ($p < 0.05$).

Discussion: Moderate oxidative stress was present in patients with lumbar spinal disorders and neurological symptoms compared with healthy controls. In particular, ROM was increased significantly in cases with motor weakness. These results suggest that ROM values reflect the severity of neuronal damage.

A novel therapeutic strategy for 3' untranslated region of neuropathic pain target genes

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Introduction: Axonal transport of mRNA associated with mechanism of neuropathic pain remains unclear in peripheral sensory neuron. RNA-seq analysis reveal that Nav1.8 mRNA with novel long 3' untranslated region (UTR), but not conventional short 3'UTR, is exclusively transported and accumulates in peripheral axon. Thus, we hypothesized that long variant of 3'UTR increase caused by nerve injury-specific condition might play an important role for the onset and maintain of neuropathic pain. The purpose of this study is to investigate what mRNAs have differential increase of 3'UTR in axons of nerve injury model based on RNA-seq.

Materials and Methods: Rat peripheral neuropathic model, sciatic nerve entrapment (SNE), was generated according to the procedures described previously. To obtain RNA from pure neuronal samples, DRG neurons of SNE and sham rats were cultured on modified Boyden chambers. RNA isolated from axonal and cell body compartments was processed for high throughput RNA sequencing (RNA-seq). Using a combination of 3' rapid amplification of cDNA ends (RACE), Southern blot and cloning & sequencing, exact sequence information of candidate mRNAs' 3' UTR variants was obtained.

Results: RNA-Seq read aligned to the rat reference genome showed more than 100 mRNAs expression beyond the 3' end region. 3' RACE followed by Southern blot identified both conventional and alternative 3' UTR variants in the SNE samples whereas only conventional 3' UTR expression was observed in the sham samples. Notably, differential increase of extended 3' UTR in ipsilateral axon compartment was observed in some RNAs associated with endoplasmic reticulum-anchored autophagy receptor, ribosome metabolisms and voltage-gated ion channel. Cloning and sequencing results showed that the novel 3' UTR variant is produced by alternative splicing coupled with alternative polyadenylation.

Conclusions: Peripheral nerve injury enabled alternative splicing in the 3' UTR of some mRNAs suggesting that this variant is an attractive target for the specific treatment of peripheral neuropathy. The mechanism may be responsible for enhanced axonal localization, as this region is highly implicated in the regulation of mRNA transport.

The Impact of Degenerative Disc Disease on Regional Volumetric Bone Mineral Density (vBMD) measured by Quantitative Computed Tomography

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Introduction: It has been reported that degenerative disc disease (DDD) is associated with higher bone mineral density (BMD). Most of the previous studies utilized dual X-ray absorptiometry (DXA). However DDD is often associated with proliferative bone changes and can lead to an overestimation of BMD measured with DXA. Trabecular volumetric BMD measured with quantitative computed tomography (QCT) is less affected by those changes and can be a favorable alternative to DXA for patients with degenerative spinal changes. The aim of this cross-sectional observational study is to investigate the effect of DDD on regional vBMDs measured by QCT in patients undergoing posterior lumbar fusion at a single academic institution.

Materials and Methods: Institutional ethics board approval was obtained for this study. We reviewed the data of consecutive patients undergoing posterior lumbar spinal fusion between 2014-2017 who had a routine preoperative CT scan and MRI within a 90 day interval. Patients on any anti-osteoporotic treatment were excluded and 132 patients were included in this study. QCT measurements were conducted in L1 to S1 vertebral trabecular bone. Any apparent sclerotic lesions that might affect vBMD values were excluded from the area of interest. Among 660 discs of the 132 patients, levels with spontaneous fusion, previous fusion surgery, or poor image quality were excluded and 626 discs were analyzed. The vBMDs of each level were defined as the average vBMD of the upper and lower vertebrae. To evaluate DDD, 5-grade Pfirrmann grade, Modic grade, and total end plate score were documented. Univariate regression analysis and multivariate analyses with a generalized linear mixed model adjusted with individual variability of segmental vBMDs were conducted with vBMD as the response variable. The statistical significance level was set at $p < 0.05$.

Results: Mean age (\pm SD (range)) was 65.9 ± 11.3 (26-87). 58.3% of the patients were female. Mean vBMD (\pm SD) was 119.0 ± 39.6 mg/cm³. Univariate analyses demonstrated that Pfirrmann grades showed negative associations with vBMD ($p < 0.001$ in all grades), whereas any Modic changes (type 1, $p = 0.012$; type2, $p = 0.002$, type3, $p = 0.019$) and high endplate score (Score 10-12, $p < 0.001$) were associated with high vBMD. After adjusting with age, body mass index, race, disc level, gender, and previous surgery, Pfirrmann grade was not an independent contributor of vBMD (Grade 2 vs 3, $p = 0.09$; vs 4, $p = 0.14$; vs 5, $p = 0.98$), but the presence of any Modic change (type 1, +8.3% $p < 0.001$; type2, +5.2%, $p < 0.001$, type3, +25.9%, $p < 0.001$) and high total endplate score (Score 6-7, +4.7%, $p = 0.040$, 10-12, +12.1%, $p < 0.001$) were shown to be independent contributors of vBMD.

Discussion: Our results demonstrate that the presence of Modic change and higher total end plate score were significantly associated with an increase of regional trabecular vBMDs in apparently normal bone areas, but no association was observed with Pfirrmann grade. This finding suggests that there is no direct association between vBMD and disc degeneration itself, but the concomitant endplate changes have positive effect on regional vBMD in this patient population.

Risk factors and progression rate of sacroiliac joint degeneration in asymptomatic subjects**Yusuke Sato**^{1,2}, **Yasushi Oshima**², **Kosuke Kashiwabara**³, **Yuki Taniguchi**², **Yoshitaka Matsubayashi**², **So Kato**², **Shima****Hirai**², **Naohiro Tachibana**², **Hiroyuki Hasebe**², **Sakae Tanaka**²1. *Niigata Spine Surgery Center, Niigata City, Japan*2. *Department of Orthopedic Surgery, The University of Tokyo Hospital, Tokyo, Japan*3. *Department of Biostatistics, School of Public Health, The University of Tokyo, Tokyo, Japan***Introduction:** Radiographic change of sacroiliac (SI) joint degeneration is highly prevalent in the asymptomatic population, and is associated with age (1). There have been no previous reports on risk factors or natural course of SI joint degeneration in normal subjects.**Purpose:** The aim of this study is to determine risk factors and progression rate of SI joint degeneration in asymptomatic subjects.**Methods:** This study retrospectively included 553 individuals (383 male and 170 female), who underwent the first medical checkup at our institution between the ages of 38 to 45 (average 42.4) and also underwent another examination at an interval of at least 3 years. The medical checkup included blood test and whole body computed tomography (CT). We classified SI joint degeneration from type 0 to 3, and L4/5 facet joints, L5/S facet joints, and pubis symphysis from grade 0 to 3 by axial view of CT. We investigated risk factors of SI joint degeneration and correlation in the laterality of degeneration between SI joint and L4/5 and L5/S1 facet joints. We also investigated progression rate of SI joint degeneration.

Multivariate analysis by generalized linear model with the complementary log-log link function was performed for risk factors of SI joint degeneration. Joint laterality was analyzed using Cochran-Mantel-Haenszel test for correlation and Wilcoxon signed-rank test. Kaplan-Meier survival analysis was used for investigating progression rate of SI joint degeneration. Significance was considered for P value of <0.05.

Results: 70 subjects (12.7%) showed substantial degeneration (type 2 or 3) of SI joints at the first examination. Several risk factors were identified as risk factors of SI joint degeneration (Table 1). In absolute value, laterality of SI joint degeneration was significantly more frequent than that of L4/5 or L5/S facet joint degeneration. Progression rate of SI joint degeneration from type 0 (no degeneration) to type 2 or 3 and from type 1 (slight degeneration) to type 2 or 3 were 3.4% and 35.5%, respectively at ten years.**Discussion and Conclusions:** The incidence of SI joint substantial degeneration was 12.7% in normal healthy subjects with a mean age 42.4.

Several risk factors of SI joint degeneration were identified including degeneration of pubic symphysis, L4/5 and L5/S facet joints, which means that SI joint degeneration is related with adjacent joints' degeneration.

Transitional vertebra, hip osteoarthritis, or leg length discrepancy might be related to the fact that SI joint laterality was more frequent than lumbar facet joints.

One-third of the subjects with slight degeneration (type 1) at the first examination showed progression into substantial degeneration over time, whereas those without any degeneration (type 0) rarely demonstrated progressive changes of SI joint degeneration at 10 years.

Table 1. Multivariate Analysis of Risk Factors of SI Joint Degeneration

Risk Factors	HR	95% CI	P
Male	0.60	0.47-0.76	<0.0001*
Age (yrs)	1.05	1.00-1.10	0.076
Pubic Symphysis	1.74	1.41-2.13	<0.0001*
Maximum L5/S1 Joint Grade	1.25	1.12-1.40	<0.0001*
Maximum L4/5 Joint Grade	1.38	1.17-1.64	0.0001*
BMI (kg/m ²)	1.03	1.01-1.06	0.014*
LDH per 10 (IU/l)	1.05	1.02-1.09	0.004*
ALP per 10 (IU/l)	0.97	0.97-0.99	0.006*
TC per 10 (IU/l)	1.03	1.00-1.05	0.096
Pi (mg/dl)	1.28	1.01-1.61	0.041*
*Statistically significant CI indicates confidence interval; HR, hazard ratio			

1. Eno JJ, et al. The prevalence of sacroiliac joint degeneration in asymptomatic adults. *J Bone Joint Surg Am.* 2015;97:932-6.

Improvement of the sagittal alignment and balance of the spine through a “locomotion training” rehabilitation program in patients with locomotive syndrome

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Introduction: Locomotive syndrome is a degenerative condition of reduced mobility due to the impairment of the musculoskeletal system, which has gained increased attention as a Japan's health policy target. The Japanese Orthopaedic Association (JOA) recommends “locomotion training” exercises (basically squatting and single-leg standing) to be effective in preventing locomotive syndrome. However, the extent to which “locomotion training” affects the maintenance and improvement of motor function is unknown. Therefore, a cohort study was designed to clarify effects of a “locomotion training”-based rehabilitation program on the sagittal alignment and balance of the spine.

Methods: One hundred and six patients (age, 76.1±5.9 years; male:female=12:94) who fulfilling the JOA criteria for locomotive syndrome were enrolled and prospectively followed in our outpatient clinic. While 44 patients accepted and completed our “locomotion training” rehabilitation program once per week for 6 months (20-min stretching and evaluation of self-exercise achievement), 41 patients denied the participation but received medicinal treatment (NSAIDs, pregabalin, duloxetine, and/or tramadol) throughout. Standing whole-spine radiographs for the spine-pelvis-lower extremity axis, questionnaires of the ODI and SF-36 for QOL, and piezoelectric force-plate measurement for postural stability were taken at baseline and >6 months.

Results: Exercise-intervention analysis] There were no significant differences in baseline sagittal vertical axis (SVA). However, >6-month changes in the SVA had significant differences: -5.5±20.0 mm in the exercise group versus +5.2±22.6 mm in the control group ($P=0.02$). In radiographic parameters, >6-month changes were relatively remarkable in the lumbar lordosis (LL) (+1.5±8.1° in the exercise versus -1.3±9.1° in the control, $P=0.14$), thoracic kyphosis between T5 and T12 (TK) (-0.05±5.5° versus +1.8±6.0°, $P=0.13$), and T1 slope (-0.4±6.3° versus +1.6±5.8°, $P=0.14$). No obvious differences in the ODI and SF-36 were observed. However, in force-plate examination, the center-of-pressure area (-0.4±1.8 cm² versus +0.2±1.6 cm², $P=0.07$), speed (-0.1±0.4 cm/s versus +0.1±0.4 cm/s, $P=0.03$), and distance (-5.1±24.3 cm versus +6.5±23.3 cm, $P=0.03$) all decreased in the exercise group after >6-month rehabilitation but not in the control group.

[SVA analysis] Of 40 patients with baseline SVA ≥40 mm, the SVA improvement to <40 mm was observed in 12 (30.0%), consisting of 10 (25.0%) in the exercise and 2 (5.0%) in the control groups ($P=0.16$). Baseline SVA was +51.6±10.2 mm and +79.5±34.0 mm in patients with and without endpoint SVA <40 mm, respectively ($P<0.01$). Baseline C2–C7 angle was 10.9±6.0° and 19.6±13.0° ($P=0.03$). Baseline hip-flexion angle was +8.1±2.4° and +11.2±4.0° ($P=0.02$). Then, >6-month changes were most obvious in the LL (+4.6±9.0° and -0.6±8.1°, $P=0.08$). In force-plate examination, >6-month changes were significant in the area (-1.6±5.3 cm² and +0.2±1.7 cm², $P<0.01$).

Discussion: This is the first study to demonstrate that “locomotion training” can protect against locomotive syndrome-associated positive shift in radiographic SVA alignment. Although “locomotion training” facilitates the LL increase and TK and T1-slope decreases, the LL increase is primarily effective in the SVA improvement. “Locomotion training” can also improve the standing balance, corresponding to the SVA improvement. In addition, a limited rehabilitation-induced SVA improvement in patients with marked positive SVA shift, hyperlordosis of C2–C7, and hip contracture at baseline is noteworthy.

Low-Grade Isthmic L5-Spondylolisthesis in Patients with Adolescent Idiopathic Scoliosis (AIS): Any Additional Problem?

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Introduction: The literature on concomitant isthmic spondylolisthesis in AIS is scarce and inconclusive. According to the literature, it occurs in 6.2–43% of cases. No data on clinical impact is available. Purpose of the study is to determine the prevalence of this double pathology in a significant number of patients and to answer the question whether the presence of low-grade isthmic spondylolisthesis affects the course and/or the outcome of AIS.

Methods: This is a retrospective comparative study from a single institution based on radiographs, patients' records, mean follow-up 4.4(4.3)yrs., and patient related outcome scores (PROM): (ODI, SRS-24, WHOQoL, Numerical Rating Scale for pain), mean follow-up 26.4(2.8)yrs. Surgery data was derived from Hospital records and the National Inpatient Registry, mean follow-up 25.4(2.8)yrs. All radiographic measurements were performed by a single experienced spinal radiologist. Ethical approval was obtained from the local authorities.

At the authors' institution, 1531 consecutive patients with AIS, mean age 13.9(1.8)yrs, had standing pa- and lateral whole spine radiographs, mean primary curve 29.2(11.5)°. Of them, 120(7.8%) had low-grade (slip<50%) isthmic L5-spondylolisthesis, mean slip 15.0(8.3)% (Study group=S). A control group, pair-matched for age, gender, Cobb angle, and apex level of the primary curve, was created. During the matching procedure, patients' history, symptoms, possible mode of treatment, and outcome were hidden. For two patients no adequate pair could be found (Control group=C, n=118). χ^2 statistics and t-tests were applied to calculate statistical differences in distributions between the study group and control group. Statistically significant threshold was accepted at $P<0.05$, two-tailed.

Results: At diagnosis, there was no significant difference between the patients of the Study group and the Control group concerning age (13.8y/13.9y), gender distribution (83.3/83.9% female), primary Cobb angle (29.0°/28.7°), and curve type (Th:67.5%/63.2%; Th-L:25.0%/23.9%; L:7.5%/12.8%). Back pain interfering with ADL had 4.2%/1.7%, at admission and 2.5%/4.2% at clinical follow-up.

In comparison between the groups (S/C), no significant differences were found concerning treatment: Bracing for scoliosis initiated in 42.0/43.2%. Surgery for scoliosis: 10.8%/10.2%. Scoliosis surgery despite brace treatment in 8.0/5.9%. Response rate for PROMs: 54.9/45.1%. Responders and non-responders were comparable concerning age, gender, primary Cobb angle, slip%, pain, and clinical f-up time. Results were fully comparable between the groups: ODI: 5.3 / 6.1%; SRS-24: 93.9/91.9; WHOQoL: Physical 81.0/78.5; Psychological 75.2/71.5, Social: 76.3/75.0; Environment 81.9/78.7. NRS-back pain: 2.6/2.1, -leg pain: 1.3/1.4. In the study group, 12/120(10%) patients had fusion for spondylolisthesis.

Discussion: In a consecutive series of 1531 teenagers with AIS, the prevalence of low-grade isthmic L5- spondylolisthesis was 7.8%. This percentage is lower than most figures from the literature which are mainly derived primarily from patient groups of different ages with symptomatic spondylolisthesis, some using a Cobb angle of 5° as threshold for scoliosis. Compared to a pair-matched control group, spondylolisthesis did not seem to influence the clinical or radiographic course or the patients' outcome of AIS. The results support the opinion that low-grad isthmic spondylolisthesis is a relative benign deformity. It also approves the strategy to treat each of both pathologies separately according to the generally accepted rules.

Investigation of the 3D vascular network in vertebral end plates using micro-computed tomography

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Introduction: The vertebral endplate (VEP) is characterised as a bilayer of cartilage and bone, acting as a boundary between the disc and the vertebra. The disc being the largest avascular tissue in the body, relies primarily on the nutritional pathways from the vascular network in the adjacent VEP. Disruption of this nutrient supply has been identified as a major contributor to disc degeneration, yet the 3D topology of the network is poorly understood.

The aim of this work is the characterisation of this vascular network to further understand the physiology of the vascular network and the correlation between disc degeneration and nutrient supply.

Methods: Caudal and cranial VEP sections were sampled from lumbar ovine spines and imaged using high-resolution micro-computed tomography (micro-CT) at 4.92 μm pixel size. ImageJ and ScanIP (Simpleware, Synopsys Inc., USA) were used to create 3D rendered volumes of the canal network found in the VEP using the reconstructed micro-CT images using segmentation and flood fill to isolate the vascular network. The diameter, length, orientation and depth from the VEP surface were measured for individual canals using 3D canal centreline models using ScanIP. Using custom-written routines in MATLAB (MathWorks, Inc., Natick, MA), Ward clustering analysis was then used to categorize the individual canals based on distribution of canal diameter and angle or combinations of length and depth.

Results: Figure 1 shows thinner VEP layer with a greater concentration of pores at the upper surface at the peripheral regions, compared to the central regions of the VEP. The trabecular structure in both types of samples was found to be similar. CTvox was used to create 3D rendered volume images of the micro-CT data as shown in Figure 2.

The results showed higher concentration of canals in the central regions of the VEP and in caudal VEP to the disc, as shown in Figure 3. Large transverse canals were identified running parallel to the VEP surface connected to both the disc and the vertebra, and depth-dependence of the length and diameter of the canals was recorded, as shown in Figure 4.

Discussion: This work demonstrates that the micro-CT, coupled with centreline models is an extremely useful tool for the characterisation of the vascular network in the VEP. The results revealed a depth dependence of the canals in sheep VEP characterised by their length, diameter and orientation. Further study is required to evaluate the effect of degeneration on the observed patterns and to assess reliability of these results when compared with human VEP.

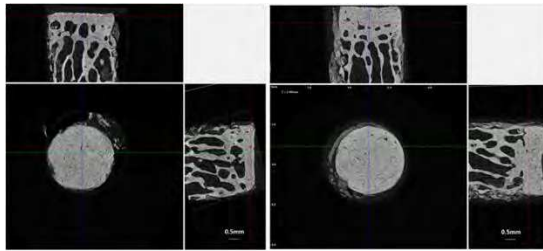


Figure 1

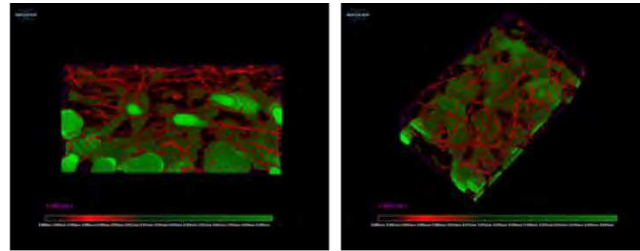
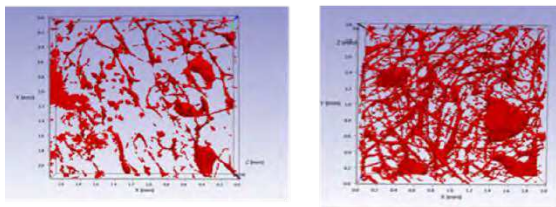


Figure 2



Peripheral Region

Central Region

Figure 3

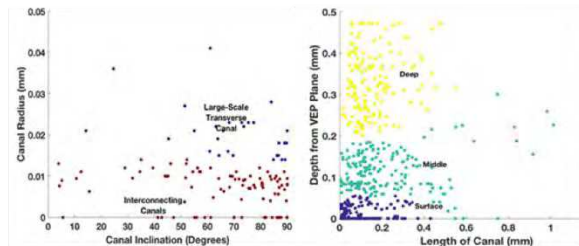


Figure 4

A deep learning based fully automated program to segment and quantify paraspinal muscles on axial lumbar spine MR images

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Introduction: As a major component of the lumbar spine, the paraspinal muscles have long been studied on T2W axial magnetic resonance (MR) images. Typically, measurements were acquired with some general image programs by manually segmenting individual muscles. Such manual segmentation relies on subjective judgements of the muscle boundaries and thus, may introduce considerable inter-rater variations. In addition, manual segmentation is rather time-consuming, limiting its application in clinical use and epidemiological study. Using techniques in deep learning, this study developed a fully automated system for quantifications of the lumbar paraspinal muscles on axial MRIs.

Methods: From a population-based database, 100 lumbar spine MRIs (DICOM format) were randomly selected (mean age 54.8 ± 15.0 years, range 25-88 years). Paraspinal muscles were measured on the axial MRI which is through the middle of the L4/5 disc. The developed system was named Spine Explorer (Tulong, 2.0). First, annotations of 80 axial MRIs were labeled, including bilateral multifidus, erector spinae, psoas, the disc and lamina, and spinal canal. Using these annotations, a Mask-Rcnn based network was trained in sequential steps to obtain the ability of automated recognition and segmentation. Upon regions of interests (ROIs) of each muscle, a thresholding algorithm was implemented to calculate an optimal threshold, which is with minimal intra-class variance in signal intensity, to differentiate muscle tissues from fat/fascia tissues within a ROI. The algorithm counts these pixels with signal below the regional threshold as muscle and those beyond as fat/fascia tissues. Another 20 axial MRIs were automatically measured using Spine Explorer and manually with ImageJ (version 1.52a, NIH, USA) to acquire measurements of cross sectional area (CSA), fat percentage (FP), and functional cross-sectional area (FCSA) for multifidus and erector spinae. Intersection-over-union (IU) was calculated to evaluate automated segmentation performance, with 80% or higher suggesting an excellent performance. Intra-class coefficient (ICC) and Bland-Altman plots were used to examine inter-software agreements for various measures.

Results: Spine Explorer was trained iteratively for 72 epochs in total. The IUs were 86.6%, 83.3%, 88.4%, for multifidus, erector spinae, and psoas, respectively, and 92.2%, 82.1% for the disc and spinal canal. After training, Spine Explorer measures an axial MRI and output measurements in less than one second. For multifidus, the inter-software ICCs were 0.92, 0.92, and 0.95 for CSA, FP, and FCSA, respectively. Similar ICCs were obtained for measurements of erector spinae (ICC=0.91-0.97). For various muscle, the measurement differences between Spine Explorer and ImageJ close to zero. B-A plots further confirmed that Spine Explorer were in good to excellent agreements with ImageJ in measuring the axial MRI.

Discussion: Using state-of-art techniques in deep learning and image analysis, a fully automated system Spine Explorer was developed to automatically segment paraspinal muscles and simultaneously acquire various quantitative measurements on routine T2W axial lumbar spine MRI. This artificial intelligence based program is accurate, efficient, and highly reliable, and therefore, can be used in large scale epidemiological studies to further explore the roles of paraspinal muscles in the pathogenesis of lumbar spinal disorders.

Whole Exome Sequencing to Identify Genetic Variants Associated with Sagittal Imbalance of Spine : A prospective, multicenter, observational cohort study

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Purpose: Sagittal imbalance (SI) of spine has become a clinical entity of importance among the elderly that causes painful disability and physical impairment. Similar to many other multifactorial diseases, SI of spine is affected by environmental and genetic factors. The authors previously developed prospective observational cohort study. We also have investigated the risk factors of this malalignment and suggested its genetic aspect. To identify genetic variations conferring the risk of SI of spine, we performed an exome-wide association study using blood samples obtained from its cohort.

Material and Methods: We investigated the influence of genetic variants on SI using whole exome sequencing in 120 individuals with SI among which 64 with severe phenotypes of SI. Statistical analyses included single variant analysis for common variants (MAF > 0.01) and rare variant analysis for low frequency and rare variants (MAF < 0.05). A joint calling strategy, and stringent variant and individual-level quality control (QC) were applied for all WES datasets. For gene based burden test, we used the PLINK/SEQ estimate of the smallest achievable empirical P-value for a gene (I-value) to adopt an adjusted Bonferroni correction for multiple testing. $P < 3 \times 10^{-5}$ ($P < 0.05$ after applying a Bonferroni correction for 20,000 genes tested) was adopted for genome wide significance.

Results: We did identify individual common variants that reached exome-wide significance using single variant analysis and rare variant analysis. Our SNP, rs78773460 in an exon of SVIL reached exome-wide significance ($P=1.15 \times 10^{-3}$). In previous studies, a variant in the supervillin gene was associated with clinical fracture and decreased total lean muscle mass.

Conclusion: Our results leave open the possibility that common variants in SVIL contribute to the risk of SI. To clarify the genetic background of SI of spine, further study should be required.

Spine Explorer: a deep learning based fully automated program for efficient and reliable quantifications of the vertebrae and discs on lumbar spine MR images

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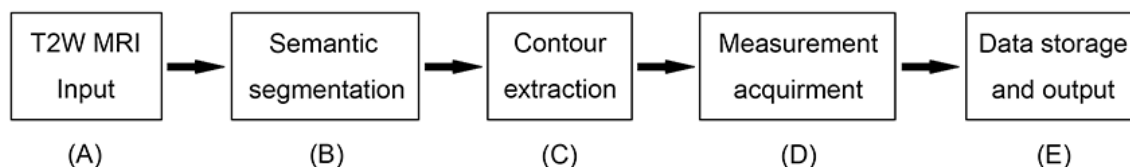
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Introduction: The absence of standard definition and measure for disc degeneration remains to be a challenge in the field of spine research. Although some conventional scales are commonly used to measure disc degeneration, assessments are based on subjective judgments and acquired qualitative measurements are inadequate to capture the progression of disc degeneration. Quantitative analysis of magnetic resonance (MR) images can improve accuracy and specificity for disc degeneration measurements, yet, such approach relies on time-consuming manual segmentation of the disc on MRI. In this study, techniques of deep learning were introduced to automatically segment and quantify the vertebra and disc on lumbar spine MRIs.

Methods: From a population-based database of lumbar spine MRIs, 50 sets of MRIs were randomly selected as training dataset and another 30 as test dataset. The working flow for the proposed fully automated program *Spine Explorer (Yitian 2.0)* was presented in **Figure 1**. Regions of interests (ROIs), which include T12-S1 vertebrae and their intervening discs, were manually segmented for 150 sagittal T2W MRIs from the training dataset. A fully convolutional network, U-Net, was trained using segmented MRIs for automated segmentation. Based on segmented ROIs, definitions and computational methods were proposed to acquire quantitative measurements of morphometrics and signal intensity for the vertebra and disc, including various definitions of diameter, height, area, bulging and signal intensity. Intersection-over-union (IU) was calculated to evaluate segmentation performance, with 100% suggesting a perfect performance. Ninety sagittal MRIs from the test dataset were automatically measured with *Spine Explorer* and manually with *ImageJ*. Intra-class coefficient (ICC) was calculated to examine inter-software agreements for various measurements. Disc degeneration measurements acquired with *Spine Explorer* were further correlated to age to assess their validities in reflecting age-related disc degeneration.

Results: The *Spine Explorer* was trained iteratively for 40 epochs till it gained no more improvement in IU. After training, *Spine Explorer* can automatically segment and measure all vertebrae and discs on a sagittal MRI in half a second. The mean IU was 95.1-95.6% for the vertebra, and 92.8-93.1% for the disc, respectively. The overall agreements for vertebral measurements between automated *Spine Explorer* and manual *ImageJ* were excellent, with ICCs ranging from 0.87 to 1.00. Other than disc bulging (ICC=0.74) and anterior disc height (ICC=0.75), the overall agreements for disc measurements were excellent (ICC=0.82-0.99). Greater anterior disc bulging and less mean disc signal intensity, as acquired with *Spine Explorer*, were associated with greater age ($r=0.44$, -0.66 , respectively, $P<0.001$ for both).

Discussion: Using state-of-art techniques in deep learning, a fully automated program, *Spine Explorer*, was developed for simultaneous quantifications of the lumbar vertebrae and discs on T2W sagittal MRIs. This program is an efficient, accurate, and reliable tool to acquire various quantitative measurements for the vertebra and disc. Application of such deep learning based programs in epidemiological studies can help to maintain consistency for studies of occurrence, etiology, and clinical relevance of lumbar disc degeneration and to improve the power to identify determinant genes for disc degeneration.



The effect of the “One Stretch” exercise on the improvement of low back pain in Japanese nurses: a large-scale, randomized, controlled trial

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Introduction: Back loading strategies lead to improvements in low back pain (LBP) in a short period of time. Accordingly, the “One Stretch,” which is a simple, daily, static back extension task, was developed by Matsudaira et al., and they reported the effect of this intervention on decreasing LBP in medical institutions. However, these previous studies showed the effect of the “One Stretch” exercise on a small number of patients (under 100 workers). To evaluate the “One Stretch” exercise's effect on improvements in low back pain (LBP), psychological factors, and fear avoidance in a large number of nurses. Therefore, the purposes of this study were to show the effect of the “One Stretch” exercise on a larger sample size (2,000 nurses) and confirm the intervention effect not only on their improvement of LBP but psychological factors and fear avoidance.

Methods: Between July 2015 and June 2016, we performed a prospective, randomized, parallel-group, multi-center study with central evaluations. Eligible patients were randomly assigned (1:1:1 ratio) to either the control group (Group A) or an intervention group (Group B: 30-min seminar about the “One Stretch” exercise, Group C: B + physical and psychological approaches to LBP treatment). The primary outcome was subjective improvement from baseline to 6 months (improved/unchanged/worsened) and overall exercise habits (good/poor).

Results: There were 4,767 participants: 1,799, 1,430, and 1,548 in Groups A, B, and C, respectively. We collected data on 3,439 participants (949, 706, and 751 in Groups A, B, and C, respectively) at the 6-month follow-up. The improvement rates in Groups A, B, and C were 13.3%, 23.5%, and 22.6%, respectively. The rates of worsened pain were 13.0%, 9.6%, 8.1%, respectively, which decreased as the degree of the intervention increased (Cochran-Armitage trend test: $p < 0.0001$). In Groups A, B, and C, 15.6%, 64.9%, and 48.8% participants, respectively, complied with the intervention, and the exercise habits in Group A (control group) were low (chi-square test: residual analysis, $p < 0.01$). After adjusting for the participants' backgrounds, we examined the association between the improvement in LBP and the intervention, using the multivariable logistic regression analysis. In the multivariable logistic regression analysis, the LBP of participants in both treatment groups was significantly improved by about two times compared with that in the participants in the control group.

Discussion: The findings of this randomized, controlled trial suggested that the “One Stretch” standing back extension exercise effectively improved and prevented LBP in a large sample of nurses, as reported in previous studies. It is likely that the population approach about daily practice of this simple exercise and the exercise itself can benefit our society, especially in industrial health.

Assessment of sarcopenia in patients with sagittal imbalance and symptomatic lumbar spinal stenosis

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Introduction: Sarcopenia has been demonstrated to be associated with several diseases and may lead to poor clinical outcomes. Although there would be a potential association between sagittal imbalance (SI) and sarcopenia, no studies have examined this relationship. The purpose of this study was to investigate the relationship between sarcopenia and patients with SI by assessing handgrip strength (HGS) and paraspinal muscles' (PSMs) volume, which were compared with those in patients with lumbar spinal stenosis (LSS).

Methods: As a cross-sectional matched cohort study, A total of 54 paired consecutive patients with SI and LSS who were scheduled to undergo spine surgery for severe SI and LSS were enrolled after propensity score matching. The prevalence of sarcopenia, as defined by HGS, was compared between two groups. The HGS was used to define sarcopenia in the present study, and HGS values of <26 kg for 11 men and <18 kg for women were defined as sarcopenia according to the guidelines set by the Asian Working Group for Sarcopenia. Preoperative HGS, cross-sectional area (CSA) of psoas (PS) and multifidus (MF) muscles, and clinical outcomes including visual analog scale (VAS) for back/ leg pain, Oswestry Disability Index (ODI), and EuroQOL (EQ-5D) were compared between both groups. Within each SI and LSS group, clinical outcomes were compared between sarcopenia and non-sarcopenia subgroups. The correlation of HGS and CSA of PSMs to clinical outcomes was evaluated.

Results: Thirty (55.6%) and 31 (57.4%) patients were defined as sarcopenia in the SI and LSS groups, respectively, and the prevalence of sarcopenia was not significantly different between the two groups ($P = 0.848$). Mean HGS \pm standard deviation (SD) values were 17.5 ± 6.6 and 17.6 ± 5.9 kg in the SI and LSS groups, respectively, and there was no significant difference between the two groups ($P = 0.944$). However, the CSA of the PS and MF muscles in the SI group were significantly lower than those in the LSS group ($P = 0.003$ and $P < 0.001$, respectively). There was no significant difference in VAS score for back and leg pain in those with and without sarcopenia in both groups. However, patients with sarcopenia showed significant higher disability and lower health-related quality of life, in terms of ODI and EQ-5D, respectively, compared to those without sarcopenia in both SI and LSS groups. Multiple regression analysis confirmed that HGS and CSA of MF showed significant correlation with ODI in both SI and LSS groups ($R^2 = 0.315$ and $R^2 = 0.385$ in the SI and LSS group, respectively), and HGS was correlated with EQ-5D in both groups ($R^2 = 0.129$ and $R^2 = 0.276$ in the SI and LSS group, respectively).

Discussion: There was no significant difference in the prevalence of sarcopenia between SI and LSS groups, however, PSMs' volume in SI group was significantly lower than those in LSS group. Sarcopenia was associated with SI as well as LSS, and showed negative impact on clinical outcomes in terms of disability and health status.

Does dural sac cross-sectional area predict the presence of subjective lumbar spinal stenosis symptoms after 10-year follow-up?

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Purpose: North American Spine Society (NASS) mentions that lumbar spinal stenosis (LSS) is a clinical syndrome which is associated with diminished space available for the neural and vascular elements in the lumbar spine secondary to degenerative changes in the spinal canal. From our previous study, the magnitude of dural tube compression on MRI did not predict the presence of LSS symptoms. However, there is no data more than six-year follow-up. The purpose of this study was to assess the influence of the magnitude of dural tube compression on MRI on LSS symptoms at ten-year follow-up.

Participants and method: This was a prospective cohort study of 459 participants who were assessed for LSS using a specially designed and validated questionnaire (Konno 2007) and conventional MRI of the lumbar spine. After ten year, 298 subjects (follow-up rate 64.9%) were assessed for LSS using the same questionnaire. On MRI, transverse slices were aligned as parallel as possible to each intervertebral disc. The dural sac cross-sectional area (DCSA) of L1/2–L5/S1 on the T2-weighted image was measured using the conventional formula described by Hamanishi (1994). The smallest DCSA of L1/2–L5/S1 in each participant was divided into five categories: less than 25mm², 25–49.9 mm², 50–74.9 mm², 75–99.9 mm², and 100 mm² or more. The number of intervertebral discs of which the smallest DCSA was less than 50 mm² (ranged 0-5) was also analyzed. The time course of the subjective LSS symptoms and the relationship between the subjective LSS symptoms and magnitude of dural tube compression on MRI were analyzed.

Results: 1. At the ten-year follow-up, 29 of 79 LSS-positive participants in the initial year (36.7%) were reclassified as LSS negative, and 26 of 219 LSS-negative participants (35.2%) were reclassified as LSS positive.

2. The magnitude of the dural sac cross-sectional area on MRI did not directly affect the presence of LSS at the ten-year follow-up using a multiple logistic regression analysis.

Discussion: In degenerative spine disease, it is well known that degenerative changes do not always cause symptoms. This means that dural tube compression is an anatomical cause for LSS; however, LSS is not always symptomatic. From the present study, LSS symptoms were changeable. And furthermore, anatomical dural tube compression on MRI did not predict the presence of clinical LSS symptoms at the 10-year follow-up. The relationships between symptomatic and asymptomatic LSS in people with dural tube compression still remain unclear.

Cross-sectional and one-year follow-up study for the relationship between lumbar spinal stenosis and low back pain in the community

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Purpose: Low back pain (LBP) is not an essential symptom in a diagnosis of lumbar spinal stenosis (LSS). On the other hand, severe dural tube compression is an anatomical cause for LSS; however, anatomical dural tube compression is not always symptomatic. The purpose of this study was to investigate the relationship between lumbar spinal stenosis and low back pain.

Participants and method: In the initial assessment, 1876 participants in the community agreed to participate. They were assessed for LSS using a specially designed and validated questionnaire (Konno 2007), LBP continuing more than 24 hours, Roland-Morris Disability Questionnaire (RDQ) and numerical rating scale (NRS; 0: no pain, 10: the worst pain intensity) of LBP. And 459 of them received conventional MRI. One year later, 1111 of them were reassessed by the same assessments. For assessment of RDQ, norm-based RDQ score was used because of consideration of the gender and age. Norm-based RDQ score were available for less than eighty years old. 50 point is the average of national norm about each item; more than 50 point means QoL is better and less than 50 point means QoL is worse than the average. On MRI, transverse slices were aligned as parallel as possible to each intervertebral disc. The dural sac cross-sectional area (DCSA) of L1/2–L5/S1 on the T2-weighted image was measured using the conventional formula described by Hamanishi (1994). The smallest DCSA of L1/2–L5/S1 in each participant was divided into five categories: less than 25mm², 25–49.9 mm², 50–74.9 mm², 75–99.9 mm², and 100 mm² or more. The number of intervertebral discs of which the smallest DCSA was less than 50 mm² (ranged 0-5) was also analyzed.

Results: 1. 102 of 387 participants (26.4%) classified as LSS-positive showed LBP and 143 of 1469 participants (9.4%) classified as LSS-negative showed LBP. NRS of LBP was 6.1±2.2 in LSS-positive group and 5.5±2.1 in LSS-negative group. Norm-based RDQ score was 48.1±10.2 in LSS-positive group and 55.6±6.9 in LSS-negative group. There were statistical differences of the prevalence of LBP, NRS of LBP and norm-based RDQ score between two groups (p<0.0001, p=0.0278, p<0.0001).

2. In the point of dural tube compression on MRI, any statistical difference of NRS of LBP was not detected between LSS- positive and –negative group. On the other hand, norm –based RDQ score in less than 25mm² of the smallest DCSA and three or more of less than 50mm² of DCSA were lower than the norm score.

3. Using logistic-regression analysis, the predictive factors for the presence of low back pain one year later was not find out.

Discussion: In the present study, clinically diagnosed LSS was not always related to LBP. On the other hand, anatomical dural tube compression did not influence on the degree of LBP, but had possibility to relate to LBP-related QOL such as RDQ. These mean that LSS-related LBP might be influenced by degenerative change of lumbar spine itself rather than pathophysiology of LSS.

Bone formation during restoration of rounding vertebral deformity in pediatric spondylolisthesis

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Introduction: Rounding of lower vertebrae surface associated with L5 spondylolisthesis is reported to risk factor for slippage. We previously reported that reducing mechanical stress of anterior upper corner due to tail suspending lead to repair deformity of vertebra. However, detail of the bone formation during the restoration of rounding deformity is yet to be clarified.

Methods: We used the previously reported spondylolisthesis rat model (4-week-old, L5/6 bilateral facetectomy and L5 partial laminectomy). This rats was divided into 2 groups control group (observation without tail suspending) and immature suspending group (starting tail suspending using a tail suspending device at 2 weeks after surgery). The lumbar spines were harvested for histology, and we focused on immunohistochemical examination.

Results: In control group, expression of type X collagen (Col-10) disappeared and type II (Col-2) collagen increased (Figure1). In suspending group, osteogenesis was observed with time, and Col-10 was also (Figure1). At 4 weeks after the start of suspension, the anterior upper corner was restored with bone tissue, and Col-2 and Col-10 did not appear in the correct array like ordinary growth plate, were seen in a mosaic pattern (Figure1). Furthermore, chondrocyte-like cells and osteocyte-like cells coexist in the restored bone tissue, and expression of both Col-1 and Col-2 was observed in chondrocyte-like cells (Figure2).

Discussion: From the expression pattern of Col-1 and Col-2, the bone formation in the restoration of rounding deformity improves deficient of endochondral by reducing mechanical stress and may have promoted redifferentaiton, in addition the third bone formation called transchondroid ossification may also be involved.

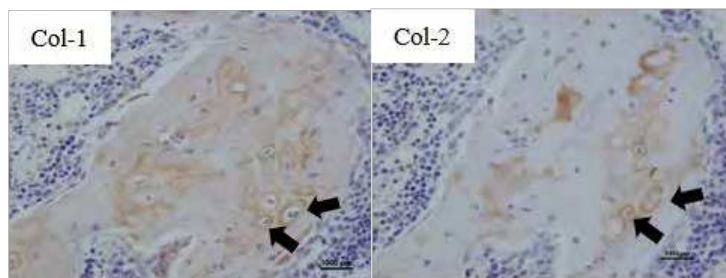
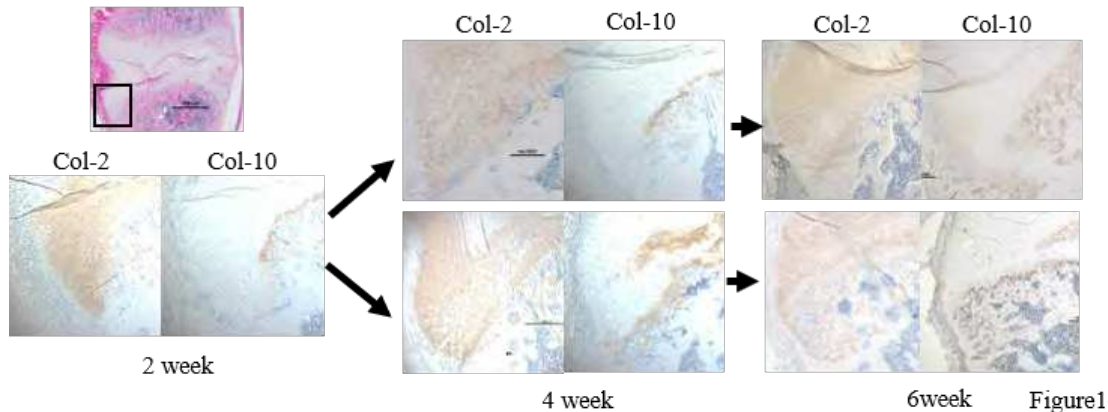


Figure2

Development of a guide for the conservative treatment for acute OVF according to a prospective, randomized, multi-center study by the comparison of rigid and soft-brace treatments

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Introduction: Osteoporotic vertebral fractures (OVF) worsen the QOL in the elderly, due to residual lower back pain and spinal deformity. The major conservative treatment could be using some brace. However, all the previous reports regarding the brace treatment for OVF has had small sample sizes, resulting in insufficient difference.

Then, we performed a nationwide multicenter, randomized prospective clinical trial to compare the effects of hard and soft braces, and to establish an ideal initial brace treatment for OVF.

Methods: Fresh and one-level OVF occurred at between T10 and L2, females from 65 to 84 years old, and 4weeks from their injury was included. We randomly assigned patients to two brace groups using web-based clinical system. Patients used the brace for 12 weeks and were followed up for 1 year.

The primary outcome measure was the anterior vertebral body compression ratio at 1 year. Secondary outcome measures included scores on the European Quality of Life-5 Dimensions (EQ-5D-3L), visual analogue scale (VAS) for low back pain, and Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ) at 1-year follow-up duration.

Results: Total of 382 cases were enrolled. Among 284 patients who were randomized (mean age 75.7 years), 80% (228/284) of available study participants completed the trial. The anterior vertebral body compression ratio at 12 weeks was significantly kept higher in the hard brace group ($p < 0.05$). However, there were finally no statistically significant differences in the patient's anterior vertebral body compression ratio at 1 year (mean score, 55.5 in the rigid-brace group vs 53.0 in the soft-brace group, $P = 0.20$), in VAS for low back pain, in JOABPEQ pain related disorder score, or in quality of life between groups (difference in EQ-5D-3L).

Discussion: Among patients with fresh osteoporotic vertebral fractures, the 12-week hard brace treatment did not result in statistically greater prevention of spinal deformity than soft brace at 1 year after brace application. Also VAS, QOL were not different. Our multicenter RCT findings do not support this 12-week hard brace treatment for OVF.

Association between core stability and low back pain in high-school baseball players

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Introduction: Core stability might play an important role to prevent low back pain in adolescent athletes. The present study aimed to determine an association between core stability and the seasonal prevalence of low back pain among high-school baseball players.

Materials and Methods: We evaluated core stability in 755 high-school baseball players (190 pitchers, 565 fielders; mean age, 16.1 years; range, 15 - 17 years) using a pressure biofeedback core stabilizer. All players had participated in annual medical evaluations comprising a self-completed questionnaire and a physical examination. With the player in the spinal position, stabilizer pressure biofeedback was placed under the back at the L4-5 level and inflated to 40 mmHg. A decrease of 20 mmHg during hip-extension and flexion tasks indicated "insufficient core stability". The prevalence of present and previous seasonal low back pain and associations with core stability were investigated. Data were statistically analyzed using Wilcoxon and chi-square tests.

Results: Insufficient core stability (45.8%) was confirmed in 346 players (pitchers 102; fielders 244). The prevalence of insufficient core stability was higher among pitchers who developed low back pain with lumbar extension compared with those who did not (22.6% vs. 11.2%, $p = 0.0364$). However, the prevalence of previous seasonal low back pain was not associated with core stability in pitchers. Core stability was not associated with either the present or previous seasonal prevalence of low back pain among fielders.

Discussion: Insufficient core stability might be not an important risk factor for seasonal low back pain in high-school baseball players. In contrast, low back pain upon lumbar extension was associated with insufficient core stability only among pitchers. Evaluations of core stability might be more important for pitchers than for fielders.

A prevention project for low back disorders in Japanese elite swimmers: 10 years follow-up of lumbar intervertebral disc degeneration

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Introduction: Lumbar disc degeneration (DD) is associated with low back pain. Previously, we reported a higher incidence of DD in swimmers compared to other athletes. In 2008, we initiated a project to reduce low back disorders in Japanese elite swimmers. This prevention project has 2 parts. First, we assessed DD and disc bulging (DB) using MR imaging. Second, we implemented a stability training regimen for the lumbar spine using physical trainers at competitions and training camps. In the present study, we investigate the impact of this project on the incidence of DD in elite swimmers.

Methods: Participants were Japanese swimmers who participated in the Beijing, London, and Rio de Janeiro Olympics (Rio), as well as elite national swimmers who had lumbar MR imaging from 2008 to 2017. A total of 384 swimmers (217 males and 167 females; mean age, 21.2 years) were included in this study. Using T2-weighted lumbar sagittal MR images, the presence of DD was assessed and the degree of DD was categorized by Pfirrmann's classification. A classification greater than Grade III was considered degenerated. The DB was evaluated with or without the presence of DD. Participants with DD and DB at one or more disc levels were categorized as DD and DB subjects, respectively. The proportions of DD and DB subjects were determined, and the correlation between the presence of DD and age was assessed. Differences in the proportion of DD subjects at 22 years old in the first half (until 2012) of the project compared to that the second half (after 2013) was analyzed by χ^2 test. We also evaluated the change in DD and DB grade of the participants over the study period.

Results: The proportions of DD and DB subjects were 51% and 35.4%, respectively. The correlation between DD subjects and age was strong ($r=0.93$). The proportion of DD subjects in Olympic swimmers was lowest in those that participated in Rio (41.2%). No swimmers withdrew from the Rio Olympics due to low back pain. The proportion of DD subjects at the age of 22 was 72% in the first half of the study and 50% in the second half of the study. However, the difference was not significant. The DD grades progressed in 30 of 85 swimmers (35.3%) who had two or more sessions of MR imaging. New DB appeared in 15 subjects (17.6%). However, our evaluation method failed to detect a new herniation in one swimmer, because his DD and DB grades did not change.

Discussion: The proportion of DD subjects was lowest at the most recent Olympic Games compared to previous games. Furthermore, the proportion of DD subjects at the age of 22 showed a decrease in the second half of the project period. Therefore, our low back disorder prevention project may delay the progression of DD in Japanese elite swimmers. In order to clarify this project effect, we need to continue the project and to review MR evaluation methods that can detect low back disorders.

Poor flexibility is negative predictive factors of bone union in adolescent athletes with spondylolysis

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Introduction: In athletes, the major concern after the treatment of spondylolysis is resuming play and previous activity levels and preventing the recurrence of spondylolysis. To prevent recurrence, union of defects is important. Union is more likely to occur in unilateral active spondylolysis, compared to the bilateral and pseudobilateral active spondylolysis. However, the relationship between physical function and union of defects in spondylolysis remains unclear. We aimed to identify radiological variables and physical fitness factors that were associated with the successful union of defects in patients with spondylolysis.

Methods: We retrospectively analyzed adolescent athletes with spondylolysis who underwent conservative treatment. All patients went the nonoperative treatment protocol, were recommended discontinued sports activities and underwent rehabilitation. Patients with terminal spondylolysis or who did not discontinue sports activities were excluded. We compared spondylolysis severity (very early, early, progressive, terminal), condition of the contralateral pars and physical fitness factor [abdominal muscle strength (modified Kraus-Weber test), finger floor distance (FFD), heel-to-buttock distance (HBD), straight leg raising (SLR), Numerical Rating Scale (NRS)] in the union and nonunion groups. Significant factors with a p value of <5% in univariate analysis were included as independent variables in the subsequent multivariate analysis. Multivariate analysis was performed by logistic regression using these significant independent variables, with union of defect as the dependent variable.

Results: Of 207 patients with spondylolysis who underwent rehabilitation 141 patients less than 18 years of age with 246 defects were included in the final analysis. Union group was achieved in 67.1% (165/246) of the pars interarticularis defects and 70.9% (100/141) of the patients. Univariate analysis revealed a significant difference in the SLR test, severity and condition of the contralateral pars between the two groups ($p < 0.05$), but there were no significant differences in sex, age, period of rest, activity restrictions, NRS, FFD, and HBD tests between the union and nonunion groups. On multivariate analysis, Progressive stage of pars interarticularis defect (odds ratio [OR], 0.14 ; $p < 0.05$), Progressive and terminal stage of contralateral pars interarticularis defect (OR, 0.21 and 0.11 ; $p < 0.05$), and SLR (OR, 1.06 ; $p < 0.05$) were significantly associated with union of defect.

Discussion: We found that not only higher defect stage and contralateral defect but also poor flexibility was a negative predictive factor of union of defect in athletes with spondylolysis, despite cessation of sports activities. As poor flexibility of hamstrings affects daily lumbar movement and posture, there is a possibility that the load on the defect is increased. While managing these patients with conservative therapy, it is important to stabilize the lumbar vertebrae by encouraging patients to use a thoracolumbar orthosis, improve body flexibility by routine stretching, and reduce the burden on the lumbar vertebrae. However, we did not investigate posture and movement pattern. Future studies should include the posture and movement pattern and examine relationship with spondylolysis.

1. Fujii K, Katoh S, Sairyo K, Ikata T, Yasui N : Union of defects in the pars interarticularis of the lumbar spine in children and adolescents. The radiological outcome after conservative treatment. Bone Joint J 86 : 225 - 231, 2004
2. Sairyo K, Sakai T, Yasui N : Conservative treatment of lumbar spondylolysis in childhood and adolescence : the radiological signs which predict healing. Bone Joint J 97 : 206 - 209, 2009
3. Sakai T, Tezuka F, Yamashita K, Takata Y, Higashino K, Nagamachi A, Sairyo K : Conservative treatment for bony healing in pediatric lumbar spondylolysis. Spine 42 : E716 - E 720, 2016
4. Esola MA, McClure PW, Fitzgerald GK, Siegler S : Analysis of lumbar spine and hip motion during forward bending in subjects with and without a history of low back pain. Spine 21 : 71 - 78, 1996
5. Yamazaki K, Kota S, Oikawa, Suzuki Y : High defect stage, contralateral defects, and poor flexibility are negative predictive factors of bone union in pediatric and adolescent athletes with spondylolysis. J Med Invest 65 : 126 - 130, 2018

The Effects of Abdominal Draw-in Maneuver on Electromyographic Activities in Response to a Sudden Release from Loading in Subjects with Non-specific Chronic Low Back Pain

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Introduction: Appropriate timing and magnitude of muscle activities in the superficial trunk are considered as contributing factors to the prevention and improvement of non-specific chronic low back pain (CLBP) [1]. The sudden release from loading is known as a contributing mechanical circumstance to low back pain. The subjects with non-specific CLBP has shown that the superficial trunk muscles exhibited increased activity compared to the healthy subjects without non-specific CLBP during sudden release from loading [2]. The intervention of abdominal draw-in maneuver (ADIM) has been recommended to achieve appropriate coordination between the deep and the superficial trunk muscles [3]. However, it has remained unknown whether the intervention of ADIM can change the muscle activities of superficial trunk following a sudden release from loading in the subjects with non-specific CLBP. The purpose of the present study was to investigate the effects of the intervention of ADIM on electromyographic (EMG) activities of superficial trunk muscles during sudden release from loading.

Methods: Seventeen subjects with non-specific CLBP (21.8 +/- 2.0 years old, mean +/- SD) and 16 healthy subjects without non-specific CLBP (21.9 +/- 1.5 years old) participated in the present study. Non-specific CLBP was defined as pain localized between the 12th rib and the inferior gluteal folds at least 3 months. All subjects were placed in a semi-seated position and a cable held with an electromagnet was attached to their chest at T9 to serve as resistance for isometric trunk extension (Fig. 1). The resisted force was adjusted to 20% of body weight for each subject and suddenly released with an electromagnet. The EMG of the right thoracic erector spinae (ES) at T9 was recorded using a wireless surface EMG system (WEB-1000; Nihon Kohden). The peak root mean square (RMS) value within 250msec following the sudden release was derived (Fig.2) [2]. Peak RMS values during the task were normalized to that during maximum voluntary isometric contractions (MVIC). The subjects with non-specific CLBP were tested before and after 4 weeks of the ADIM intervention. Independent t-test and paired t-test were used to compare between the two groups and between pre- and post-intervention in non-specific CLBP group ($P < 0.05$).

Results: At baseline, peak RMS of thoracic ES EMG activities was significantly higher in non-specific CLBP group than healthy control group ($P=0.020$, Fig. 3). After ADIM intervention, non-specific CLBP group showed that significantly decreased peak RMS of EMG activities for thoracic ES ($P=0.042$, Fig. 3).

Discussion: We first showed the intervention of ADIM decreased the EMG activity of superficial trunk muscle in response to a sudden release from loading. This finding is consistent with a previous study that reported the activity of superficial trunk muscles was decreased during slow trunk movements after ADIM intervention [3]. The present finding shows the possibility to alter the muscle activities of superficial trunk in subjects with non-specific CLBP.

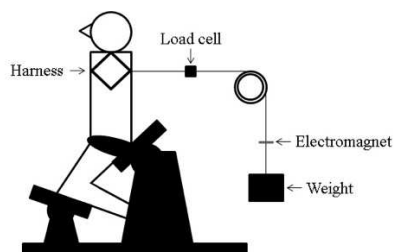


Fig.1. Experimental set-up for sudden release from loading. All subjects were placed in a semi-seated position with the pelvis restrained from any motion. The weight was adjusted to generate the resisted force for 20% of body weight.

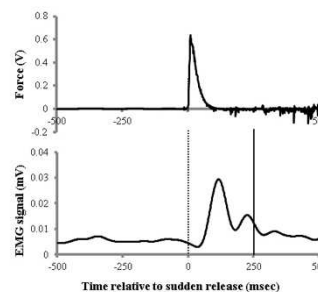


Fig.2. Muscle response to sudden release from loading. An example of a typical EMG trace after data reduction in a subject without non-specific CLBP. The dotted line indicates sudden load release as time 0. The vertical solid line indicates 250 msec after the sudden release. The peak RMS value within 250msec following the sudden release was derived.

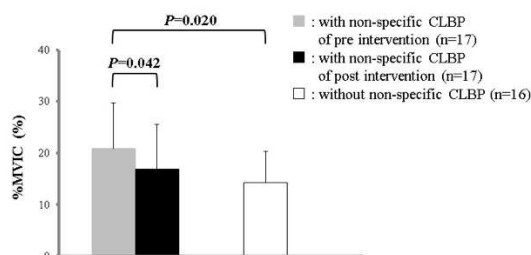


Fig.3. Peak RMS value of thoracic erector spinae activity.

- Hodges et al. J Electromyogr Kinesiol. 2003.
- Radebold A et al. Spine. 2000.
- Tsao H et al. J Pain. 2010.

Automatic segmentation of paravertebral muscle image of lumbar vertebrae MRI by artificial intelligence in young men of northern China

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Guoxin Jin¹

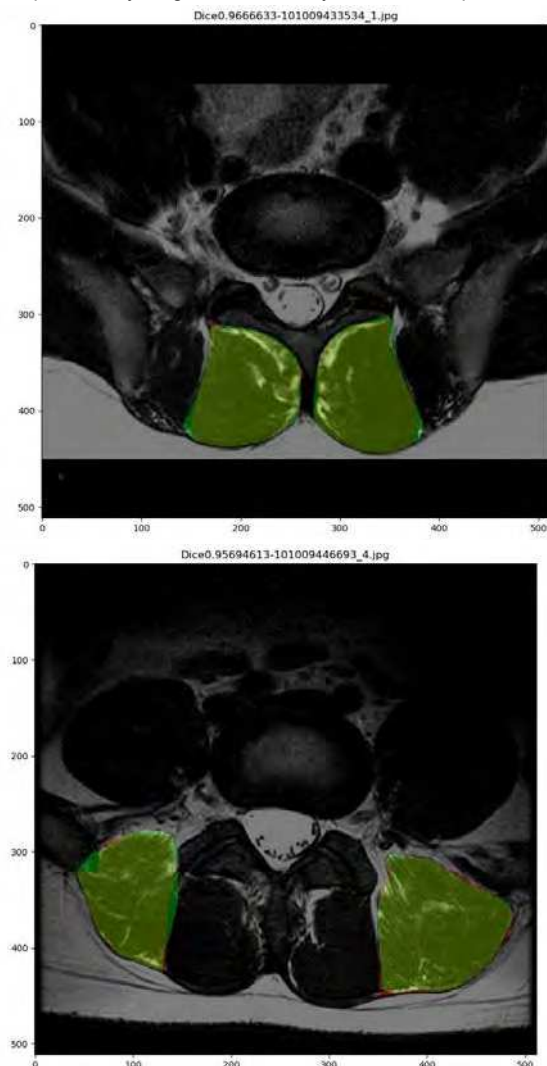
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Introduction: Evidences show that sarcopenia is significantly correlated with chronic low back pain, PJK, screw loosening, Cage displacement and other adverse outcomes after lumbar surgery. Meanwhile, the severity of sarcopenia is negatively correlated with bone mineral density. At present, the boundary segmentation of paravertebral muscles in lumbar MRI images is accomplished manually by medical experts in this field. It is not only time-consuming and laborious, but also because of the subjective differences between different doctors in theory and practice, the segmentation results are also different and have poor repeatability. In order to improve work efficiency and obtain more stable and objective segmentation results, we introduce the computer technology of artificial intelligence deep learning to assist doctors in the analysis of paravertebral muscle images. Our goal is to train a large number of labeled hand-segmented images using deep learning method, and the final model can fully automate the segmentation of paravertebral muscle images on lumbar MRI.

Methods: 69 cases of 18-35 year old men in northern China underwent lumbar MRI examination. A total of 621 axial slices of L3-4, L4-5 and L5-S1 discs were extracted from T2-weighted images. All images were pre-processed by brightness and contrast adjustment, and normalized. Five spine surgeons and one radiologist used Photoshop graphics software to mark the boundary of erector muscle and multifidus muscle manually. Then the whole images divided into 495 training sets and 126 test sets. A new deep convolution neural network based on attention mechanism is proposed, which enlarges useful features and suppresses irrelevant features by re-calibrating feature maps on channel dimensions. Finally, the network converged low dimensional and high dimensional features to achieve paravertebral muscle end-to-end training.

Results: After deep learning network training, more than 93% of the automatic segmentation accuracy (Dice coefficient) was achieved in the test set of lumbar spine MRI paravertebral muscle images, and the ability to approach human medical experts was achieved.

Discussion: Automatic recognition of lumbar paraspinal muscle MRI image segmentation method by artificial intelligence can greatly help doctors to analyze the paraspinal muscle morphology and lean muscle quantification, and is expected to accomplish the preliminary diagnosis of the key structure of spine and related diseases with artificial intelligence automatic analysis.



Comparison of the physical activity of the upper limbs and trunk in patients with low back pain evaluated using a wearable tracker: a validation study

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Introduction: Accelerometers can be used to evaluate waking and sleeping movements. Although a correlation between accelerometer data captured at the wrist and waist has previously been reported, this has not been evaluated in patients with low back pain. Therefore, this study aimed to evaluate correlations between movement measured at the wrist and waist, using wearable accelerometers, in patients with low back pain.

Methods: Twenty patients with chronic low back pain, with an average daily pain intensity $>5/10$ on a visual analog scale, and twenty healthy volunteers were enrolled. The objective physical activity of participants was evaluated using the Actigraph Micro-Motion logger. Two Actigraphs were simultaneously worn by each participant, one on the non-dominant wrist and the other at the waist, for one week. The activity level was analyzed with the mean active count of the zero-crossing mode (ZMAC) and proportional-integrating mode (PMAC). The zero-crossing mode indicates the number of movements in a 1-min epoch, and the proportional-integrating mode indicates the total amount of movement in a 1-min epoch. Differences in the ZMAC and PMAC for daytime activities captured by the wrist and waist accelerometers were evaluated using a Mann-Whitney U test, and the correlation between the two sets of data were evaluated using the non-parametric Spearman's rho (ρ) correlation coefficient in both the low back pain and control groups. Additionally, the mean active count of waist to wrist ratio in the LBP group was compared with that of the control group. Similarly, during sleep, we also evaluated sleep efficiency (SE) and wake time after sleep onset (WASO).

Results: In daytime activity, the ZMAC and PMAC was greater for the wrist than waist, and the amount of waist movements relative to wrist movements was significantly lower in patients with low back pain than in healthy volunteers ($p < 0.05$). Despite these differences, ZMAC and PMAC at the wrist and waist were strongly correlated in both groups ($r = 0.935$, $r = 0.888$ for the ZMAC and PMAC in the control group, and $r = 0.965$, $r = 0.912$ in the low back pain group, respectively). During sleep, although there was no difference in either measured SE at the wrist or waist or WASO, measurements were strongly correlated in both groups ($r = 0.541$, $r = 0.567$ for the SE and WASO in the control group, and $r = 0.813$, $r = 0.569$ in the LBP group, respectively).

Conclusions: We identified a strong correlation between movement data, measured with the Actigraph system at the wrist and waist, during both daytime activities and sleep in patients with low back pain. Therefore, a wearable accelerometer worn on the wrist may sufficiently and reliably measure the amount of movement of patients with low back pain, simplifying data capture for clinical and research purposes and improving patient comfort.

Relationship between the Vitamin D Concentration and Bone Turnover Marker Levels in Patients Undergoing Spinal Surgery.

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Introduction: It is known that the bone fusion rate after spinal fusion surgery is inferior in patients with reduced blood vitamin D concentrations (25 OHD). However, in contrast to osteoporosis evaluations, there have been no detailed studies of the 25 OHD levels in elderly patients undergoing spinal surgery. The purpose of this study was to clarify the relationship between 25 OHD level and the bone turnover markers in patients undergoing spinal surgery.

Methods: Among 220 spinal surgery patients of >60 years of age, we excluded 77 patients (internal administration of osteoporosis drug, n=51; spinal metastasis, n=6; vertebral body fracture, n=13; renal function deterioration, n=12). The final population included 149 patients (male, n=96; female, n=47). The relationships between 25 OHD and bone turnover markers (TRACP 5 b, P 1 NP), intact PTH, and the bone mineral density (YAM) at the time hospitalization were investigated. According to the guidelines, the blood levels of 25 OHD were classified into the following categories: satisfactory (≥ 30 ng/ml), insufficient (20 ng/ml to <30 ng/ml) and deficient (<20 ng/ml). For each group, the frequency of intact PTH (≥ 60 pg/ml), calcium phosphate (CaP) product ($27 \text{ mg}^2/\text{dl}^2$ in blood), and YAM (<80%) was investigated.

Results: 1) The mean blood level of 25 OHD was $16 \text{ ng}/\text{m}^2$ (male, $17 \text{ ng}/\text{m}^2$; female, $13 \text{ ng}/\text{m}^2$), and 75% of the patients showed 25 OHD deficiency (male, 68%; female, 89%).

2) In males, there was no significant correlation between 25 OHD and TRACP 5 b, P 1 NP, intact PTH and YAM. In females, only an intact PTH showed a weak correlation ($r = -0.30$, $p < 0.05$) with blood 25 OHD, there was also no significant correlation between 25 OHD and TRACP 5 b, P 1 NP and YAM.

3) The frequency of intact PTH ≥ 60 pg/ml in the male and female patients of the 25 OHD-deficient group was 25% and 31%, respectively, the frequency of CaP product $< 27 \text{ mg}^2/\text{dl}^2$ was 44% and 14%, and the frequency of lumbar spine YAM <80% was 8% and 23%.

Discussion: Among elderly patients undergoing spinal surgery, 85% of the female patients showed 25 OHD deficiency. On the other hand, there was no correlation between the 25 OHD level and the bone turnover marker levels or bone mineral density, few patients with 25 OHD showed decreased CaP product levels. Thus, it is possible that vitamin D deficiency is overlooked in the general osteoporosis assessments performed in routine practice.

Prevalence and risk factors for low back pain in male college athletes

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Background: Low back pain (LBP) in young athlete is known to be a common problem, but considerably less is understood regarding the etiology of such pain. The purpose of this study is to investigate the prevalence and risk factors for low back pain in male college athletes.

Method: We conducted self reporting questionnaire survey regarding existence of LBP for 1,044 athletes in college (mean age 19.8±1.2 years old). Firstly, we investigated prevalence rate of LBP in whole subjects and investigated its relationship with athletic background, consisting of age, height, body mass Index (BMI) (kg/m²), sports duration, kind of sports, and competition level. The athletes who experienced national and world competition were classified as high-level group, the others were classified as a middle-level group. The chi-square test, Man-Whitney test, and Tukey test were used to test associations between LBP and other categorical variables (age, height, BMI, duration, level), and to compare the prevalence of LBP between high-level and middle-level groups. Statistical significance of p value less than 0.05 was adopted.

Results: Prevalence of LBP in college athletes in the current study was 17.0% (178 of 1,044). Age, height and duration were not associated with LBP. BMI of LBP positive group was higher than LBP negative group (25.7±4.5 vs. 24.2±3.9) (P=0.003). The prevalence rate of LBP had wide range in 18 different sports (4.5% - 53.3%). Shot put (53.3%) and judo (35.1%) were significantly higher compared to the most infrequent long-distance running (5.4%), and badminton (4.5%) (P<0.05). Prevalence rate of LBP in high-level group was higher than in middle-level group (19.2% vs. 13.6%)(P=0.019). Risk factors associated with LBP in college athletes were high competition level (odds ratio = 1.42; 95% confidence interval (CI): 1.00 to 2.02), and high BMI (odds ratio = 1.08; 95% CI: 1.04 to 1.12).

Conclusion: Similar to the past study of the prevalence of back pain in athletes, this study indicated that the prevalence in athletes varies widely depending on the sports disciplines. Although, some reports claim that BMI is not related to the LBP in athlete, this study indicated that high BMI and high-level athletes might increase prevalence rate of LBP in male college athletes.

1. Triki M. et al. Prevalence and risk factors of low back pain among undergraduate students of a sports and physical education institute in Tunisia. *Libyan J Med.* 2015 Mar 9;10:26802.
2. Fett D. et al. Back pain in elite sports_A cross-sectional study on 1114 athletes. *PLOS ONE.* <https://doi.org/10.1371/journal.pone.0180130> June 29, 2017

Paresthesia in the soles of the feet correlates with myelopathy in spinal disease

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Introduction The cause of lower limb symptoms among those presenting with gait disorders may in some cases be regarded as cervical spine disease rather than a lumbar disorder. Considering subjective symptoms in lumbar spinal stenosis (LSS) often involves listening to complaints of lower limb pain or numbness. In listening to cases of cervical spondylotic myelopathy (CSM), hearing complaints of "feeling as if a piece of paper is attached to the sole of the feet" has led to consideration that complaints of paresthesia in the soles might be effective for screening as an influence in cervical spinal disease. The present study was performed to elucidate the characteristics of disease and lower-limb and imaging findings in cases of paresthesia in the soles.

Subjects and methods Subjects were 187 patients (105 males, 82 females; mean age, 69.4 years) with low back pain or lower limb symptoms who underwent cervical or lumbar spinal surgery. More specifically, they comprised 112 cases of cervical spinal surgery (Group C) and 75 cases of lumbar spinal surgery (Group L), with investigation for pre-operative paresthesia in the soles, lower limb physical findings, and MRI of the cervical spine. Candidate-influencing factors included age, sex, height, weight, disease, diabetes, lower-limb deep tendon reflex, lower-limb superficiality, deep sensation, T2-weighted image sagittal-section MRI at the level of maximum spinal cord compression and cross-sectional imaging at the level of maximum spinal cord compression ratio of the anteroposterior to transverse diameter (anteroposterior compression ratio, APCR), and presence of T2-weighted image high-intensity signal. Statistical analysis included presence of paresthesia in the soles as the dependent variable and other parameters as independent variables, with multiple logistic regression analysis performed using the AIC stepwise method and application of the χ^2 test to the relationship between presence of paresthesia in the soles and cervical spinal cord level of maximum spinal cord compression (MSCC).

Results Paresthesia in the soles was present in 57 cases (44 in Group C, 13 in Group L) and absent in 130 cases (68 in Group C, 62 in Group L). Multiple logistic regression analysis resulted in the selection of Group C (odds ratio (OR) 3.1; 95%CI 1.3-7.6), with deep sensory disturbance (OR 10.4; 95%CI 3.8-28.3), and with plantar superficial paresthesia disorder (OR 3.7; 95%CI 1.7-8.0; $p < 0.05$). No significant difference was found in presence of paresthesia in the soles or cervical spinal cord APCR, and cervical spinal cord level of MSCC could not be confirmed as influencing paresthesia in the soles.

Discussion Paresthesia in the soles was found to be related to cervical cord disease, but characteristics of cervical spinal cord MSCC in relation to the presence of the disorder could not be elucidated. Because lower limb deep sensory disorder and plantar superficial paresthesia are involved in dorsal tract disorder, paresthesia in the soles can be effective as a finding for predicting CSM in cases where the main complaint is the condition of the lower limbs.

Significance of vitamin D in low back pain in the elderly

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Introduction Vitamin D (Vit.D) deficiency is greatly associated with musculoskeletal diseases. Insufficient Vit.D has been implicated in a range of diseases involving other body systems, including metabolic, autoimmune, psychiatric, respiratory, cardiovascular disorders, and cancers. Some studies have shown a positive association between Vit.D deficiency and low back pain (LBP), while others have failed to find an association. The aim of this study was to investigate whether Vit.D deficiency is associated with LBP in elderly people using a population-based prospective cohort study.

Methods We enrolled 323 subjects (133 men and 190 women, mean age: 72.9 years) aged ≥ 65 years who participated in a population-based prospective cohort study. We examined blood tests results, including serum 25(OH) Vit.D levels; Oswestry Disability Index (ODI); visual analog scale (VAS) score for back pain; whole spine radiography; body composition; walking speed; 2-step value; grip strength; back muscle strength; percentage of the young adult mean (%YAM); prevalent vertebral fracture; EuroQol-5D (EQ-5D) score; and locomotive syndrome. We investigated the correlation between Vit.D deficiency and LBP (ODI and back pain VAS score) or the various aforementioned parameters. Vit.D deficiency was defined as levels of < 20 ng/ml of serum 25(OH) Vit.D; and LBP, as an ODI score of > 12 points (Tonosu, Eur Spine J, 2012). For the statistical analysis, we used the Spearman correlation coefficients, Mann-Whitney U test, and chi-square test. Factors related to LBP were assessed using a multivariate logistic regression analysis.

Results The prevalence of Vit.D deficiency was 65.3% (35.1% in men and 71.2% in women, $P < .01$). The prevalence of LBP was 49.5% (40.6% in men and 53.1% in women, $P < .01$). Vit.D blood levels had no significant correlations with ODI and back pain VAS scores but had a significant correlation with muscle mass, grip strength, back muscle strength, 2-step value, %YAM, and EQ-5D score. The prevalence rates of vertebral fracture and locomotive syndrome were significantly higher in the subjects with than in those without Vit.D deficiency. The ODI score significantly correlated with sagittal vertical axis (SVA), T1 pelvic angle, pelvic incidence and lumbar lordosis, pelvic tilt, age, body mass index, 2-step value, walking speed, back muscle strength, grip strength, %YAM, and EQ-5D score. The multivariate logistic regression analysis revealed that Vit.D deficiency was not independently associated with LBP, but SVA of ≥ 100 mm (odds ratio OR], 27.7) and advanced age of ≥ 73 years (OR, 7.04) were.

Discussion Vit.D deficiency and LBP were commonly associated with a muscle parameter, osteoporosis, and physical function; however, Vit.D deficiency was not directly associated with LBP in the elderly people. This suggests that Vit.D supplementation is not useful for treating low back pain in elderly people.

Lumbar spine facet joint osteoarthritis in professional athletes

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Introduction: Facet joint osteoarthritis (OA) reportedly develops frequently in athletes, due to repeated, localized mechanical stress on the facet joints. However, the association between low back pain (LBP) and radiographically observed facet joint OA remains controversial. The purpose of this study was to assess the prevalence, distribution, morphology and symptom of lumbar spine facet joint OA among professional athletes compared with age- and sex-matched controls.

Methods: Group A comprised 53 professional athletes (45 baseball players and 8 football players; mean age, 25.1 years; range, 18-34 years) who had seen our institution. Lumbar images from CT and MRI were evaluated for all players. Group C comprised 102 age- and sex-matched controls (102 males; mean age, 24.1 years; range, 18-30 years) who had undergone whole-spine CT for examination of multiple high-energy injuries in the emergency department of our institute. Subjects with a history of lumbar spine surgery were excluded. The prevalence, distribution, morphology and symptom of lumbar spine facet OA were reviewed. Wilcoxon and chi-square tests were used for statistical analyses.

Results: Facet OA of lumbar spine was significantly more frequent in Group A (52.6%) than in Group C (5.8%; $p < 0.0001$). Facet OA most commonly occurred at L4/5 in both groups. However, only 8 players (15.1%) with facet OA experienced symptomatic OA that was evaluated by intra-articular diagnostic injections.

Discussion: The prevalence of lumbar spine facet OA was increased among professional athletes compared with age- and sex-matched controls. Dynamic rotational mechanical stress may thus influence the development of lumbar spine facet joint OA in professional athletes. However, few cases of symptomatic facet OA were included in our study.

Angiogenesis in a moderately degenerated ligament is one of the causes of ligamentum flavum hematoma

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Introduction: Although pathological studies have investigated the etiology of the degenerative disease of the ligamentum flavum, no studies have aimed to identify the causes of ligamentum flavum hematoma by focusing on angiogenesis from the immunohistochemical perspective.

Methods: Of 149 specimens of the ligamentum flava resected from 93 patients who had undergone microscopic laminectomy for spinal disease, 52 with clinical data and microscopy results were included. The severity of ligamentum flavum degeneration was classified into 4 grades (grades 0–3), and the extents of amyloid deposition and angiogenesis were examined according to severity. The clinical factors investigated were patient age, severity of degeneration, ligament thickness, and the presence or absence of spondylolisthesis. On the basis of these data, correlation coefficients between the clinical factors and amyloid deposition and the presence of CD34-positive stromal cells were calculated.

Results: Amyloid deposition showed strong correlations with age (0.66), severity of degeneration (0.50), and ligament thickness (0.51), whereas the presence of CD34-positive stromal cells negatively correlated with age (–0.29) and severity of degeneration (–0.32).

Discussion: Before the start of our observation, we had expected that amyloid deposition, which reflects the severity of inflammation, would correlate with age, severity of degeneration, ligament thickness, and the presence of spondylolisthesis and that angiogenesis would increase as degeneration progressed. However, angiogenesis negatively correlated with age and severity of degeneration. We assumed that angiogenesis contributed to tissue repair and that the amyloid deposition represented the outcome of degeneration. A typical clinical picture of ligamentum flavum hematoma is a man in his early old age with preserved physical activity. This corresponds to a phase when a moderately degenerated ligament shows angiogenesis. In conclusion, angiogenesis in a moderately degenerated ligament is one of the causes of ligamentum flavum hematoma.

Protocol for a prospective, one-armed, nonrandomized, un-blinded, safety and feasibility study of exercise therapy using the lumbar type Hybrid Assistive Limb (HAL) for non-specific low back pain

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Introduction: Non-specific low back pain is a kind of low back pain without apparent clear etiology. It tends to resistant to conservative therapy. Several kinds of drug therapy and exercise therapy have been reported to show modest efficacy.

The Hybrid Assistive Limb (HAL) is a newly developed wearable robotic suit that interactively assists joint motion based on the wearer's voluntary motor drive. The HAL for Care Support Lumbar type (HAL lumbar type) has been specifically developed to reduce the wearer's lumbar load. The HAL lumbar type could assist exercise including standing and walking even in elderly people. We hypothesized that exercise therapy using the HAL lumbar type might have the potential to attenuate symptoms in non-specific low back pain patients. Therefore we intend to perform a safety and feasibility study.

Methods: The current trial is a prospective, one-armed, nonrandomized, un-blinded, safety and feasibility study. A total of 20 patients with non-specific low back pain will be enrolled. Participants will undergo standing, trunk flexion/extension and walking exercise with the HAL lumbar type. Exercise will be performed 3 times a week for 3 months, resulting in a total of 12 sessions. Our primary endpoint is safety and feasibility. Any adverse events will be collected. Our protocol has been approved by our Institutional Review Board.

Discussion: If the current trial can successfully show the safety and feasibility, we will move forward to the next phase of the clinical trial with control arms to elucidate the therapeutic efficacy of exercise with the HAL lumbar type for non-specific low back pain.

Does the level of occurrence of vertebral body fractures and disc degeneration affect spinal alignment and low back pain? – The Wakayama Spine Study

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Purpose: Although osteoporotic vertebral body fracture (VF) and disc degeneration (DD) can cause poor posture and low back pain in elderly individuals, the degree to which these symptoms are influenced by the level of occurrence of VF and DD is often unknown. The purpose of this study was to examine the influence of the level of occurrence of VF and DD on posture and lower back pain in a general population.

Study design: A cross-sectional study

Method: Of the 952 subjects who participated in the second survey of Wakayama Spine Study, 794 (239 men, 555 women, mean age 63.6±13.1 years) underwent sagittal whole-spine radiography in a standing position and whole-spine magnetic resonance imaging (MRI). The C7 sagittal vertical axis (C7 SVA) was measured in the radiograph. Morphological VF of the thoracolumbar vertebra (T2–L4) was evaluated using the SQ method (Grades 0–3), and lumbar DD (L1/2–L 5/S) was evaluated using the Pfirrmann classification (Grades 1–5) with MRI. Information on the presence or absence of low back pain within the past month was obtained through interviews.

Statistics: Multiple logistic regression analysis was performed using the presence or absence of poor posture (defined as a C7 SVA of 50 mm or higher) and low back pain as objective variables. The SQ grade at the 5 segments (T2–T4, T5–T7, T8–T10, T11–L1, L2–L4) or the Pfirrmann grade at the 5 intervertebral disc levels of the lumbar vertebra was used as an explanatory variable and sex, age, and BMI were used as adjustment variables.

Results: Poor posture and low back pain were observed in 12% and 39% of the participants, respectively. The proportion of those who complained of low back pain in the poor posture group was 55%, and the proportion of those who complained of low back pain in the normal group was 36%. The segment level of VF that had a significant correlation with poor posture was T11–L1, and the odds ratio when the sum of the SQ grade reached 3 or higher (vs. 2 or less) within the segment was 2.3 (95% CI: 1.2–4.2). The DD segment level that had a significant correlation with poor posture was only L5/S, and the odds ratio of grade 5 (vs. 4) was 2.6 (1.4–4.7). The segment level of VF that had a significant correlation with low back pain was also T11–L1, and the odds ratio when the sum of the SQ grade became 2 or higher (vs. 1 or lower) was 1.6 (1.1–2.4). The DD segment level significantly associated with low back pain was only L5/S, and the odds of grade 5 (vs. 4) was 1.8 (1.2–2.7).

Conclusion: Among factors related to poor posture and low back pain in the elderly, the thoracolumbar junction is important for VF and the lumbosacral junction is important for DD. We believe that this study raises important points for consideration when surgical interventions for vertebral body fractures or corrective fixation of spinal deformities are planned.

Paravertebral Muscles Show Cross Activation in Double but also in Single AIS curves, with a Correspondent Oxygen Consumption: An Electromyographic and Near Infrared Spectroscopic Study

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Introduction: The role of muscles in scoliosis etiology and/or pathogenesis is somehow controversial. Previous *electromyographic (EMG)* studies have shown different muscle activations between the concave and convex sides of the scoliotic curve, but results are not coherent among studies. To our knowledge very little information is available on the metabolic consumption by paravertebral muscles. *Near Infrared Spectroscopy (NIRS)* provide a non-invasive, in-vivo, real-time monitoring of tissue oxygenation. Our protocol involved the placement of 8 electromyography wireless probes (sEMG) and 2 NIRS probes while subjects were asked to perform the Biering-Sorensen endurance test. The aim of this study is to develop and preliminarily check a model that integrates the assessment of muscle activation (through EMG) and metabolic adaptation (through NIRS) during a fatiguing protocol.

Methods: 19 patients (17 females and 2 males) diagnosed with adolescent idiopathic scoliosis aged between 10 and 15 years were recruited. The EMG probes were bilaterally placed on the paravertebral muscles (D3, D11, L4 level, respectively) and on biceps femoris muscles. The NIRS probes were bilaterally placed at L4 level. Subjects were asked to perform the Biering-Sorensen endurance test until muscle exhaustion¹. Deoxy-hemoglobin (deoxyHHb) was used to evaluate local muscle oxygen consumption. Numeric Rating Scale was administered immediately before and after the test execution. SRS-22 questionnaire was administered before test execution to evaluate the quality of life. In the analysis of the NIRS data we consider only the test not the recovery, then the mean of the total hemoglobin and deoxygenated hemoglobin was extrapolated. sEMG was continuously recorded throughout the endurance test. On the rectified signal, mean frequency (MF) and mean amplitude of the recordings were analysed. The initial and final transient phases of the total time of the test were discarded from the analysis.

Results: We found a difference in muscle activation between sides ($p < 0.001$ at the lumbar level; $p = 0.041$ at the thoracic level), with a greater EMG muscle activity in the convex side of the curves. We also found a correlation ($r=0.8$) between increased electrical activity and increased regional oxygen consumption (Figure). We also found in subjects with a single scoliotic curve, an activation below the curve on the opposite side with an EMG and metabolic pattern equal to subjects with double curves (cross-activation).

Discussion: The study confirmed greater EMG muscle activity in the convex side. A correlation between metabolic and electromyographic activity has been demonstrated also in low back pain patients, but we used a more accurate instrument and an endurance test instead of a dynamic one². The most important discovery concerned muscle cross-activation: an increased muscular and metabolic activation at the convex side of the scoliotic curve, as already reported in some, but not all studies.³ Cross activation of muscles appears not only in double but also single curves, consensual with metabolic consumption. These results can open new research perspectives in etio-pathogenetic research, but also in therapeutic evaluation and understanding (non operative treatment: bracing and scoliosis specific exercises particularly).

1. Villafañe, JH. et al. Validity and everyday clinical applicability of lumbar muscle fatigue assessment methods in patients with chronic non-specific low back pain: a systematic review. *Disabil Rehabil.* 2016 Sep;38(19):1859-71.
2. Kovacs, KM. et al. Localized oxygen use of healthy and low back pain individuals during controlled trunk movements. *J Spinal Disord.* 2001 Apr;14(2):150-8.
3. Oliva-Pascual-Vaca Á. et al. Assessment of paraspinal muscle hardness in subjects with a mild single scoliosis curve: a preliminary myotonometer study. *J Manipulative Physiol Ther.* 2014 Jun;37(5):326-33.
4. Tsai, YT. et al. The electromyographic responses of paraspinal muscles during isokinetic exercise in adolescents with idiopathic scoliosis with a Cobb's angle less than fifty degrees. *Chang Gung Med J.* 2010 Sep-Oct;33(5):540-50.

The effect of Runx2 mixed with cell penetrating peptide on differentiation of mesenchymal stem cells into osteoblasts.

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Introduction: Because the number of medially healthy, elderly patients who need spine fusion surgery or bone injury repair increased, there is a need for new strategies that can enhance bone formation by selective osteogenesis with osteoblast differentiation and proliferation. To investigate the biological effects of cell penetrating peptide (CPP) mixed with transcription factor as Runx2 on differentiation of osteoblasts from rat mesenchymal stem cell (MSC)s.

Methods: MSCs were isolated from bone marrow aspirate harvested from a rat femur. The isolated MSCs were classified into four groups as PBS, Runx2 alone, CPP+Runx2, and osteogenic groups according to the kinds of preparation before seeding. The differentiation of MSCs into osteoblast and proliferation and mineralization of differentiated osteoblasts were assessed using cell counting, alizarin red staining, and gene expression related to osteoblasts. This study was supported by a grant without potential conflict of interest-associated bias in the text of the paper.

Results: The cell count in CPP + Runx2 group was superior to others. The extent of mineralization in CPP + Runx2 group was superior to PBS and Runx2 alone groups. We identified the number of CPP+Runx2 materials located in intra-cytoplasmic area was superior to that in Runx2 group. Also, the expression of osteocalcin in CPP + Runx2 group was higher than others at 7 and 14 days after differentiation of MSC.

Discussion: The CPP combined with Runx2 had an effect on the osteogenic differentiation of MSC. The selective osteogenesis using the CPP combined with Runx2 may be good candidate biomaterials to provide a bone substitute.

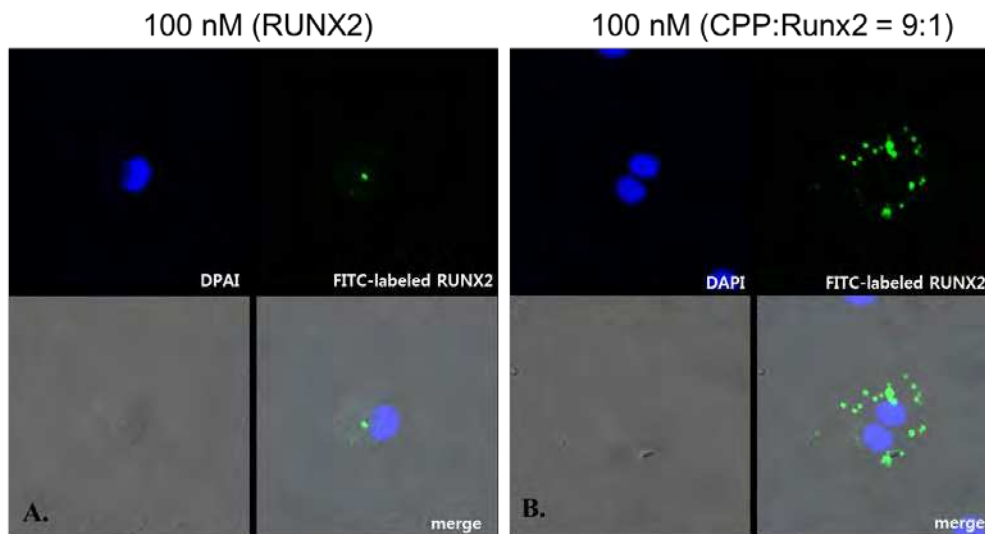


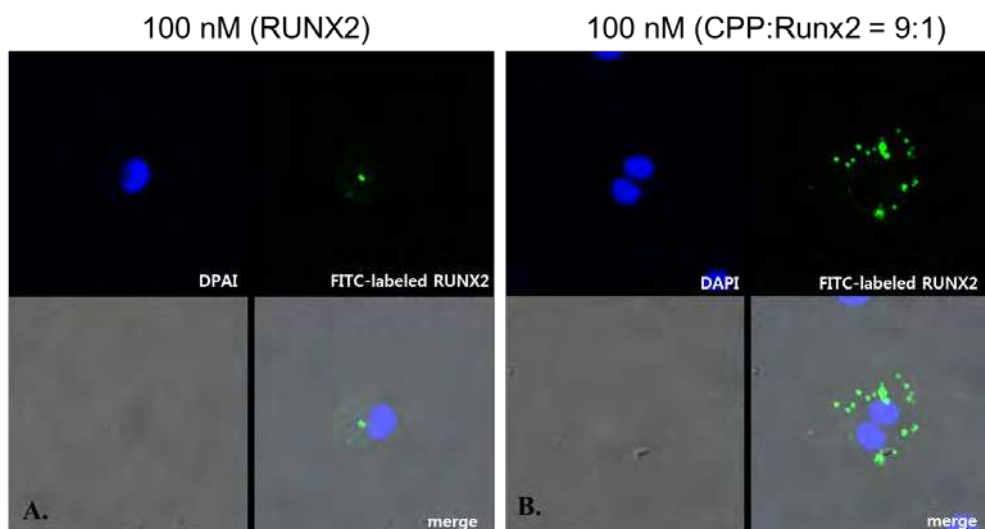
Figure 1. Confocal microscopic analysis

The Nucleus was stained with DAPI (4',6-diamidino-2-phenylindole) (blue color) and FITC (Fluorescein isothiocyanate) labeled Runx2 was shown green color. The number of CPP mixed Runx2 was superior to that in Runx2 (merge images in A and B). DAPI= 4',6-diamidino-2-phenylindole, FITC= Fluorescein isothiocyanate, CPP= Cell penetrating peptide.

Figure 2. Proliferation and differentiation of MSCs according to different groups

Figure A, B and C show the cell counts and degree of alizarine rad staining at 7, 14, and 21 days after seeding. The degree of alizarine red staining in CPP+Runx2 well was similar to that in osteogenic media.

MSC = mesenchymal stem cell, CPP = cell penetrating peptide



The Associations between Bone Material Properties Measured by Fourier Transform Infrared Spectroscopy (FTIR), Bone Microstructure, and Bone Mineral Density among Caucasian Patients Undergoing Lumbar Spinal Fusion

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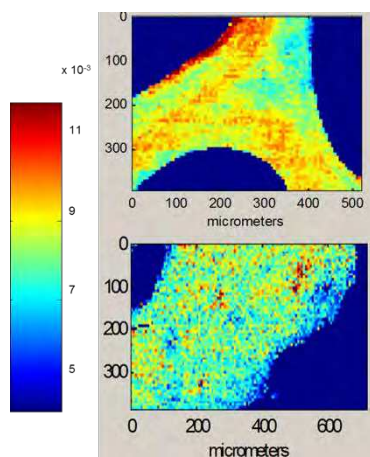
Introduction: Currently, the gold standard for assessing bone health is to measure bone mineral density (BMD) with dual x-ray absorptiometry (DXA). While BMD has been reported to account for 70% of bone strength, the remainder is thought to be related to “bone quality” which consists of two major components: microstructure and material properties. Although many researchers have investigated bone-quality factors, little is known about the mutual relationship between the components. We conducted a comparison study utilizing human bone biopsies from patients who underwent lumbar spinal fusion. We hypothesized that the material property components of bone might be associated with the microstructure and overall BMD measurement.

Methods: We prospectively enrolled 60 patients who underwent posterior lumbar spinal fusion at a single academic institution. Considering racial differences and effect of anti-osteoporotic drugs, we only included Caucasian patients without anti-osteoporotic medications in this study. As part of the surgical procedure, bone specimens were taken from the iliac crest. We assessed parameters from measurements obtained from three different imaging modalities: Fourier transform infrared spectroscopy (FTIR) for material properties, microcomputed tomography for microstructure (Micro-CT), and volumetric BMD (vBMD) of four different sites (L1/2, S1, sacral alae, and iliac crest) measured by quantitative computed tomography (QCT). The correlations between these parameters were analyzed. The statistical analyses were conducted using Pearson’s correlation and linear regression tests with gender stratification. The statistical significance level was set at $p < 0.05$.

Results: We identified 43 (20 male, 23 female, median age 63 (range: 30-83)) Caucasian eligible patients who had complete data of FTIR, micro-CT, and QCT-vBMD. Among women, the carbonate-to-phosphate ratio (C/P) in trabecular bone was positively correlated with the QCT-vBMDs of the S1 body ($r=0.430$, $p=0.040$) and iliac crest ($r=0.497$, $p=0.016$). C/P also correlated with the bone volume fraction (BV/TV) ($r=0.543$, $p=0.007$) and apparent density (AD) ($r=0.531$, $p<0.001$) in micro-CT (Figure 1). After adjusting for age, C/P demonstrated no significant association with vBMDs ($p=0.263$ in S1, $p=0.011$ in iliac crest), but still had significance with respect to BV/TV ($p=0.025$, R-square = 0.24) and AD ($p=0.020$, R-square=0.24). Among men, no variable demonstrated significant correlation (Table1).

Discussion: Although the underlining biological background remains unclear, we found that the material property of bone expressed as C/P was an independent contributing factor for BV/TV and AD in micro-CT. In an age- and BMD-matched case-control study, Boskey et al. demonstrated that low C/P was an independent risk factor for fragility fracture among postmenopausal women. (1) However, the causal mechanism has yet to be well-explained. According to Maquer et al., BV/TV was the strongest contributor of trabecular bone stiffness, accounting for 87% of the variance of the bone elastic properties. (2) Our findings suggest that the association between lower C/P and fracture can be partially explained by the microstructural change expressed as low BV/TV.

Figure 1. FTIR images (C/P) of patients with different levels of BV/TV; (upper) image: patient with high BV/TV (15.9%); (lower) image: patient with low BV/TV (10.2%).



Carbonate to phosphate ratio vs (iliac crest)		Unadjusted		Age-adjusted
		Coefficient	p-value	p-value
Women	BV/TV	0.53	0.01	0.02
	vBMD	0.50	0.02	0.12
Men	BV/TV	-0.10	0.67	0.66
	vBMD	0.18	0.44	0.25

Table 1. Summary of correlation and age adjusted regression analyses

1. Boskey AL, Donnelly E, Boskey E, Spevak L, Ma Y, Zhang W, Lappe J, Recker RR. Examining the Relationships Between Bone Tissue Composition, Compositional Heterogeneity, and Fragility Fracture: A Matched Case-Controlled FTIRI Study. *J Bone Miner Res.* 2016 May;31(5):1070-81. doi: 10.1002/jbmr.2759.
2. Maquer G, Musy SN, Wandel J, Gross T, Zysset PK. Bone volume fraction and fabric anisotropy are better determinants of trabecular bone stiffness than other morphological variables. *J Bone Miner Res.* 2015 Jun;30(6):1000-8. doi: 10.1002/jbmr.2437.

Characteristics of psychological factors in Japanese low back pain patients ~Comparison between Japan and the United States using Comprehensive Psychological Factor Rating Scale (OSPRO–YF)~

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Introduction: In recent years, psychological factors in patients with low back pain (LBP) have attracted more and more attention. Patient-based evaluation is a common strategy to understand these factors. However, some of the clinical limitations in evaluating psychological factors are that the ways of expressing pain and the influence of stress can differ depending on cultural and ethnic characteristics.

We aimed to compare the characteristics of psychological factors in Japanese LBP patients with US counterparts using the Optimal Screening for Prediction of Referral and Outcome Yellow Flag Assessment Tool (OSPRO–YF, Lentz, et al. JOSPT,2016), which evaluates psychological factors such as depression, fear avoidance, and pain coping.

Methods: We administered a Japanese version of OSPRO-YF, translated based on the international guidelines for scale translation, to Japanese LBP patients who visited our hospital. We statistically compared the scores between the Japanese cohort and a previous counterpart study from the US. P < 0.05 was considered to be statistically significant.

Results: The present study included 108 Japanese subjects (ave. 64.7 ± 14.6 yo, m/f = 31 /77), and the previous counterpart study 118 Americans. The Japanese subjects showed significantly higher scores in overall score (Japan / US; 36.9 ± 9.7 / 32.5 ± 11.7 points), depression (12.0 ± 2.7 / 8.0 ± 2.6 points) and pain coping (13.6 ± 5.4/ 10.9±5.8 points) (P<0.05, ea), while the fear avoidance score (11.3 ± 4.9 / 13.6 ± 6.3 points) were significantly higher in Americans.

Discussion: Japanese LBP patients showed significantly higher scores in overall OSPRO-YF score, depression, and pain coping score. Fear avoidance scores were lower in the Japanese cohort, indicating that they are more anxious toward pain than American patients, while their pain acceptance and self-efficacy are higher with less pain avoidance thinking. The result may be due to acquired cultural and inherent genetic differences, and also can reflect a previous study reporting that Japanese patients have a higher tendency to be more anxious and subjective. We should consider the cultural differences and specificity in evaluating psychological factors of LBP patients using the OSPRO–YF.

	Depression	Fear avoidance	Pain coping	Total
JAPAN	12.0±2.7*	11.3±4.9*	13.6±5.4*	36.9±9.7*
US	8.0±2.6*	13.6±6.3*	10.9±5.8*	32.5±11.7*

(points, *: P<0.05)

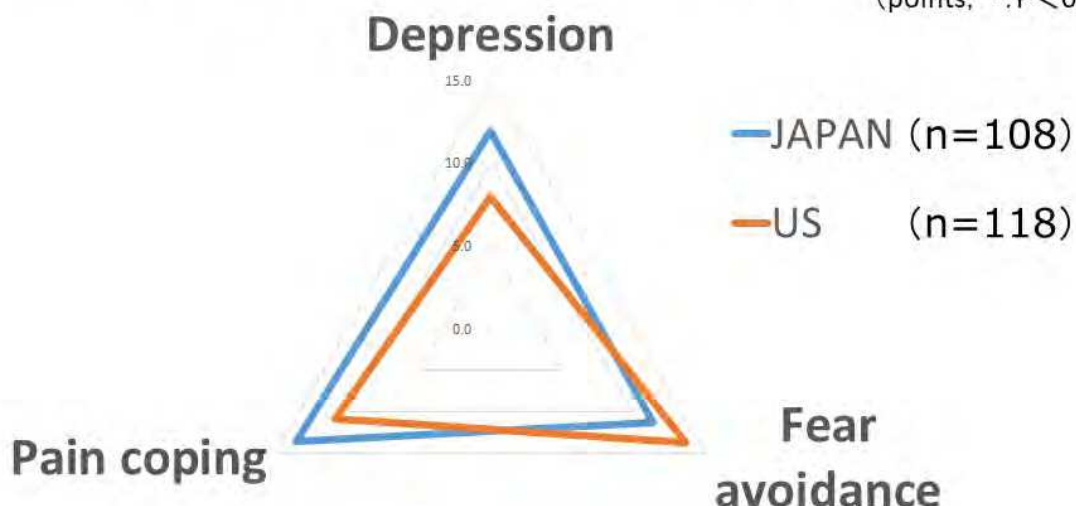


Fig. Psychological factors in low back patients (OSPRO-YF)

Correlation between osteoporotic vertebral fracture and abdominal trunk muscle strength in the elderly women

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Introduction: We developed an innovative exercise device for abdominal trunk muscles that also measures muscle strength (Figure). This device enables patients to perform abdominal trunk muscle exercises in a sitting position without requiring movement of the lower back. It has a built-in measurement system for abdominal trunk muscle strength. Our previous studies demonstrated that our device was a reliable tool to measure abdominal trunk muscle strength, and strengthening exercise with the device increased the strength and activated the diaphragm and pelvic floor muscles as well as the abdominals. We investigated the correlation between the strength and spinal deformity in the lumbar spine in the elderly women.

Methods: One hundred ninety-two elderly women, who were scheduled to have surgeries for degenerative diseases of the lower extremities in our hospital. Before surgery, body height, body weight, body-mass index, grip strength, knee extensor muscle strength, and bone mineral density of the lumbar spine (L-BMD) were measured. Abdominal trunk muscle strength was also measured using our device. A full-spine standing radiogram and NRS of back pain from 0 to 4 was taken in all subjects. According to the findings of the radiogram, the subjects were divided into the 4 groups consisting of the normal group (n = 123) without specific findings, the spondylolisthesis group (n = 30) with degenerative spondylolisthesis at sagittal plane in the lumbar spine, the scoliosis group (n = 15) with degenerative scoliosis in the lumbar spine, and the fracture group (n = 24) with osteoporotic vertebral fracture in the lower thoracic or lumbar spine. A Tukey-Kramer honestly significant differences test was used to compare all the measurements including the abdominal trunk muscle strength in the 4 groups. To identify factors that were associated with the radiological findings of osteoporotic vertebral fracture, a multivariate logistic regression analysis was performed.

Results: The average abdominal trunk muscle strength was 5.6 kPa in the normal group, 5.5 kPa in the spondylolisthesis group, 4.6 kPa in the scoliosis group, and 3.0 kPa in the fracture group. That of the fracture group was significantly lower than those of the normal and spondylolisthesis groups. Among the 4 groups, there were no significant differences in the other measurements including L-BMD and NRS of back pain. Of the 24 cases in the fracture group, 20 had asymptomatic vertebral fractures without any treatment histories with braces and/or surgeries. In a multivariate analysis, a weakness of the abdominal trunk muscle strength and a low L-BMD were associated with the findings of osteoporotic vertebral fracture in the cross-sectional study.

Discussion: The results of this study indicated that a weakness of the abdominal trunk muscle strength in the elderly women was associated with vertebral fracture in the lower thoracic or lumbar spine. The strength measurement with the device can be a risk assessment of osteoporotic vertebral fracture.



Relationship between spinopelvic parameters and chronic neck, back and multiregional pain

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Introduction: Sagittal balance plays an important role in the transmission of shearing and compressive forces through the anterior and posterior vertebral column. Abnormal sagittal alignment may alter normal load transmission and spinal mobility, which leads to disc degeneration and spinal pain. The pain can be localized in the neck and back, or it can be multiregional in some cases. Several studies have focused on the sagittal and spinopelvic parameters in different conditions, but information on how these parameters vary in individuals with different regions of spinal pain is still limited. As such, this study aims to assess the spinopelvic parameters in patients with neck, back and multiregional (neck and back) pain, and its association with structural changes of the lumbar spine.

Methods: 118 Southern Chinese subjects were recruited from the Hong Kong Neck/Low Back Pain Cohort (62% females; mean age: 53.4 years). Only those subjects with complete clinical profile, no history of trauma and no visible structural spine deformity, such as scoliosis and spondylolisthesis were included. Standing lateral full-length radiographs were achieved for all patients. The sagittal vertical axis (SVA), Global tilt angle (GTA), T1-pelvic angle (T1PA), T1 sagittal tilt (T1ST), lumbar lordosis (LL), pelvic incidence (PI), sacral slope (SS), and pelvic tilt (PT) were assessed. The lumbar lordosis index was also calculated (LLI=LL/PI). Radiographs were also used to assess *lumbar* discs for the presence or absence of disc space narrowing and osteophytes. Scores were assigned to each subject on the basis of presence or absence of disc space narrowing from 0-5 for each five lumbar segments and 0-10 for the osteophytes on each endplate of five lumbar segments. Subject demographics including body mass index (BMI) was also obtained. Data was analyzed using One-way ANOVA and regression analysis.

Results: Intra-rator reliability for all measurements was found to be excellent. There were 24% patients with neck pain, 56% with back pain and 20% reported both neck and low back pain. No significant differences were observed between age, BMI, scores of lumbar disc space narrowing and osteophytes among the three groups. SVA was significantly higher in patients with only back pain ($p=0.01$) while T1ST and LL were significantly lower in these patients ($p=0.01$ & $p=0.01$). Subjects with multiregional pain did not show any significant difference with any of the parameters. Significant association was observed between osteophyte scores and age ($r=0.35$, $p<0.001$), BMI ($r=0.21$, $p=0.003$), LL ($r=-0.18$, $p=0.03$) and LLI ($r=-0.24$, $p=0.003$). Disc space narrowing showed significant association with BMI ($r=0.17$, $P=0.03$), PI ($r=-0.21$, $p=0.001$) & SS ($r=-0.23$, $p=0.006$).

Discussion: The results of the study reveal that the main markers of overall sagittal balance (SVA and T1ST) are closely associated with low back pain as compared to neck or multiregional pain. Any deviation in the sagittal balance tends to have a stronger link with those lumbar spine segment changes that can lead to back pain. Structural changes such as osteophytes and disc space narrowing seen in these chronic pain subjects are linked with PI, LL and SS, but this relationship requires further study.

Feedforward activation of quadratus lumborum is equivalent to that of transversus abdominis during shoulder abduction movement

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Introduction: Transversus abdominis (TrA) attaching to the lumbar vertebrae through the thoracolumbar fascia has a feedforward activation and therefore plays an important role in stabilizing the lumbar vertebrae. Similar to TrA, quadratus lumborum (QL) attaches directly to the lumbar transverse processes in the deep layer of the trunk muscles. If QL also has a feedforward activation, further contribution to the lumbar stabilization by QL is expected in addition to TrA. To clarify the feedforward activation of QL, this study aimed to compare the muscle onset timing of QL with that of TrA and the other trunk muscles during shoulder movement.

Methods: Thirteen healthy males participated in this study. Participants stood in the relaxed standing position and abducted right shoulder joint to 135 degrees as fast as possible after the lamp stimulus ahead. Measurements were repeated three times. The fine-wire intramuscular electrodes were inserted into the left TrA, QL anterior (QL-A) and posterior (QL-P) at the L3–4 level guided by using ultrasonography. The surface electrodes were attached to the left rectus abdominis (RA), external oblique (EO), internal oblique (IO), lumbar erector spinae (LES), lumbar multifidus (LMF) and right middle deltoid (MD). The muscle activities were measured by a wireless EMG telemeter system set at 2000Hz. The onset timing of each muscle was defined the point where the EMG amplitude exceeded a threshold of 2 standard deviations above baseline for 20ms constantly. Baseline threshold was decided by averaged amplitude for 50ms at relaxed standing position before the lamp stimulus. Onset time of MD was defined as zero and time difference between MD and other muscles were calculated to determine the relative onset time of each trunk muscle. The average time of three trials was taken as the representative value of each muscle. One-way ANOVA with post-hoc Tukey test was used to compare the onset time of each trunk muscle. The significance level was set at $p < 0.05$.

Results: The onset of RA was excluded from statistical analysis since EMG amplitude exceeded baseline threshold in only 5 of the 13 participants. There were no significant difference among onset of TrA (-23ms), QL-A (-12ms) and QL-P (-14ms). However, the onset of TrA, QL-A and QL-P were significantly earlier than that of EO (+22ms), IO (+57ms), LES (+27ms) and LMF (+29ms). Additionally, the onset of EO was significantly earlier than that of IO ($p < 0.05$, figure).

Discussion: The results of this study indicated that the feedforward activation of QL was equivalent to that of TrA. Since QL demonstrates high activity during ipsilateral trunk lateral bending, we suggested that QL showed the feedforward activation to control the trunk posture during rapid contralateral shoulder abduction. Previous studies have reported differences in the feedforward activation of TrA with and without low back pain. The feedforward activation of QL may also contribute to prevent low back pain.

Disclosures: This study was supported by a grant-in-Aid for Scientific Research (C) from the Japan Society for the Promotion of Science. No conflicts of interest are declared.

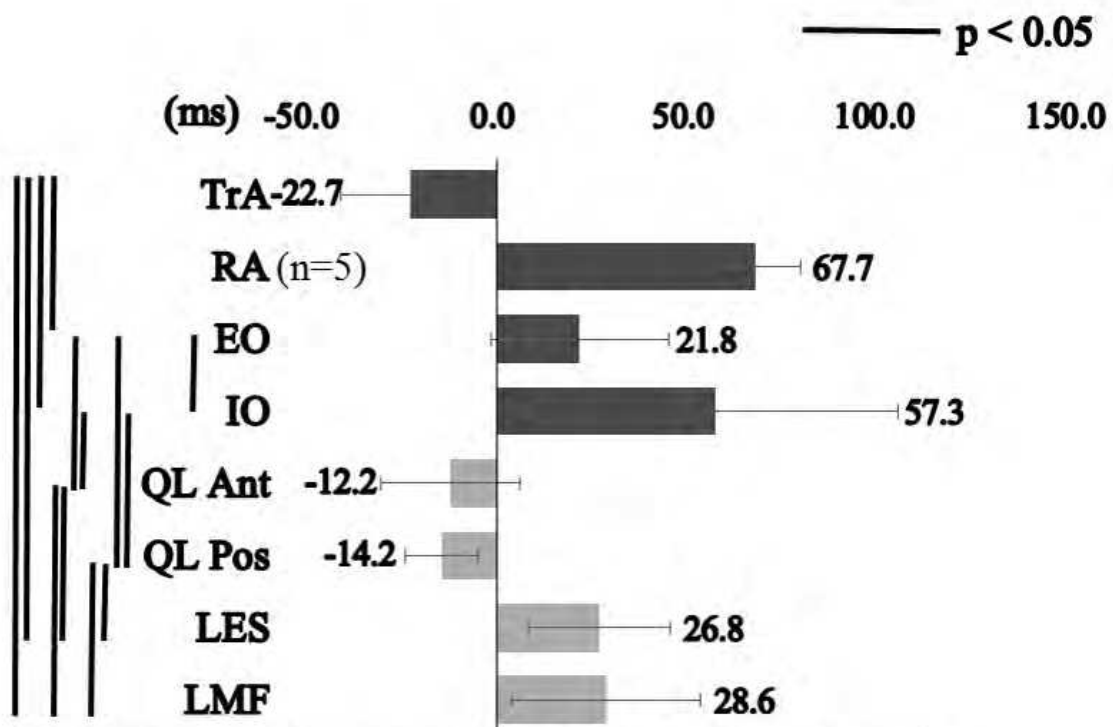


FIGURE. The relative onset time of each trunk muscle based on the onset time of MD during shoulder abduction

Association between low back pain prevalence and work engagement in Japanese hospital workers

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Introduction: Working in the positive and fulfilled psychological state means a state of high level work engagement, and it is expected that health conditions of the people who are engaged in their work are better than of the workaholism. Although there are several reports on the relationship between workaholism and low back pain (LBP), there are no reports investigating relationships between work engagement and LBP. The purpose of this study is to clarify the relationship between LBP prevalence and work engagement of hospital workers, using both scales for work engagement and workaholism.

Methods: Among hospital or medical facility workers, 699 people had cooperated by participating in this study. The study included a questionnaire survey on LBP, lifestyle habits and work conditions. At the same time measurements of their muscle mass and muscle strength were also carried out. The median of the Utrecht Work Engagement Scale for measuring work engagement (WE) and The Dutch Workaholism Scale for measuring workaholism (WH) were used to classify the participants into four groups: the group with high WE and low WH, the group with low WE and low WH, the group with high WE and high WH, and the group with low WE and high WH respectively. First, LBP prevalence of four groups was compared. Next, we performed multiple logistic regression analysis focusing on the presence or absence of LBP as the dependent variable, the above four groups as the independent variable, and body functions, lifestyle habits, working environment, psychosocial and psychiatric factors as covariates.

Results: The group with high WE and low WH had the lowest LBP prevalence. The multivariate-adjusted odds ratios (95% confidence interval) for LBP prevalence were 1.77 (1.05 - 2.98) among the group with low WE and low WH, 2.01 (1.19 - 3.37) among the group with high WE and high WH, and 2.33 (1.32 - 4.09) among the groups with low WE and high WH, relative to the ratio among the group with high WE and low WH group.

Discussion: Prevalence of LBP in the high WE low WH group was found to be lower than those in the other groups. Even when WH is high, LBP was low if WE is high. Among hospital workers, the workaholism alone is not sufficient to get the precise measurement of the extent of the prevalence of LBP. It may be also necessary to consider the interaction with work engagement.

Chronic coccydynia treated conservatively with a 3-year follow up. A series of 120 patients

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Introduction: The long term results of the conservative management of coccydynia are not known. We present a study with two goals: to report these results with a mean follow up of 3 years and to search predictors of a good result.

Methods: 141 new consecutive patients with chronic coccydynia (>2 months) were enrolled in 2015. At inclusion, they were administered a VAS (sitting position, 10cm) and two questionnaires: the Paris Questionnaire (PQ, 10 points) and a partial adapted Dallas Questionnaire (sections relevant to coccyx pain, DQ, 30 points). They were managed first with dynamic films and a steroid injection in the affected disc or at the apex (spicule). The second line treatment was a repeated injection or manual therapy or surgery if indicated. Sitting aids were systematically advised. The follow up consisted of a telephone interview and a VAS at 6 months and 3 years. The results were categorized as follow; good: VAS≤3, fair: VAS>3 and ≤5 and failure: VAS>5 or coccygectomy (whatever its result). *Statistics.* Bivariate and multivariate analyses were carried on.

Results: *At baseline*, they were 106 females (75.2%) and 35 males, age 43±10 yrs. A provocative event was found in 42.7% (trauma: 40, child delivery: 12 (of which 4 fractures and 5 dislocations), loss of weight: 9 (of which 7 spicules). VAS, PQ and DQ: 6.4±1.1, 7.0±2.6 and 14.3±2.1 respectively. The dynamic films showed 35 rigid coccyges (25%), of which 25 spicules, 23 with normal mobility (14%), 29 with hypermobility (29%), 50 with dislocation (37%) and 4 fractures with pseudoarthrosis. 120/141 (85.1%) had a telephone interview at 6 months and 3±0.5 years. 21/141 were lost for follow up. *At 3 years*, 56 patients (46.7%) had a good result with the conservative treatment (VAS≤3). According to the dynamic films, patients with spicule or hypermobile coccyx did better than those with normal mobility (i.e. no visible lesion) or dislocation (the most severe lesion). According to patients'opinion, the treatment which worked the best was injections for 33, manipulation or physio for 10, acupuncture or psychotherapy for 3 and none, with a natural recovery, for 10 (good result group). 52 patients (43.3%) had a poor result, which should be alleviated by the fact that 25/52 had a coccygectomy and 7 more declined the operation despite a correct indication, letting 20 cases with intractable pain (16.7%). 12 patients (10.0%) had a fair result.

In a bivariate analysis, the factors of good prognosis at 3 years ($p<.05$) were a low score at the Paris and Dallas Questionnaires, a lower pain intensity on the VAS, the lack of a provocative event, no dislocation on the dynamic films and a shorter duration of complaints at inclusion and *in a multivariate analysis*, the lack of a provocative event and a low score at the Dallas Questionnaire.

Discussion: The results of conservative management with a long term follow up are encouraging, especially if one considers that a coccygectomy can be recommended in certain cases of the failure group.

Multidisciplinary pain management program for the patients with chronic low back pain in Japan

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Introduction: Multidisciplinary pain management is a useful method for the treatment of chronic low back pain. A biopsychosocial model of well-being is a very important concept in the multidisciplinary treatment. The biopsychosocial model is a general model or approach stating that biological, psychological, and social factors play significant roles in human functioning in the context of disease and illness. In Japan, we are implementing a multidisciplinary pain management program guided by the IASP recommendations for such a program. Currently there are few facilities in Japan that administer a multidisciplinary pain management program, especially an inpatient program. The purpose of this study is to describe our inpatient pain management program using the biopsychosocial method of self-pain management, and to report preliminary results of the program.

Methods: Our 3-week inpatient pain management program is implemented by a team of orthopaedic surgeons, psychiatrists, physical therapists, clinical psychologists, nurses, pharmacists, and nutritionists. The program consists of exercise therapy by physical therapists, psychological therapy by psychologists, and cognitive behavior therapy by each specialist. The goals of the program are to return the patient to a functional daily life habit. The program includes education in coping methods for chronic low back pain. Participation in some lectures and psychotherapy programs includes not only patients but also their family members or significant others. The patients are evaluated using a brief pain inventory scale(BPI), a pain catastrophizing scale (PCS), a pain disability assessment scale(PDAS), a hospital anxiety and depression scale(HADS), a pain self-efficacy questionnaire(PSEQ), and the EQ-5D. Physical functions(flexibility, muscle endurance, walking ability and physical fitness)are also evaluated. Statistical analyses of our data were performed using the paired t-test and Wilcoxon matched pairs signed rank sum test with Bonferroni correction after Friedman test. Values of $P < 0.05$ were considered to indicate statistical significance.

Results: 23 patients (8 male and 15 female; 20-79 years old (Average 52.2 years old)) were analyzed from April 2015 to March 2018. Comparing results between before and after the program, the following statistically significant improvement were seen in BPI, PCS, HADS anxiety and depression scale, PSEQ, EQ-5D, and physical function(muscle endurance and walking ability). Eight (4 male and 4 female) of 23 patients could be analyzed 3 and 6 months after the program. Statistically significant improvement was seen in PCS (rumination and helplessness)(before the program-three months after the program and before the program-six months after the program), PDAS and HADS(anxiety)(before the program-six months after the program),HADS(before the program-six months after the program),PSEQ (before the program-after the program) , and physical function(before the program-after the program).

Discussion: We developed an inpatient pain management program. We may be able to improve the coping mechanisms of our patients for dealing with chronic low back pain, and that the program can improve their quality of life and physical function. Our inpatient multidisciplinary pain management program is being expanded to better assist the patients with chronic low back pain.

Can the conventional MRI substitute for the 3D-MRI to diagnose lumbar foraminal stenosis?

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Introduction: The diagnosis of lumbar foraminal stenosis (LFS) is still difficult. We have reported the utility of 3D-MRI by calculating a novel diagnostic parameter, foraminal stenotic ratio (FSR) (Yamada K, et al. Spine J.2017). FSR indicates the degree of fat obliteration in the neural foramen, and reflects severity of the stenosis. FSR also reportedly contributed to distinguish patients requiring surgery among symptomatic LFS patients. However, measurement of FSR using 3D-MRI is time-consuming. FSR also can be calculated on conventional MRI. The purpose of this study was to investigate whether the conventional MRI substitute for the 3D-MRI on evaluation of FSR.

Methods: A total of 77 patients, 154 foramina at L5-S, were investigated in this study. This study included consecutive patients who were performed both T2 3D-MRI and conventional T1 sagittal MRI for lumbar degenerative disorders. Patients who are under 40 years old or underwent surgery at L5-S or implantation at L5 were excluded. FSR were calculated by the reported methods on reconstructed images using 3D-MRI (3D-FSR). FSR were also evaluated by ratio of slices which showed fat-obliteration around nerve root to the slices of neural foramen on parasagittal images using conventional MRI (con-FSR). Difference and correlation between 3D-FSR and con-FSR were evaluated.

Results: The average evaluated slices per a foramen were 20.2 by 3D-FSR and 3.8 by con-FSR. As a whole, the difference absolute value between 3D-FSR and con-FSR was 9.6% and correlation coefficient was strong (0.893, $p < 0.001$). In patients with con-FSR < 50%, the difference was 5.1% and correlation coefficient was 0.777. In contrast, the difference was 20.2% and correlation coefficient was 0.54 in patients with con-FSR \geq 50%. Subject included 6 patients who have succeeded conservative treatment for LFS, and 11 patients who have required surgical treatment for LFS. The 3D-FSR showed significant difference between patients with successful conservative treatment and patients requiring surgery (41.7% and 87.7%, $p < 0.001$), however, the con-FSR did not ($p = 0.21$).

Discussion: The con-FSR were sufficiently reliable for 3D-FSR in patients with < 50%. Therefore, patients with no or slight LFS on conventional MRI might be shown same assessment even on the 3D-MRI. However, the reliability was weak in patients with \geq 50%. Patients with 3D-FSR \geq 50% were reportedly likely to require surgical treatment. Therefore, additional 3D-MRI investigation is required in case with \geq 50% of con-FSR to assess actual severity of the stenosis. In conclusion, Conventional MRI was not fully substitute for 3D-MRI on evaluation of FSR. 3D-MRI is required in not all cases, but in case with suspected LFS on conventional MRI.

Hypertrophy of the Ligament Flavum in Degenerative Lumbar Stenosis Associated with Fibrosis Induced by Macrophage

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Introduction: Age-related fibrosis and decrease in the elastin-to-collagen ratio of the ligament flavum (LF), however, macrophages are key cells for the inflammatory processes as regulators directing inflammation to chronic pathological changes. The objectives of this study was to investigate the followings: (1) The role of macrophage infiltration on hypertrophy of the LF in degenerative lumbar stenosis (DLS) compared with that of non-degenerative spinal condition (NDS) of the lumbar spine; (2) Correlation between expression of antibodies against macrophages and thickness of LF.

Methods: Concentrations of macrophage infiltration were analyzed in the surgically obtained LF specimens from DLS (n =22) and NDS (n =17). The localization of anti-macrophage antibodies (Mac-387, CD 68, F4/80) within the LF was determined using immunohistochemical study. Plasma levels of soluble macrophages were measured by enzyme-linked immunosorbent assay (ELISA), respectively. The thickness of the LF was measured with axial T1-weighted magnetic resonance imaging (MRI).

Results: The cells that express anti-macrophage antibodies ratio in the LF observed in DLS group were statistically higher than in NDS group. Mac-387⁺ cell counts is 14.86±6.81 in group A and 6.23±4.86 in group B ($P=0.000$). CD68⁺ cell counts is 15.77±7.36 in group A and 10.29±4.70 in group B ($P=0.012$). F4/80⁺ cell counts is 16.04±7.42 in group A and 9.52±3.74 in group B ($P=0.001$). In ELISA, the plasma levels of soluble macrophages was significantly increased in DLS compared with patients in the other groups ($P=0.006$). Thickness of LF in patients was significantly correlated with only F4/80 antibody ($R^2=0.319$, $P=0.003$).

Discussion: In this study, anti-macrophage antibodies-expressing cells are significantly related to LF hypertrophy from patients with spinal stenosis. These findings suggest that enhanced macrophage infiltration contributes to the disease process by hypertrophied LF in DLS. Considering the roles of macrophage, accumulation macrophages within the LF are prominent pathobiologic features of human LF hypertrophy. Unregulated expression of macrophage cooperatively augments the recruitment of neutrophils into the affected LF, leading to generation of chemoattractant proteins (chemokines) results in attraction of the first line of defense. This recruitment of mononuclear cells might induce fibroblast and inflammatory cell proliferation in the LF in DLS patients. the hypertrophied LF of DLS patients show significant increases in anti-macrophage antibodies-expressing cells are significantly related to LF hypertrophy suggesting that the elevated macrophage activity might play a role in LF hypertrophy induced by tissue inflammation and fibrosis. In conclusion, the hypertrophied LF of DLS patients show significant increases in anti-macrophage antibodies-expressing cells are significantly related to LF hypertrophy suggesting that the elevated macrophage activity might play a role in LF hypertrophy induced by tissue inflammation and fibrosis.

Relationship among spinal alignment, bone mineral density, and muscle mass in elderly osteoporosis patients

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Introduction: Patients with osteoporosis often complain of back pain associated with pathological vertebral fractures which cause abnormal spinal alignment. Recently, the relationship between abnormal spinal alignment and low back pain has become increasingly more apparent, and corrective surgery for such conditions is being performed. However, few reports attribute muscles as the cause of abnormal spinal alignment. We hypothesized that decreasing muscle mass in elderly patients with osteoporosis could also cause abnormalities in spinal alignment. This study evaluated the relationship among spinal alignment, bone mineral density, and muscle mass in elderly patients with osteoporosis.

Methods: A total of 50 patients aged over 75 years with severe osteoporosis and pathological vertebral fractures were included in this study. In all cases, we evaluated the sagittal vertical axis (SVA), pelvic tilt (PT), pelvic incidence minus lumbar lordosis (PI-LL), bone density by dual-energy X-ray absorptiometry analysis, and trunk and limb muscle mass by bioelectrical impedance analysis (TANITA MC-780A). Low back pain was evaluated by the Oswestry Disability Index (ODI). Trunk and limb muscle mass computations were performed by dividing body weight by body height squared. Corrected trunk muscle mass and corrected limb muscle mass (skeletal mass Index: SMI) were also measured. Correlations among parameters were evaluated using Pearson's correlation coefficient.

Results: The mean age of patients was 80.3 years and the average number of vertebral bodies fractured was 3.4. Significant low positive correlations were identified between PI-LL and trunk muscle mass, SVA and trunk muscle mass, and limb muscle mass and PT ($r = 0.30$, $r = 0.31$, and $r = 0.30$, respectively). When patients were divided into 2 groups, a normal group and an abnormal spinal sagittal alignment (imbalanced) group which had a PI-LL of 10 degrees or more compared with the normal group, the ODI score was higher and more vertebral body fractures occurred in the imbalanced group versus the normal group ($p < 0.05$). However, both corrected trunk muscle mass and SMI were higher in the imbalanced group versus the normal group ($p < 0.05$).

Discussion: Patients with osteoporosis and a spinal sagittal imbalance had more vertebral fractures and a higher risk of low back pain, which was in agreement with our hypothesis. Interestingly, patients with an abnormal spinal sagittal alignment tended to have a higher trunk and limb muscle mass than we had hypothesized. The mechanism for sagittal plane imbalances causing low back pain could be muscle fatigue produced by continuous paravertebral muscle contraction, as has been previously reported. Significantly higher than normal muscle mass and high back pain scores in the patients in this study may reflect such an etiology. However, since muscle mass is not necessarily proportional to muscle strength, a concurrent evaluation of muscle strength is necessary in the future.

Severe lumbar intervertebral disc degeneration is associated with Modic changes and fatty infiltration in the paraspinal muscles at all lumbar levels, except L1-L2: A cross-sectional analysis of 50 symptomatic females and age-matched 50 symptomatic males

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Introduction: Low back pain is a common public health problem associated with lumbar intervertebral disc degeneration. It is still unclear, whether intervertebral disc degeneration is an isolated process or accompanied by other degenerative events. We aimed to analyze whether disc degeneration was associated with vertebral end-plate changes and fatty infiltration in the paraspinal muscles. We also aimed to identify whether severity of disc degeneration influenced this association.

Methods: We conducted this cross-sectional magnetic resonance imaging (MRI) study in patients who visited outpatient clinics with low back pain and had lumbar spine MRIs between 2017 and 2018 at a community-based hospital. We evaluated lumbar spine MRIs of the patients who met the following criteria: History of low back pain with/without leg pain that lasted for more than 6 weeks, having no motor and/or sensorial deficits, having normal peripheral vasculature. Intervertebral disc degeneration, vertebral end-plate changes, and fatty infiltration in the multifidus, erector spinae and psoas muscles at all lumbar intervertebral disc levels were evaluated on lumbar spine MRIs of 50 symptomatic females and age-matched 50 symptomatic males.

Results: We evaluated lumbar spine MRIs of 50 symptomatic females and age-matched 50 symptomatic males (mean age 40,03±12,97 years; mean BMI: 26,96±4,90 kg/m²). Females had higher lumbar intervertebral disc degeneration scores at L4-5, L5-S1 levels and in total ($p < 0,042$). Females had more fatty infiltration in the multifidus and erector spinae muscles at L4-5 and L5-S1 levels, while males had more fatty infiltration in the psoas muscle at L5-S1 level ($p < 0,041$). Patients with severe intervertebral disc degeneration were more likely to have increased fatty infiltration in the multifidus and erector spinae muscles. The rate of having vertebral end-plate changes was also higher in patients with severe intervertebral disc degeneration.

Discussion: Severe disc degeneration in the lumbar spine is closely associated with Modic changes, and fatty infiltration in the multifidus and erector spinae muscles. We suggest that disc degeneration is not an isolated event. It is rather a continuum of the events that could be clearly shown in the future prospective large-sample sized studies.

References:

1. Luoma K, Riihimaki H, Luukkonen R, Raininko R, Viikari-Juntura E, Lamminen A. Low back pain in relation to lumbar disc degeneration. *Spine (Phila Pa 1976)*. Feb 15 2000;25(4):487-492.
2. Hicks GE, Morone N, Weiner DK. Degenerative lumbar disc and facet disease in older adults: prevalence and clinical correlates. *Spine (Phila Pa 1976)*. May 20 2009;34(12):1301-1306.
3. Teichtahl AJ, Urquhart DM, Wang Y, et al. Lumbar disc degeneration is associated with modic change and high paraspinal fat content - a 3.0T magnetic resonance imaging study. *BMC Musculoskelet Disord*. Oct 21 2016;17(1):439.

Poor posture causes shoulder girdle muscles hypoactivity and lower back muscles hyperactivity during using a smartphone

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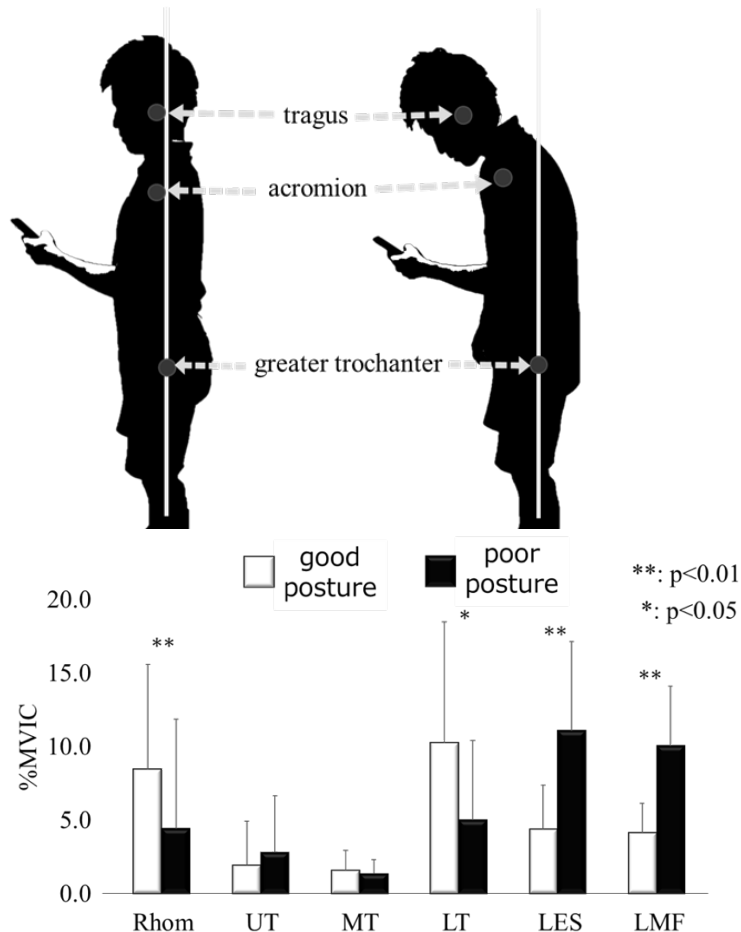
Introduction: Many people often present poor posture such as forward head and rounded shoulder during using a smartphone. Poor posture during using a smartphone is considered as a risk of shoulder, neck, and low back pain. The aim of the present study was to clarify the activity of shoulder girdle and lower back muscles in different postures during using a smartphone.

Methods: Sixteen healthy males participated in this study. Participants maintained two postures, good posture and poor posture, for 10 seconds with holding a smartphone (figure1). The fine-wire intramuscular electrodes were inserted into the rhomboid major (Rhom) under ultrasonography guidance. The surface electrodes were attached to the upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), lumbar erector spinae (LES), and lumbar multifidus (LMF). The muscle activities were measured by a wireless EMG telemeter system. Sampling rate was set at 1000Hz. Maximum voluntary isometric contractions (MVIC) for the shoulder girdle and lumbar muscles were measured as an index of standardization after completing all of the posture trials. The analysis section was set to the middle 5 seconds of each posture holding for 10 seconds. EMG activity was represented as percent maximum voluntary isometric contraction (%MVIC). %MVIC was calculated by which the root mean square value was normalized by the root mean square value of the MVIC. Student t test was used to compare each muscle activity. The significance level was set at $p < 0.05$.

Results: Significantly higher muscle activities were showed in poor posture compared to good posture in the LES ($11.1 \pm 6.1\% \text{MVIC}$ vs $4.4 \pm 3.0\% \text{MVIC}$ respectively, $p < 0.01$) and LMF ($10.0 \pm 4.0\% \text{MVIC}$ vs $4.1 \pm 2.0\% \text{MVIC}$ respectively, $p < 0.01$). Significantly lower muscle activities were showed in poor posture compared to good posture in the Rhom ($4.4 \pm 7.5\% \text{MVIC}$ vs $8.4 \pm 7.2\% \text{MVIC}$ respectively, $p < 0.01$) and LT ($5.0 \pm 5.4\% \text{MVIC}$ vs $10.2 \pm 8.3\% \text{MVIC}$ respectively, $p < 0.05$). There was no significant difference between each posture for UT ($2.8 \pm 3.9\% \text{MVIC}$ vs $1.9 \pm 3.0\% \text{MVIC}$ respectively, $p = 0.09$) and MT ($1.3 \pm 1.0\% \text{MVIC}$ vs $1.6 \pm 1.3\% \text{MVIC}$ respectively, $p = 0.54$, figure2).

Discussion: From the results of this study, poor posture displayed less Rhom and LT activity, greater LES and LMF activity than those in good posture. It is suggested that weakness or underactivity of Rhom and LT can cause forward head and rounded shoulder posture. It is considered that poor posture which head and shoulder displace forward results in anterior shift of center of gravity and increase trunk flexion torque. As a result of trunk flexion torque increased, the muscle activity of LES and LMF, which generate trunk extension torque, increased and these worked to offset trunk flexion torque. The results of the current study indicate that hypoactivity of shoulder girdle muscles lead to hyperactivity of lower back muscle and might be a cause of musculofascial low back pain.

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The importance of mechanical forces affecting for the union of osteoporotic vertebral fracture

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Introduction: The treatment of osteoporotic vertebral fracture (OVF) has been focused on pharmaceuticals for osteoporosis to encourage union. However, OVF will be occurred by mechanical external force, and cannot be ignored for disturbing union of OVF naturally. The aim of this study is to determine the influence of external mechanical force against the internal healing potential for the union of OVF.

Methods: Sixty-seven patients who were treated non-operatively for a single-level thoracolumbar fresh OVF were enrolled. They were treated with soft lumbosacral orthosis and underwent osteoporosis treatment randomly assigned to 20 ug of daily teriparatide (TPD) or 35 mg of weekly alendronate (BP). Background status of age, gender, medical history, past vertebral fracture, femoral bone mineral density (fBMD) measured using dual-energy X-ray absorptiometry, nutritional status (albumin, calcium adjusted for albumin level, phosphorus), estimated glomerular filtration rate (eGFR), BAP (bone formation marker) and TRACP5b (bone resorption marker) at 24 weeks after injury were measured for internal biochemical evaluation affecting for fracture healing. Radiographic parameters included pelvic incidence (PI), pelvic tilt (PT), lumbar lordosis (LL), thoracic kyphosis (TK), sagittal vertical axis (SVA), and distance between SVA and the center of fractured vertebra (DSVA) using an upright whole spine radiograph at 24 weeks after injury. Posterior wall fracture was examined using CT. Radiographic union was diagnosed in the presence of trabecular continuity using CT without abnormal motion in flexion-extension radiographs at 24 weeks by independent three observers. Univariate analysis and multinomial logistic regression analysis were performed to evaluate associations for union status. Cut-off value was determined by receiver operating characteristic curve (ROC curve) using Youden index.

Results: Fifty patients achieved a radiographic union (union group), and 17 patients were diagnosed as delayed union (non-union group). Regarding univariate analysis for union versus non-union groups, significant factors were as follows; age = 72.1+/-1.0 versus 78.4+/-1.7 (p=0.002), eGFR = 71.9+/-2.7 versus 59.6±4.6 ml/min/1.73m² (p=0.024), DSVA 4.6+/-0.6 versus 10.1+/-0.9 cm (p<0.0001), and posterior wall fracture = 53% versus 94%. Adjusted by pharmaceutical agents, DSVA was significantly larger in the non-union group than the union group (P=0.014). Multinomial logistic regression analysis considering age over 75 years, gender, medical history regarding diabetes mellitus, pharmaceuticals, past vertebral fracture, fBMD under 0.55 g/cm², posterior wall fracture, albumin under 4.0 g/dl, eGFR under 70 ml/min/1.73m², and DSVA over 7.5 cm showed the significance in eGFR (p=0.0312) and DSVA (p<0.0001). Area under the curve of ROC curve regarding DSVA for union status was 0.876.

Discussion: The current study demonstrated that DSVA, which is a representative external mechanical factor affected for union status, affected for union status of OVF more than the factors of internal healing ability as eGFR. DSVA is considered as the parameter related to flexional bending moment for fractured vertebra. For the treatment of OVF, protecting from the external mechanical force to crush the healing process may be prior to encouraging internal healing ability.

An investigation of infective endocarditis as a complication of vertebral osteomyelitis

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Background: Infective endocarditis (IE) is traditionally associated with a high risk of complications such as cerebral emboli, splenic and renal infarction, and/or glomerulonephritis. It has recently been recognized that the incidence of vertebral osteomyelitis (VO) and IE co-infection is higher than previously believed. However, the incidence of IE in VO patients and the outcomes of these patients are still uncertain. The purpose of the present study was to investigate the incidence and risk factors for IE in patients with VO and to review the clinical features and outcomes of patients with VO with and without IE.

Material and methods: We retrospectively reviewed 129 cases of VO that were diagnosed at our institution from 2010 to 2017. Patients with prior spinal surgery and those with tuberculosis and no definitive bacteriologic diagnosis were excluded.

A total of 62 men and 45 women (mean age, 70 years; range, 23–95 years) were included in the study. We recorded the demographic data, underlying medical illness, vertebral level involved, predisposing cardiac risk factors, valve involvement, bacteriologic diagnosis, echocardiographic studies, radiologic images, treatment and the outcome.

Results: IE was diagnosed in 9 patients (7%). Six of the 9 patients with IE had undergone spinal surgery. Six patients required cardiac surgery, refractory bacteremia occurred in one patient, and one patient died. Eight patients had positive blood cultures, 6 patients had diabetes mellitus, and 4 patients had a history of heart disease. Seven patients were infected with Gram-positive bacteria (MSSA, n=2; MRSA, n=1; *S. aureus*, n=2; and others, n=2), and 2 patients were infected with gram-negative bacteria (*E. coli*, n=2).

Discussion: Since back pain is common in IE and VO, physicians need to have a high index of suspicion to avoid missing this important complication. Some studies have reported the prevalence of IE in patients with VO ranges from 2% to 43.3%. In this study, the prevalence of IE was 7%. Echocardiography was only performed for 60% of the patients; thus, our search for IE may have been insufficient. However, this study shows that the occurrence of IE in association with VO is not rare. The therapeutic management of IE often requires cardiac surgery and IE can be fatal. Thus, in patients with pyogenic vertebral osteomyelitis, IE should be investigated not only when it is clinically suspected (with a history of cardiac disease, in immunocompromised patients) but also in cases involving streptococcal infection and blood culture-positive cases.

Analysis of lumbar trunk muscles in healthy volunteers using surface electromyography during postoperative exercise programs for lumbar spine surgery

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Introduction: Additional limb movement increases abdominal activity during trunk muscle exercise. We have introduced unilateral thigh raising exercises combined with bilateral arm maximum elevation in a sitting position as specific isometric exercises of core trunk muscles for an early stage after lumbar decompression surgery. However, the effects of our intended postoperative exercises on the activity of lumbar trunk muscles have not yet been determined. The aim of the present study was to determine the core muscle activity in healthy young volunteers using surface electromyography during our intended postoperative exercises.

Methods: We included 27 male and 5 female healthy volunteer participants in the present study. Activities of 3 trunk muscles, the external oblique (EO), internal oblique (IO), and lumbar spine erector muscles (LE), were measured bilaterally using surface electromyography during exercises intended after lumbar spine surgery. The participants performed 3 types of exercises in a sitting position: bilateral arm maximum elevation (Ex1), additional unilateral thigh raising on the side ipsilateral to the measurement, coupled with Ex1 (Ex2), and thigh raising on the contralateral side, coupled with Ex1 (Ex3). Integrated rectified waveform (iEMG) values were measured per second in each muscle bilaterally during stable muscle contraction during each exercise. We determined the changes in the iEMG values during exercises from those measured while the participant was sitting. A one-way ANOVA, multiple comparison test was performed using SPSS version 24.0, with the significance level set to 5%.

Results: The mean changes in iEMG (μV) in the 3 exercises were (Ex1: 0.63 ± 4.2 , Ex2: 3.41 ± 7.7 , Ex3: 1.28 ± 5.9) in EO, (1.59 ± 3.1 , 11.9 ± 18.7 , 2.03 ± 4.9) in IO and (0.04 ± 3.0 , -0.08 ± 4.1 , -0.37 ± 3.1) in LE. Increases of EO and IO muscle activities in Ex2 were significantly greater than those in Ex1. By contrast, there was no significant change of LE muscle activity found between the 3 exercises.

Discussion: We found that unilateral thigh raising combined with bilateral arm maximum elevation may be an effective exercise to increase EO and IO muscle activity without change of LE muscle activity. Thus, our postoperative exercise program was considered an appropriate method by which to increase trunk stability through promoting core muscle activity without a load on the back extensor at an early stage after lumbar posterior decompression surgery.

Low back pain among 906 nurses :Is the prevalence higher in orthopedics wards?

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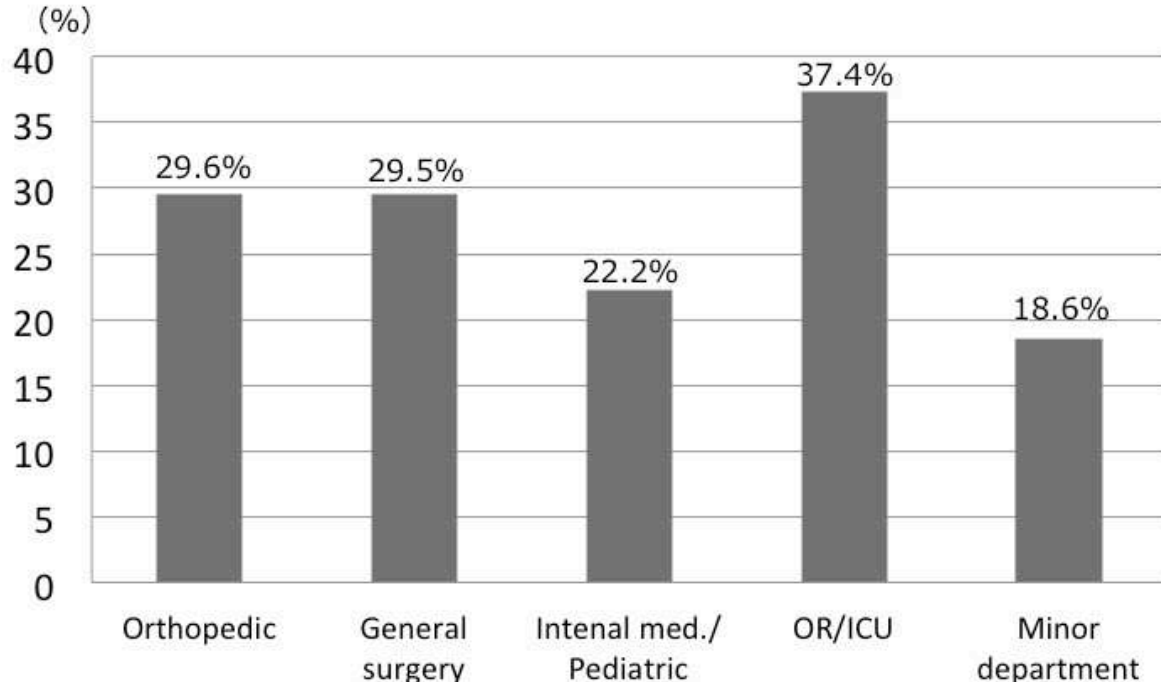
Introduction: Several studies have been reported prevalences of low back pain (LBP) were 46 to 65% in nurses who worked for hospitals. Although the prevalence of LBP was high, there was no detailed report on the condition of working situation in the nurses. The purposes of this study were to investigate the condition of LBP in nurses who were working for hospitals and examine the difference of the prevalence of LBP among wards where the nurses were working.

Methods: Study subjects consisted of 906 individuals who were working as nurses for a university hospital (except for outpatient clinics). A questionnaire survey was conducted these subjects regarding LBP. The questionnaires were Oswestry Disability Index (ODI) and an original questionnaire consisted of current LBP, past LBP history, smoking history, exercise history, fear of recurrence of LBP. Five hundreds sixty-seven subjects provided responses and 205 subjects with incomplete replies were excluded. Therefore, 362 subjects with valid responses were included in the final analysis. These subjects consisted of 43 males, and 319 females, with average age of 30 years (range, 21-56 years). The subjects were classified into two groups according to current LBP: LBP[+] group and LBP[-] group. For comparisons between the two group, the unpaired test or chi-square test was used. The level of significance was set less than 5%.

Results: The prevalence of current LBP was 32.0 % and past history of back pain was 46.0 %. The prevalence of current LBP were 29.6 % in orthopedic ward, 29.5 % in general surgery ward, 22.2 % in internal medicine ward and pediatric ward, 37.4 % in operating room (OR) and intensive care unit (ICU), and 18.6 % in minor department wards (ophthalmology, dermatology, otolaryngology, psychiatry) (Figure 1). Although these differences did not reach statistical significance ($p=0.127$), the prevalence of current LBP was higher in OR and ICU than in minor department wards. There was no significant difference in gender, age, body mass index, smoking history, exercise history between the LBP[+] group and the LBP[-] group. ODI was significantly higher in the LBP[+] group than in the LBP[-] group (LBP[+]: 13.6 ± 7.5 , LBP[-]: 3.9 ± 4.8 , $p<0.001$). Fear of recurrence of LBP was significantly higher in subjects with past LBP history than in those without past LBP history ($p<0.001$).

Discussion: The prevalence of LBP of nurses working in surgical wards (including orthopedic ward, OR, and ICU) was higher than those in internal medicine and minor department wards. This study suggested that we should address the prevention of nurse's LBP considering the environment of the working situation.

Figure 1: The prevalence of low back pain



The Early Bird Catches The Worm: Do paraspinal muscle fatty infiltration and intervertebral disc degeneration start earlier than expected?

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Introduction: Low back pain is a common disorder in adolescents. It has been reported that 18-32,9% of the adolescents had low back pain. Chronic and recurrent low back pain is more common in girls (33%) than in boys (26%). Magnetic resonance imaging (MRI) is defined as the gold standard for the spine evaluation, since it provides excellent visualization without radiation.

In this study, we aimed to identify degree of fatty infiltration in the lumbar paraspinal muscles and lumbar intervertebral disc degeneration in symptomatic adolescents with low back pain with/without leg pain. We also aimed to identify whether these degenerative processes are associated with gender, lumbar intervertebral disc herniation, and body fat composition in this decade of life.

Methods: We conducted this cross-sectional magnetic resonance imaging (MRI) study in adolescents who visited outpatient clinics with low back pain with/without leg pain. Patients' demographics and MRI findings were recorded. One author evaluated the patients in terms of intervertebral disc degeneration, and one other author evaluated fatty infiltration in the paraspinal muscles at all intervertebral disc levels on T2-weighted lumbar spine MRIs.

Results: We evaluated lumbar spine MRIs of 63 adolescent patients (mean age: $15,71 \pm 1,11$ years). Females had significantly higher fatty infiltration scores for the multifidus and the erector spinae muscles at L5-S1 level when compared to males ($1,83 \pm 0,37$ vs $1,46 \pm 0,56$ $p=0,004$; $1,23 \pm 0,50$ vs $0,96 \pm 0,30$ $p=0,017$). Patients with lumbar intervertebral disc herniation had significantly higher Pfirrmann scores at L4-5 and L5-S1 levels, and in total than those without disc herniation ($p < 0,001$). Patients with thick low back subcutaneous fat tissue had higher fatty infiltration scores for the erector spinae at L4-5 level than those with thin low back subcutaneous fat tissue ($1,07 \pm 0,67$ vs $0,66 \pm 0,65$, $p = 0,028$).

Discussion: Fatty infiltration most probably starts with the multifidus and erector spinae at lower lumbar levels in females and in those with thick low back subcutaneous fat tissue. Adolescents with lumbar intervertebral disc herniation had more disc degeneration at lower lumbar levels. We suggest that adolescents with low back pain with/without leg pain have already had disc degeneration and fatty infiltration at lower lumbar levels.

References:

1. Urrutia J, Besa P, Bengoa F. A prevalence study of thoracic scoliosis in Chilean patients aged 10-20 years using chest radiographs as a screening tool. *J Pediatr Orthop B*. Mar 2018;27(2):159-162.
2. Weinstein SL. Natural history. *Spine (Phila Pa 1976)*. Dec 15 1999;24(24):2592- 2600.
3. Chen JB, Kim AD, Allan-Blitz L, Shamie AN. Prevalence of thoracic scoliosis in adults 25 to 64 years of age detected during routine chest radiographs. *Eur Spine J*. Oct 2016;25(10):3082-3087.
4. Labelle H, Richards SB, De Kleuver M, et al. Screening for adolescent idiopathic scoliosis: an information statement by the scoliosis research society international task force. *Scoliosis*. 2013;8:17.

The evaluation of computed tomography Hounsfield units before and after treatment of spinal metastatic tumor of lung cancer

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Introduction: Recent progress in treatments for lung cancer, such as the advent of immune checkpoint inhibitors (group I), molecular-targeted drugs (group M), radiation therapy (group R) and bone-modifying agents (BMAs; group B) in addition to classic chemotherapy (group C) has improved the outcomes of patients. However, BMAs as well as other therapies occasionally lead metastatic vertebral bodies to bone sclerosis. The use of computed tomography (CT) Hounsfield units is reportedly useful for evaluating the stiffness of cancerous bone in vertebral bodies. We investigated the therapeutic effectiveness of CT Hounsfield units measured before and after therapy for spine metastasis.

Methods: The subjects were 61 patients (19 females and 48 males, average age: 68 years) being treated for lung cancer and spinal metastasis at the Department of Pulmonary Medicine, Saga University Hospital. We evaluated the chemotherapy regimens and transition of mean CT units for the elliptical area restricted to the trabecular area of the vertebral bodies with or without tumors (L1 through L4), measured on axial images. The chemotherapy regimens included group B, M and R (n=9); only group M (n=8); group C and R (n=7); group B, C and R (n=6); group B and C (n=6); group B and M (n=5); only group C (n=4); group B, I and R (n=4); group M and R (n=3); group I and R (n=3); only group I (n=2) and group B and R (n=2) (Fig. 1).

Results: The CT values of the vertebrae were significantly increased after treatment, regardless of the presence of metastases (Fig. 2). In the BMA group, the CT value of the vertebral bodies were also increased regardless of the presence of metastases (without: 126%, with: 323%; $p<0.001$). Similar findings were noted in the groups without BMAs (without: 131%, with: 232%; $p<0.001$). Significant differences in CT values were noted between the groups with and without BMAs ($p<0.05$).

Discussion: We noted an increase in the CT values in vertebral bodies after chemotherapy in the primary treatment of lung cancer. This result suggests that treating primary sites facilitates an increase in the vertebral stiffness with metastasis much as the treatment to metastatic site. Markedly increased CT values were noted in the group receiving BMAs compared to those not receiving BMAs. The use of BMAs in addition to cognitive therapies may cause an osteoblastic response. The limitation of our study is that the follow-up period was short and the patient population was small due to the poor prognosis. In addition, the CT scanning interval was not consistent between patients. We conclude that regardless of the use of BMAs in combination with treatment at the primary site causes osteosclerosis at the metastatic site of lung cancer as evaluated by the Hounsfield CT index. And furthermore, the group with BMAs make greater metastatic site bone sclerosis than the group without BMAs.

Japanese version of Bad Sobernheim Stress Questionnaire-Brace for Adolescent Idiopathic Scoliosis patients

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Introduction: Patients with adolescent idiopathic scoliosis (AIS) under brace treatment feel stress not only from the scoliosis itself but from wearing a brace. The Bad Sobernheim Stress Questionnaire-Brace (BSSQ-brace) was developed to assess the psychological stress induced by brace treatment in patients with AIS. The purpose of the present study is to develop a Japanese version of BSSQ-brace and evaluate its reliability.

Methods: A Japanese adaptation (JBSSQ-brace) of the English version of BSSQ-brace was developed using the guideline-based adaptation process, consisting of five stages, to assess the psychological effects of brace treatment in Japanese patients with AIS. We conducted JBSSQ-brace in 44 patients with AIS at our clinic. Internal consistency and reliability were assessed by Cronbach's alpha and the test-retest method.

Results: JBSSQ-brace achieved excellent internal consistency (Cronbach's alpha = 0.87) and substantial reliability (interclass correlation coefficient = 0.85). The median JBSSQ-brace score was 16.5 (standard deviation 5.5), and 41% of the subjects felt medium-to-high stress from brace treatment.

Conclusion: JBSSQ-brace provides a new effective instrument to evaluate stress levels in Japanese patients with AIS under brace treatment.

Is spinal deformity related to the aerobic capacity of patients with adolescent idiopathic scoliosis? A systematic review.

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Introduction: While patients with severe adolescent idiopathic scoliosis (AIS) are known to have poor aerobic capacity, there is no consensus regarding whether some components of the spinal deformities are the determinants of aerobic capacity in patients with different severity of AIS. Unfortunately, no systematic reviews have summarized and compared the relations between these components and aerobic capacity in AIS patients, which may inform clinical practice. Therefore, the objective of the current systematic review was to summarize the associations between various structural characteristics and aerobic capacity of patients with AIS during exercise tolerance tests.

Methods: Eight electronic databases were searched for relevant publications, from inception to November 2016. Two reviewers independently screened the titles, abstracts, and full-text of potential articles according to the selection criteria. Two other independent reviewers extracted data and appraised the methodological quality of the included studies using relevant risk of bias evaluation tools. Associations between various spinal parameters and aerobic capacity were summarized qualitatively because the heterogeneous data did not allow the conduction of a meta-analysis.

Results: Of 1,045 identified citations, eight studies (377 participants) met the inclusion criteria. The overall methodological quality was low to moderate. Many included studies did not justify the sample size or adjust for confounders. Interestingly, aerobic capacity of AIS patients (expressed as maximum oxygen intake (VO_{2max})) as estimated by treadmill exercise tolerance tests differed from that deduced from cycloergometer exercise tolerance tests. Using treadmill tests, three studies found that the average body weight normalized VO_{2max} in patients with mild to moderate curves (Cobb angles between 20° and 45°) was significantly lower than the normative values. Likewise, two studies revealed that patients with mild curves had significantly poorer ventilatory efficiency (as indicated by higher ventilation volume per VO_{2max}) than healthy individuals during a treadmill test. One study found that increased thoracic Cobb angles were associated with decreased VO_{2max} ($r = -0.71$; $p < 0.01$). Another study showed that patients with mild to moderate curves had significantly poorer exercise tolerance, lower anaerobic threshold and a higher breathing frequency than healthy controls during treadmill exercise tolerance tests. Conversely, using cycloergometer exercise tolerance tests, three studies found that the curve angle or number of scoliotic vertebrae was unrelated to body weight normalized VO_{2max} or maximum tidal volume/inspiratory capacity ratio. Interestingly, one study showed that patients with Cobb angles $> 40^{\circ}$ displayed slightly decreased VO_{2max} and mild hyperventilation during a cycloergometer exercise tolerance test.

Discussion: While existing results suggested that suboptimal aerobic capacity might start to occur in patients with mild thoracic curves, these findings might be confounded by various factors (e.g., physical fitness levels or muscularity). Future cohort studies should determine if suboptimal aerobic capacity in patients with AIS is related to poor fitness level and/or spinal deformities. However, given the beneficial effects of aerobic exercises on aerobic capacity, clinicians can recommend AIS patients to perform regular aerobic training in order to optimize their aerobic capacity.

An accepting attitude and lack of negative cognition leads to less pain and disability related to chronic low back pain

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Introduction: Pain perception varies depending on the individual and influences treatment outcome. Psychological acceptance and wellbeing may affect pain perception and hence affects the rehabilitation of patients with chronic illnesses. This may have a profound impact on the functional capabilities of patients undergoing rehabilitation for chronic low back pain (LBP). Inclusion of psychological assessment and therapy in treating this group of patients may encourage improved self-perception and eventual return to normal social role. The aim of study is to determine the impact of psychological factors on pain perception and function, for potential application in rehabilitation.

Methods: This was an assessment of a prospectively collected cohort of patients with chronic LBP enrolled in a 14-week rehabilitation programme comprising of intensive occupational therapy, physiotherapy and clinical psychology sessions. Assessments were conducted at baseline, 8-weeks and 14-weeks with questionnaires and interviews. An array of tests and inventories were used for functional and psychological assessment. Intensity of pain was assessed with Visual Analogue Scale (VAS), whereas patients' self-perceived function and disability were evaluated with Oswestry Disability Index (ODI) and Spinal Function Sort Score (SFSS). For their psychological states, Bradburn Affect Balance Scale (BABS) was adopted to assess their general wellbeing, while Beck Depression Inventory (BDI) was used to specifically identify patients with inclination to depression. Acceptance of Illness Scale (AIS) was also used as a measure of patient response towards illness and its encompassing disability. Paired t-test and Wilcoxon signed rank tests were used to evaluate any statistically significant change before and after the programme. Spearman's correlation test was used to correlate change in psychological parameters with that of physical and functional parameters.

Results: A total of 191 patients (26.2% female) were recruited, with mean age of 40.2 years old (range 20-60 years). After the programme, ODI improved significantly (47.0 to 45.0, $p < 0.05$), as with SFSS (98.3 to 108.1, $p < 0.05$). Significant improvement was also observed in AIS (21.4 to 22.6, $p < 0.05$) and BABS (0 to 4.3, $p < 0.05$). However, patients reported increased BDI (17.0 to 19.5, $p < 0.05$). An inverse correlation between change in AIS and change in VAS at rest ($r_s = -0.19$, $p < 0.05$) and under exertion ($r_s = -0.28$, $p < 0.05$) was observed. Conversely, change in BABS correlated positively with change in VAS at rest ($r_s = 0.16$, $p = 0.045$) and under exertion ($r_s = 0.23$, $p = 0.004$). Similarly, change in BDI was found to correlate positively with VAS at rest ($r_s = 0.22$, $p < 0.05$) and under exertion ($r_s = 0.20$, $p < 0.05$). Change in AIS correlated inversely with change in ODI ($r_s = -0.33$, $p < 0.05$). On the other hand, change in BDI positively correlated with change in ODI ($r_s = 0.30$, $p < 0.05$).

Discussion: Patients' attitude towards chronic LBP influenced their self-perception of pain and function. Improved acceptance to their condition reduces their perceived pain. This may be related to development of an adaptive response to pain or modulating their perception of pain. Lack of negative cognitions also leads to less pain and disability. Improvements in key areas of depression, including anhedonia, loss of self-worth, hopelessness and guilt may prove to be important in rehabilitating this group of patients with chronic LBP.

Prognostic factors for the failure of antibiotic treatment of patients with pyogenic vertebral osteomyelitis

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Introduction: Patients with pyogenic vertebral osteomyelitis (PVO) are usually initially treated conservatively. However, we should consider surgical treatment for cases resistant to conservative treatment. Although there are several previous studies about the risk factors for the failure of conservative treatment, most of them defined failure as the need for surgical treatment; however, the indication for surgery was not clear and depended on the surgeon's preference.

In our hospital, treatment for PVO has been administered in the department of infectious diseases; hence, almost all patients with PVO have received conservative treatment. The purpose of the study was to investigate prognostic factors for failure of antibiotic treatment under circumstances with few surgical interventions.

Methods: We included 62 consecutive patients who were diagnosed with PVO and treated between April 2007 and March 2017. We excluded 15 patients for the following reasons: PVO other than lumbar and thoracic infections, previous spinal instrumentation, and no C-reactive protein (CRP) measurement. After these exclusions, we retrospectively reviewed 47 patients.

Failure of treatment was defined as a sustained CRP value (>1 mg/dl) after 6 weeks' treatment, the need for surgery because of paralysis, or death due to the infection. Using logistic regression analysis and a receiver operating characteristic (ROC) curve analysis, we investigated the following possible prognostic factors: the CRP value on admission and one week after treatment, the presence of an epidural abscess, and comorbidities.

Results: The mean age of the 47 included patients was 69.2 years; 35 (75%) were men. Thirty-nine (83%) patients presented with back pain, and 24 (51%) presented with fever. The most frequent comorbidities were diabetes mellitus (n=16) and malignancy (n=16), followed by coronary disease (n=7) and end-stage renal disease (n=6). On admission, the average white blood cell count (WBC) was 10,700 and the CRP value was 13.8 mg/dl. The average CRP after one week of treatment was 6.4 mg/dl. The outcomes were as follows: epidural abscess, n=25 (53%); antibiotic treatment failure, n=20 (42%); persistent CRP (>1 mg/dl) after 6 weeks' treatment, n=18 (38%); surgery due to paralysis, n=2 (5%); and death because of the infection, n=6 (13%).

Logistic regression analysis revealed that the CRP value after one week of treatment was a significant risk factor for treatment failure (odds ratio=1.2; 95% confidence interval, 1.0 to 1.4; p=0.04). The ROC curve indicated that the CRP cut-off value was 5.0 mg/dl. Epidural abscess was not a significant risk factor for treatment failure.

Discussion: In our retrospective study, we found that persistently high CRP values one week after initiation of antibiotics was a prognostic factor for the failure of conservative treatment, and the cut-off value for CRP was 5.0 mg/dl. Thus, we should consider further intervention for those cases. A multivariate analysis did not show that an epidural abscess was a risk factor for treatment failure. Therefore, PVO accompanied by an epidural abscess does not necessarily require surgical treatment.

Association of spinopelvic alignment with lumbar Psoas /erector spinae in 60s women.

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Introduction: The pelvic parameter in the standing position is a very important factor in whole spine alignment. Pelvic incidence (PI) is a fixed anatomical value, whereas pelvic tilt (PT) and sacral slope (SS) can have various values depending on age and posture. According to the formula $PI = PT + SS$, certain values are divided into PT and the other into SS, but no research has been done on how these ratios are determined. We assume that the volume and fat infiltration of the psoas muscle and the erector spinae muscle are important factors in determining this ratio. In order to reduce bias, we analyzed the relationship between pelvic parameters and lumbar psoas/erector spinae muscle in women who did not show deformity in the 60s.

Methods: Participants were women 60–69 years old (N = 112) who underwent whole spine X-ray and MR L-spine, independent in activities of daily living. Patients with previous spinal surgery, severe deformity (SVA > 9.5 cm, coronal curves > 30°), history of total hip arthroplasty, long-term steroid medication, and patients with congenital spinal deformity were excluded. The final inclusion was 52 subjects. We measured PT, PI, SS, lumbar lordosis (LL), PI-LL, sagittal vertical axis of C7 (SVA) in standing whole spine X-ray using Surgimap®. On MR L-spine, the sum area of right and left psoas muscle and erector spinae muscle of L3/4 and L4/5 mid-disc level were measured (P3/4 area, P4/5 area, E3/4 area, E4/5 area). The region of interest (ROI) value was also obtained to evaluate muscle fat infiltration (P3/4 ROI, P4/5 ROI, E3/4 ROI, E4/5 ROI). We also calculate the ratio of psoas and erector spinae muscle (P/E) to reduce the individual BMI difference. Using the median value of P/E, we divide the relatively small and large psoas group (low psoas group: P/E < median value).

Results: Three pelvic parameters (PI, PT, SS) did not show any correlation with BMI, DBM, age (only within 60 to 69), height, and weight. In addition, the pelvic parameter was not significant in the simple correlation with the muscle area and ROI value. There was no significant difference in PI, PI-LL, and SVA between groups according to psoas and erector spinae ratio. In the large psoas group, PT and SS were significantly different from small psoas group (large psoas PT: 20.08±6.32, SS: 32.77±8.11; small psoas PT: 27.09±10.78, SS: 24.56±9.96, p=0.033, p=0.020, respectively).

Discussion: Our results suggest that an increase in psoas/erector spinae ratio is associated with a high SS, low PT. These results show that the relative ratio of psoas/erector muscle acts in determining the standing spinopelvic parameter.

Evaluation of novel controlled thermal energy and rotational capsular tissue shaving system demonstrates clinical benefits in patients suffering from low back facet joint pain at 1-year post treatment

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Introduction/Background: Facet Joint Syndrome (FJS) is among the leading causes of low back pain and affects millions globally. Typically manifesting from spinal osteoarthritis (OA), FJS is a painful, chronic condition whose treatment options, often temporary in nature, have remained unchanged in the past four decades. A novel, minimally invasive system has been developed to provide potential long-term relief via a combination of controlled thermal energy and rotational capsular tissue shaving of the bony structure to disrupt nociceptive signals and receptors. We hypothesized that use of this novel system would result in sustained pain relief and improved health metrics associated with mobility.

Methods: This prospective study included patients with chronic intractable pain of the low back resulting from FJS who had failed conservative treatments for pain. Patients who were treated between 15th July 2017 and 23rd February 2018 were evaluated for joint groupings treated, pain and quality of life as measured by the visual analog score (VAS), medication log, Oswestry Disability Index (ODI) and EQ-5D-5L. Follow-up was conducted at 1, 3, 6 and 12 months' post-treatment; data reported correspond to these time points.

Results: A total of 28 patients (60.7% females; average age 55.1±11.5 years) were evaluated. Prior to treatment, 18 patients regularly used one or more prescribed analgesics and had predominately undergone either physiotherapy (81.4%), spinal injections (86.4%), or both to alleviate pain. A total of seven joint groupings were treated, with L3 – S1 (45.6%) and L4 – L5 (17.5%) being the most common. Baseline average VAS_{back} prior to treatment was 74.7±14.2mm, a 42.0±16.6 ODI score with a EQ-5D-5L score of 3 (out of 5). At 1, 3, and 6 months post-treatment, VAS_{back} decreased to 31.7±17.5mm (-57.5%), 25.5±22.9mm (-65.8%), and 17.7±18.3mm (-76.3%). Similarly, ODI 1, 3, and 6 months post-treatment decreased to 19.9±14.4 (-52.7%), 20.1±15.0 (-52.3%), and 14.1±9.9 (-66.4%). These decreases from baseline were consistently observed in more than half of the study population. EQ-5D-5L scores post-treatment remained, on average 32% below baseline values.

Conclusions: Review of real world cases from five independent sites across Europe also had demonstrated reduction in pain scores and general improvement of health metrics up to 6 months following treatment similar to our study as evidenced by improvement in VAS_{BACK}, ODI and EQ-5D-5L scores.

The association of back muscle strength and sarcopenia-related parameters in the patients with spinal disorders

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Introduction: Trunk skeletal mass and back muscle strength are important parameters in the treatment of aging spinal disorders; however, the associations between back muscle strength, trunk muscle mass, and sarcopenia-related parameters in patients with spinal disorders have not been well studied. The present study aimed to investigate the incidences of severe sarcopenia, sarcopenia, presarcopenia, and dynapenia in patients with spinal disorders, and to investigate the relationships between sarcopenia-related parameters and trunk muscle mass and back muscle strength.

Methods: This cross-sectional observational study included 230 consecutive patients with spinal disorders who visited our outpatient clinic (age range 65–92 years). We measured back muscle strength, handgrip strength, gait speed, and appendicular and trunk skeletal muscle mass using bioimpedance analysis. We classified the subjects into the sarcopenia, dynapenia, or normal stages in accordance with the guidelines set by the European Working Group on Sarcopenia in Older People, and used the cutoff values reported in the guidelines set by the Asian Working Group for Sarcopenia.

Results: Back muscle strength was significantly correlated with trunk muscle mass (males: $r=0.47$, $P<0.001$; females: $r=0.39$, $P<0.001$), handgrip strength (males: $r=0.67$, $P<0.001$; females: $r=0.59$, $P<0.001$), and gait speed (males: $r=0.49$, $P<0.001$; females: $r=0.51$, $P<0.001$). The respective incidences of the sarcopenia, dynapenia, and normal stages were 16.4%, 26.7%, and 56.9% for males, and 23.7%, 50.9%, and 25.4% for females. Dynapenia was significantly more prevalent in females than in males. Back muscle strength in the normal group was significantly greater than that in the sarcopenic and dynapenic groups.

Discussion: Back muscle strength is significantly correlated with trunk muscle mass and sarcopenia-related parameters in patients with spinal disorders. Back muscle strength in the sarcopenic stage is significantly lesser than that in the normal stage. Although sarcopenia is a multifaceted geriatric syndrome, spinal disorders might be one of the risk factors for disease-related sarcopenia.

Relationship between degenerative changes in paraspinal muscles and lumbar spinal stenosis in the community

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Introduction: A dynamic lumbar factor is associated with the onset of symptoms of lumbar spinal stenosis (LSS). Since the paraspinal muscles contribute to lumbar stabilization, it is expected that their functional decline influences the onset of symptoms of LSS. However, the correlation between degenerative changes in the paraspinal muscles and LSS is still unclear. The present study aimed to clarify the relationship between degenerative changes in paraspinal muscles and the onset of LSS symptoms in an 11-year prospective cohort study involving the local community.

Methods: This study included 117 community-dwelling people (age: 47-89 years, mean: 73.8 years) who participated in annual health check-ups in both 2004 and 2015. We analyzed the presence of fatty degeneration of the paraspinal muscles using MRI findings in 2004 by the method of Kjaer and a self-administered, self-reported history questionnaire for LSS. We compared the prevalence of LSS in 2015 with the presence or absence of fatty degeneration of the paraspinal muscles in 2004. Furthermore, we examined the intensity of low back pain using a numerical rating scale and assessed functional disability due to low back pain (Roland Morris Disability Questionnaire; RDQ) in 2015.

Results: 1. Forty-eight subjects (41.0%) had fatty degeneration of the paraspinal muscles in 2004 (F group) and the remaining 69 subjects (59.0%) had no fatty degeneration (NF group). There were no statistically significant differences between the two groups in height, weight, body mass index, and history of diabetes and dyslipidemia. The intensity of low back pain (LBP) in 2004 was 4.4 ± 2.4 in the F group and 3.3 ± 2.1 in the NF group, indicating a statistically significantly higher intensity of LBP in the F than the NF group ($p=0.0355$), although there was no statistically significant difference between the two groups in RDQ scores. 2. In 2015, there were six (12.5%) LSS-positive participants in the F group, and four (5.8%) in the NF group, indicating a statistically significant difference between the two groups ($p=0.0262$). In the F group, the prevalence of LSS 11 years later was higher than in the NF group. The intensity of LBP in 2015 was 5.0 ± 2.0 in the F group and 3.7 ± 1.7 in the NF group, indicating a statistically significantly higher pain intensity in the F group ($p=0.0039$). There was, however, no statistically significant difference between the two groups in RDQ scores.

Discussion: The presence of degenerative changes in paraspinal muscles is associated with the onset of LSS symptoms and LBP intensity.

Does the volume of herniated disc influence on the spontaneous resorption of lumbar disc herniation and the changes of Oswestry Disability Index?

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Introduction: The size of herniated disc is regarded as an important parameter to predict resorption of herniated disc and good clinical outcome. In previous reports, the measurement of size of herniated disc was done using too simplified grade system on 2 dimensional image. We analyzed the changes of the volume of the herniated lumbar disc (VHD) treated with conservative treatment and its relationship with clinical outcome.

Methods: We retrospectively reviewed consecutive 48 patients with one-level lumbar HNP between Jan 2008 and Dec 2015. All patients were without neurology and treated conservatively under informed consent. Magnetic resonance images (MRI) at baseline and final follow-up (at least 2 year follow-up) were used to evaluate the VHD, which was obtained using multiplying the sum of slice thickness and inter-slice gap with the cross sectional areas of herniated disc at all sagittal images between both lateral border of pedicles. Back and leg visual analogue scale (VAS) and Oswestry disability index (ODI) at baseline and final follow-up were adopted to evaluate clinical outcome. We compared large HNP group (baseline VHD $\geq 1000\text{mm}^3$, n=20) and small HNP group (n=28) using student t-test and kai square test.

Results: Overall, mean age was 41.4 ± 14.2 years. Seven patients had HNP in L3-4, 28 patients in L4-5, 13 patients in L5-S1. VHD decreased in 28 patients (58.3%) and mean volume changed from 1105.1 ± 716.4 to $799.0 \pm 485.7\text{mm}^3$ ($P=0.017$). Clinical outcome improved in 40 patients (83.3%). ODI greater than 20 was 18 (37.5%) at baseline and 1 (2.1%) at final. Mean total ODI (from 19.7 ± 8.7 to 14.7 ± 8.3), VAS for the back pain (from 4.5 ± 2.3 to 2.9 ± 2.2 , $P < 0.05$) and VAS for the leg pain (from 4.8 ± 2.4 to 3.0 ± 2.5 , $P < 0.05$) were improved significantly.

In the analysis between two groups, large HNP group had low grade of the VAS for back pain at baseline (3.7 ± 2.2 vs. 5.1 ± 2.2 , $P=0.03$) and the change of VHD (621.6 ± 862.9 vs. $80.8 \pm 333.7\text{mm}^3$, $P=0.004$). There was no significant change in clinical outcome at final follow-up between groups.

Discussion: The rate of spontaneous absorption of lumbar HNP and the volume of resorbed HNP were relatively low comparing with the previous studies. Large VHD was related with the significant resorption of VHD and low grade of back pain as baseline. However, the disability improved regardless of volumetric change of herniated disc.

Table. Comparison between Large HNP group and small HNP group

FACTORS		LARGE VHD GROUP (VHD $\geq 1000\text{MM}^3$) (N=20)	SMALL VHD GROUP (VHD<1000MM ³) (N=28)	P-VALUE
AGE (YEARS)		44.7 \pm 13.2	40.1 \pm 16.0	0.7
GENDER(M:F)		11:9	17:11	0.460
LEVEL	L3-4	2	5	0.508
	L4-5	11	17	
	L5-S1	7	6	
PFIRMAN GRADE	II	1	5	0.034*
	III	12	21	
	IV	7	2	
CONTAINMENT WITHIN PLL	Contained	16	27	0.088
	Uncontained	4	1	
MIGRATION OF HERNIATED DISC(NO)		17	9	<0.001**
MODIC CHANGE	None	7	23	0.002**
	Type 1	4	3	
	Type 2	9	2	
PRESENCE OF RIM ENHANCEMENT		6	16	0.058
HNP TYPE	Protrusion	5	25	<0.001**
	Extrusion	4	2	
	Sequestration	11	1	
VOLUME OF HERNIATED DISC (MM ³)		1722.5 \pm 727.6 → 1100.9 \pm 498.0	664.1 \pm 191.6 → 583.3 \pm 347.1	<0.001** <0.001**
RESORPTION VOLUMAN OF HERNIATED DISC (MM ³)		621.6 \pm 862.9	80.8 \pm 333.7	0.004**
MAXIMAL AREA OF HERNIATED DISC (MM ²)		122.8 \pm 76.5 → 62.3 \pm 31.0	44.8 \pm 15.2 → 39.4 \pm 22.6	<0.001** <0.005**
MAXIMAL AP DIMENSION OF HERNIATED DISC (MM)		32.1 \pm 8.8 → 32.7 \pm 12.5	25.4 \pm 7.0 → 23.2 \pm 9.3	0.005** 0.007**
VISUAL ANALOGUE SCALE(VAS)	Back	3.7 \pm 2.2 → 2.5 \pm 2.0	5.1 \pm 2.2 → 3.2 \pm 2.3	0.030*, 0.238
	Leg	4.5 \pm 2.5 → 2.2 \pm 2.1	4.9 \pm 2.4 → 3.5 \pm 2.6	
OSWESTERY DISABILITY INDEX(ODI)	Total	20.7 \pm 10.2 → 13.5 \pm 8.2	19.0 \pm 7.7 → 15.5 \pm 8.5	0.500, 0.399
	Percentage	43.0 \pm 20.5 → 28.4 \pm 17.7	39.9 \pm 16.2 → 31.8 \pm 16.8	

Reliability of measuring the volume of multifidi at multiple lumbar levels using two different software programs.

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Introduction: Changes in lumbar multifidus cross-sectional area (CSA) and composition have been suggested to be related to the presence and maintenance of low back pain (LBP). However, since the CSA of multifidus on a single image cannot represent the characteristics of the entire muscle, it is important to evaluate the muscle volume in order to comprehensively evaluate morphometry of the target muscle. Unfortunately, no study has investigated the reliability or agreement of measurements using various software programs. Therefore, this study aimed to determine the reliability and agreement in measuring the total volume (both fat and lean muscle) and lean muscle volume of lumbar multifidus using two commercially available image analysis programs, Mimics and MIPAV.

Methods: Lumbar magnetic resonance images from 10 individuals with and 10 without LBP were randomly selected from a cohort of participants in an ongoing project. An accessor used Mimics and MIPAV to separately measure total CSA and lean muscle CSA of bilateral multifidi on axial T2-weighted magnetic resonance images taken from L1 to S1 levels. Since each lumbar level (between the middle of two intervertebral discs) comprised seven images, the total volume (both lean muscle and fat tissues) and the lean muscle volume of multifidus on each side at a given lumbar level were calculated by summing the corresponding CSAs at each level and then multiplying them by 4.4mm (slice thickness and interslice gap). To determine the intra-rater reliability of each software in measuring total CSA and lean muscle CSA, the accessor randomly selected 30 images from the 20 participants and measured them twice using each software program, at least 10 days apart. The accessor was blinded to all previous measurements. Intraclass correlation coefficients ICC (2,1) were used to determine the inter-software reliability in measuring the total volume and lean muscle volume of multifidus at each lumbar level. The Bland-Altman method were used to calculate the mean difference between the measurements acquired from the two software programs and the corresponding 95% limits of agreement. Intra-rater reliability of measurements of muscle CSA using Mimics and MIPAV was assessed by ICCs (2,1) and standard error of measurement (SEM).

Results: The inter-software reliability for measuring total and lean muscle volumes of lumbar multifidi were excellent (ICCs ranging from 0.92 to 0.99) in people with and without LBP. However, compared to Mimics, MIPAV significantly overestimated the muscle volume by 0.8% to 2.6% across all measurements. The intra-rater reliability and SEM were similar for most measurements assessed by both programs, with ICC ranging from 0.91 to 0.99 for Mimics and 0.86 to 0.99 for MIPAV.

Discussion: The measurements of total volumes and lean muscle volumes of lumbar multifidi in people with and without LBP using Mimics and MIPAV were highly reliable. However, it is not recommended to compare the absolute muscle volume as measured by the two software programs. Future studies should determine the inter-software reliability, as well as intra- and inter-rater reliability of using these programs in measuring the volumes of other paraspinal muscles.

Stride length of elderly patients with lumbar spinal stenosis: Multi-center study using Two-Step test

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Introduction: The common symptoms of Lumbar spinal canal stenosis (LSS) are low back pain, leg pain, numbness, and intermittent claudication due to compression of the cauda equina or nerve roots. In addition, short stride length has been identified as a clinical symptom associated with LSS. Because short stride is a risk factor for falls, identifying the factors that is associated with short stride is critical to prevent falls in patients with LSS. Although the Two-Step test can conveniently assess maximal stride length, this test has not become widely used; therefore, its data are limited. We aimed to identify the potential factors associated with short stride of elderly patients with lumbar spinal stenosis LSS using the Two-Step test.

Methods: Clinical data of patients aged >65 years who planned to undergo surgery for LSS were prospectively collected at multiple institutions. Patients were assessed with the Two-Step test as well as Timed Up-and-Go Test (TUGT) prior to surgery. The following data were collected for each patient, 1 day before surgery: age, BMI, ZCQ score, JOABPEQ score, VAS, radiographic parameters, motor deficit, TUGT score, and Two-Step test score. Motor deficit was defined as MMT grade of ≤ 3 in at least one of these muscles.

Results: Overall, 357 consecutive patients were enrolled in this study. The score of the Two-Step test showed a moderate-to-strong inverse correlation with that of TUGT ($r = -0.65$, $p < 0.001$). For dividing two groups based on the Two-Step test score, we calculated the tentative cut-off value by referring the TUGT score used to indicate a high risk of falls in the elderly. Using this cut-off value, multivariable logistic regression analysis showed that a score of < 20 for psychological disorders in Japanese Orthopedic Association Back Pain Evaluation Questionnaire (OR = 2.4, 95% CI 1.0–5.5), motor deficit (OR = 3.1, 95% CI 1.4–6.8), and sagittal vertical axis ≥ 50 mm (OR = 2.2, 95% CI 1.4–3.6) were significantly associated with short stride in elderly patients with LSS.

Conclusions: The Two-Step test measures the maximal stride length and serves as a prediction of subjects' walking ability. Previous studies have reported that the Two-Step test score is significantly associated with age, gender, and risk of falls. Recently, we reported a significant association between the Two-Step test score and LSS symptom severity. In the present study, we revealed a close relationship between the Two-Step test and TUGT scores among elderly patients with LSS. These observations suggested that the Two-Step test can serve as a reliable screening test for functional mobility in patients with LSS. To the best of our knowledge, this multi-center study is the largest to evaluate maximal stride length of patients with LSS using the Two-Step test ($n = 357$). Using the Two-Step test, we found that low psychological status, motor deficit of the lower extremities, and forward-bent posture were associated with short stride in the patients with LSS. Therefore, it may be better to inform elderly LSS patients with these conditions of the higher risk of fall.

Quality of life in scoliosis patients during adulthood: a new evaluation tool

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Introduction: Scoliosis is a very frequent problem during adulthood. Surgery is a very common option for these patients, but there are relevant risks and side effects and not all patients are willing for such treatment. For these reasons many patients seek for a conservative treatment in rehabilitation centers. For the assessment of quality of life in patients with scoliosis the SRS-22 questionnaire was first developed, and more recently the Isyqol questionnaire, with the latter tested only in youngsters.

Objective: The aim of the present study is to test the properties of the Isyqol in a group of adults with scoliosis and compare its properties to the SRS-22.

Methods: We retrospectively review the record of all the adult patients included in our prospective database running between 2003 and 2017. The inclusion criteria were: diagnosis of idiopathic scoliosis with a curve of 30° Cobb or more, no surgical treatment, availability of the SRS-22 and Isyqol. The SRS-22 is based on 5 items (Function, Psychological wellbeing, Pain, Aesthetics and Satisfaction for treatment), with scores ranging from 5 (no impairment) to 0 (high impairment). The Isyqol is a Rasch consistent questionnaire based on 13 questions that gives a continuous value of quality of life ranging from 0 to 100. The Cronbach alpha was used to check the internal validity, and a Rasch analysis was run to explore the features of the different tools

Results: 100 patients (29 males) respected the inclusion criteria. The mean Cobb angle was 46±14°, Age 42±15. The Cronbach alpha value was above 0.70 for both questionnaires. This means that their internal consistency is good, and allows their application in a clinical setting. The Rasch analysis of the values of both questionnaires would allow a more precise comparison.

Conclusion: This is the first study reporting the general characteristics of patients affected by scoliosis attending a specialized rehabilitation center based on the SRS-22 and Isyqol questionnaires. Both questionnaire can describe the population of adult with scoliosis, and are able to assess the quality of life. Adult scoliosis patients need specific tools of evaluation mainly for quality of life and pain. The SRS-22 and the Isyqol seem to be able to accomplish this task

The relationship between the degeneration of the lumbar muscle and mal-alignment according to Schwab classification

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Introduction: Schwab classification is a useful criterion for evaluation of thoracolumbar deformity. Although Schwab classification is composed of pelvic and lumbar parameters such as pelvic incidence (PI), lumbar lordosis (LL), and pelvic tilt (PT), there is a lack of research on the relationship with lumbo-pelvic musculature. The purpose of this study is to investigate the characteristics of the psoas muscle and erector spinae muscle according to Schwab classification.

Methods: Participants were women 60–69 years old (N = 112) who underwent whole spine X-ray and MR L-spine, independent in activities of daily living. Patients with previous spinal surgery, severe deformity (SVA > 9.5 cm, coronal curves > 30°), history of total hip arthroplasty, long-term steroid medication, and patients with congenital spinal deformity were excluded. The final inclusion was 52 subjects. We measured PT, PI, sacral slope (SS), LL, PI-LL, sagittal vertical axis of C7 (SVA) in standing whole spine X-ray using Surgimap®. On MR L-spine, the sum area of right and left psoas muscle and erector spinae muscle of L3/4 and L4/5 mid-disc level were measured (P3/4 area, P4/5 area, E3/4 area, E4/5 area). The region of interest (ROI) value was also obtained to evaluate muscle fat infiltration (P3/4 ROI, P4/5 ROI, E3/4 ROI, E4/5 ROI). According to Schwab sagittal modifiers, mal-alignment was scored. (PI-LL: <10° (PI-LL 0), 10°-20° (PI-LL 1), >20° (PI-LL 2)), (PT: <20° (PT 0), 20°-30° (PT 1), >30° (PT 2)), and (SVA: <4cm (SVA 0), 4cm-9.5cm (SVA 1)). In addition, we calculate the sum of sagittal mal-alignment score (SUM): PT score (0-2) + PI-LL score (0-2) + SVA score (0-1).

Results: Regarding PI-LL factors, mal-alignment was highly correlated with increased BMI, decreased area of the erector spinae muscle, and increased ROI of erector spine muscle. For the PT factors, mal-alignment was related with low BMI, the smaller area of psoas, and increase ROI of psoas and erector spinae muscle, but not related with the area of erector spinae muscle. SVA factors were not related with the area of muscle, but ROI of psoas muscle. The distribution of SUM were; score 0 (n=14), score 1 (n=15), score 2 (n=12), score 3 (n=11). SUM score was correlated with ROI of psoas and erector spinae, but not correlated with BMI, the area of muscle.

Discussion: PI-LL factor of Schwab classification was related to erector spinae muscle area, ROI. The PT factor was related to the psoas muscle area, ROI. SVA was related to ROI of psoas and erector spinae muscle but not related to area of muscle. According to these results, Schwab classification is more related to fatty infiltration than psoas muscle and erector spinae muscle area.

Compensatory mechanisms in lumbosacral isthmic spondylolisthesis with or without segmental kyphosis

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Introduction: Isthmic spondylolisthesis (IS) is a frequent spinal disease and surgery is usually reserved for stubborn back pain and/or neurological deficits after failure of conservative treatment. Anomalous sacropelvic morphology combined with the presence of a local lumbosacral deformity can result in an abnormal sacropelvic orientation and stress at the lumbosacral junction, as well as to a disturbed global sagittal balance of the spine. Previous study has demonstrated preserved disc height and presence of segmental kyphosis were risk factors of pseudoarthrosis or instrument breakage in IS. The purposes of this study are to investigate the incidence and demographic characteristics of kyphotic configuration in lumbosacral IS and to explore the sagittal alignment of kyphotic and non-kyphotic configuration in lumbosacral IS.

Methods: We retrospectively reviewed with symptomatic single level IS (Meyerding grade I-II) who had undergone surgical intervention at our center between January 2009 and April 2018. Lumbosacral developmental spondylolisthesis was excluded. Based on the angulation profile of the olisthesis level, patients were divided into the kyphotic group and the non-kyphotic group. Slip parameters, pelvic parameters, L5/S1 disc height, L4-S1 segmental lordosis and sagittal parameters were measured. In order to evaluate the relationship between spinopelvic parameters and a morphologic parameter characteristic of each individual, pelvic incidence- lumbar lordosis (PI-LL) mismatch and the ratios of L4-S1 segmental lordosis to lumbar lordosis (L4-S1/LL), and pelvic tilt to PI (PT/PI) were also calculated. Degeneration of each lumbar intervertebral disc was stimulated on MRI by the modified Pfirrmann criteria.

Results: A total of 271 patients were included. There were 26 (9.6%) patients in the kyphotic group and 215 patients in the non-kyphotic group, respectively. Age, BMI and gender distribution were similar between the two groups ($P>0.05$). IS combined with prominently intradiscal kyphotic angulation were characterized by increased wedged of L5 vertebral bodies (anterior aspect larger than posterior), collapse of anterior and/or posterior disc space and more anterior olisthesis. Kyphotic IS demonstrated greater pelvic incidence, pelvic tilt, PT/PI, L5 incidence, PI-LL, but lower L4-S1 lordosis and L4-S1/LL than non-kyphotic IS ($P<0.05$). Moreover, severer degeneration of L5/S1 disc of kyphotic IS was evaluated on T2-weighted MRI through Pfirrmann classification. Patients with kyphotic IS reported worse ODI (5.4 ± 2.0 vs 4.7 ± 1.5 , $P<0.05$) and VAS back scores (52.0 ± 12.1 vs 44.2 ± 8.5 , $P<0.001$) quality of life. **Discussion:** Segmental kyphosis was detected in 9.6% patients with IS. IS with segmental kyphosis is observed with higher slip percentage, more wedged L5 vertebra body and advanced disc degeneration, as well as distinct sagittal malalignment characterized with LL loss, L4S1 lordosis loss and pelvic retroversion. Such sagittal profiles may have a negative effect on patients' quality of life.

Prevalence of Thoracic Scoliosis in Adolescents: Analysis of 1065 Chest Radiographs with A Comprehensive Review of Adolescent Scoliosis Prevalence in the World

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Introduction: School scoliosis screening programs (SSSPs) are widely used for reporting the prevalence and improving the awareness of scoliosis. Thus, scoliosis could be prevented and/or timely treated. However, small-degree scoliosis (10-20°) could be missed in SSSPs. Previously obtained plain chest radiographs could be used adjunct to SSSPs to detect the exact prevalence of scoliosis. In this study, we aimed to analyze prevalence of thoracic scoliosis in adolescents using posterior-anterior chest radiographs. We also aimed to compare the results with SSSPs done worldwide.

Methods: Cross-sectional radiological study using plain chest radiographs obtained in a community-based hospital and systematic literature review of articles about SSSPs retrieved from Pubmed/MEDLINE search engine. Patients born in 2001 and already had fully standing postero-anterior plain chest radiographs, obtained for reasons other than spinal conditions or trauma were enrolled in this study. Demographic variables were drafted along with radiographs using the picture archiving and communication system of the hospital. Thoracic spine coronal Cobb angles were measured using Surgimap. Scoliosis was defined as coronal plane Cobb angle equal to or more than 10°.

Results: One thousand and sixty five adolescents (519 females, 546 males) admitted to the hospital (mean age: 14,95±1,14 years; mean coronal Cobb angle was 4,40±4,03°) were included into the study. Thoracic scoliosis was detected on plain posterior-anterior chest radiographs in 10,4% of the adolescents (64 female, 47 male; 95% CI 8,6-12,4%). The prevalence of thoracic scoliosis was significantly higher in females than males (12,3%; 95% CI 9,6-15,4% vs. 8,6%; 95% CI 6,2-11,0%; p=0,047). One hundred and seven papers about scoliosis screening in adolescents were retrieved from the literature. Each continent had different scoliosis prevalence as follows; 0.06-22.7% (Asia), 0.2-6.4% (Europe), 0.4-4.5% (North America), 1.4-1.5% (South America), 1.8-1.94% (Australia).

Discussion: The SSSPs are useful to understand prevalence of scoliosis, and the factors associated with scoliosis in adolescents. Patients with small-angle curves could be missed in SSSPs. Our results showed that plain posterior-anterior chest radiographs could be used adjunct to SSSPs to detect more accurate prevalence of scoliosis in adolescents in a cost- and time-effective way.

Neuropeptide Y associations with lifestyle interventions in subjects with lumbar spinal stenosis

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Introduction: Neuropeptide Y (NPY) is elevated in painful degenerative conditions, and changes in NPY levels are associated with changes in pain levels in subjects with neck and back pain. Serum NPY concentrations are highly correlated with back pain and pain-related function in individuals with axial low back pain. Thus, the goal of this study is to examine the associations of NPY levels in subjects participating in a lifestyle intervention for lumbar spinal stenosis to 1) examine the association of baseline NPY levels to measures of function and 2) evaluate the relationship of baseline levels of NPY with response to treatment.

Methods: Sixteen patients with lumbar stenosis and BMIs of 25 or greater were recruited from a single academic center. Subjects were randomized to utilize a website designed to promote physical activity and nutrition for 12 weeks vs. usual care. Patient reported outcomes including Oswestry Disability Index (ODI), Tampa Scale of Kinesiophobia (TSK) and the Physical Function subscale of the Swiss Spinal Stenosis Questionnaire (PF) were collected at baseline and at 12 week follow up. Serum samples were collected at baseline and stored at -80°C . Serum samples were assayed for NPY using commercially available ELISA kit following the manufacturer's protocol.

Results: Participants had a mean age of 56 years and were 75% women. Average BMI was 29. A positive association was detected between baseline NPY concentration and baseline ODI, TSK and PF. A significant correlation between baseline NPY level and the change in ODI was observed in both the control group ($R^2=0.8$, $p=0.04$) and the treatment group ($R^2=0.5$, $p=0.02$), with higher levels of NPY associated with greater improvements in ODI.

Discussion: These preliminary results suggest potential utility of NPY as a biomarker relevant to both the experience of pain and response to treatment in patients with lumbar spinal stenosis. The relationship of NPY to resilience in pain conditions raises an interesting hypothesis regarding the role of coping in response to lifestyle interventions, in that patients with greater resilience may portend greater functional recovery.

The associations between spinal deformities and pulmonary functions in conservatively treated patients with adolescent idiopathic scoliosis – A systematic review and meta-analysis.

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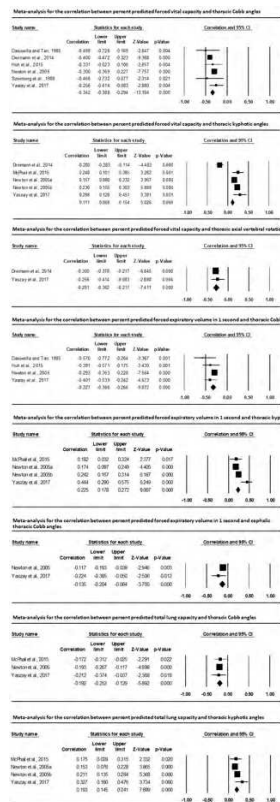
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Introduction: Some studies have shown that teenagers with adolescent idiopathic scoliosis (AIS) display pulmonary impairments although conflicting findings have been reported. Unfortunately, no systematic review or meta-analysis has been conducted to summarize the correlations between various lung function parameters and radiographic phenotypes in these patients, which can help identify AIS patients with pulmonary impairments for timely management. Therefore, the objective of the current meta-analysis was to summarize existing information regarding the associations between various lung function parameters and structural characteristics of patients with AIS.

Methods: Candidate publications were identified from eight electronic databases, from inception to November 2016. Two independent reviewers screened the titles, abstracts, and full-text of potential articles based on the eligibility criteria. Another two independent reviewers extracted relevant data and appraised the methodological quality of the included studies. The risks of bias of case-control studies, cross-sectional studies, and longitudinal studies were assessed by the Newcastle-Ottawa Quality Assessment Scale for Case-control Studies, Appraisal Tools for Cross-Sectional Studies, and Quality in Prognostic Study tool, respectively. The associations between various pulmonary parameters and spinal parameters were summarized qualitatively. Meta-analyses were conducted using random-effects models, if appropriate.

Results: Of 1,045 identified citations, 18 studies (3,075 participants) met the inclusion criteria. Fourteen included studies (2,766 patients) reported significant low-to-moderate associations between diverse spinal deformity parameters (e.g., axial vertebral rotation) and lung functions (e.g., percent predicted functional vital capacity (%FVC), percent predicted forced expiratory volume in one second (%FEV₁), and percent predicted total lung capacity (%TLC) in patients with AIS. Homogenous data from 10 studies were pooled for meta-analyses. The results showed that larger thoracic Cobb angles were related to lower %FVC ($r = -0.34$; 95%CI: -0.39 to -0.29), lower %FEV₁ ($r = -0.33$; 95%CI: -0.39 to -0.27), smaller %TLC ($r = -0.19$; 95%CI: -0.25 to -0.13), and smaller percent predicted vital capacity ($r = -0.28$; 95%CI: -0.34 to -0.22). Conversely, thoracic kyphosis angles were positively associated with %FVC ($r = 0.11$; 95%CI: 0.07 to 0.15), %FEV₁ ($r = 0.23$; 95%CI: 0.18 to 0.27), and %TLC ($r = 0.19$; 95%CI: 0.15 to 0.24). Many included studies had suboptimal methodological quality. Notably, many of them did not justify the sample sizes. They also did not report response rates, information about ethics approval, and confounders.

Discussion: Severe spinal deformities were found to be related to clinically significant pulmonary impairments in patients with AIS. However, the relations between spinal deformities and pulmonary functions in patients with mild curve remain unclear because static pulmonary function tests may not be sensitive enough to detect subtle pulmonary impairments. To this end, maximal exercise tolerance tests can be prescribed to detect small pulmonary impairments, which are amplified as the demands of pulmonary function are increased by intensive physical work. Additionally, future studies are warranted to consider the influences of other factors (e.g., physical activity levels) in affecting the associations between spinal deformities and lung function, and to determine the possibility of restoring lung functions of these patients by non-surgical and surgical means.



Dynamic spinal alignment can influence on continuous walkable distance in the patients with adult spinal deformity

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Introduction: Continuous walkable distance often decreases in the patients with adult spinal deformity (ASD). It may be attributed to poor spinal alignment. However, the true mechanism remained to be clarified. So far, spinal alignment has been evaluated only using whole spinal X-P on standing, which is static spinal alignment. The purposes of the current study were to evaluate the spinal alignment on walking (dynamic spinal alignment) and to clarify how it influences on the continuous walkable distance in the patients with ASD.

Methods: Twelve female subjects with ASD (Mean age, body height, weight, respectively; 74.8±6.7 year, 151.2±4.2 cm, 52.2±8.2 kg) were evaluated. All the subjects complained of low back pain on walking. Using the SRS-Schwab Classification, the ASD was defined as the following; 1) sagittal vertical axis(SVA) was 40 mm or more, 2) all coronal curve was more than 30 degrees. The subjects with the history of previous spinal surgery, neurological symptoms, and inability to walk independently were excluded. Based on the 6-minute walk test(6 MWT), the subjects were asked to walk on the flat hallway in 10-meter length back and forth. Continuous walkable distance(m) was measured in each subject. On standing and walking, the following analysis was performed; 1) Static spinal alignment; SVA, thoracic kyphosis(TK), lumbar lordosis(LL), and pelvic tilt(PT) on the standing whole spinal X-P. 2) Dynamic spinal alignment: Using the three-dimensional motion analysis system(8-camera VICON with 2-force plates), trunk and pelvic anteversion angle on walking were measured(dynamic trunk angle, DTA, and dynamic pelvic angle, DPA). The sampling time was 100 Hz. Statistical analysis was performed using stepwise multiple regression analysis with continuous walkable distance as object variable, and static and dynamic spinal alignment as explanatory variable. The level of significance was set at $p < 0.05$.

Results: The subjects could continuously walk mean of 203 meters. On the standing and walking, the measured values with the mean+S.D. were as the follows; SVA 190+76.9 mm, TK 28.2+14.0 degrees, LL 2.7+31.9 degrees, PT 41.0+12.6 degrees, DTA 22.1+12.8 degrees, and DPA -2.6+5.9 degrees. The DTA increased a mean of 9.5 degrees on walking, compared to standing. The LL on standing and the DTA on walking most influenced on the continuous walkable distance ($\beta=0.49$, respectively).

Discussion: This study demonstrated that the LL in the static spinal alignment and the DTA in the dynamic spinal alignment affect the continuous walkable distance in the ASD patients. As the DTA increases, the trunk inclines forward. The greater the DTA, the higher the back-muscle activity. This might induce back muscle fatigue, thus get decreased on continuous walkable distance. Whole spinal alignment should be evaluated with the dynamic condition on walking as well as with the static one on standing.

Significance of spine metastasis as initial presentation in patients with short predicted survival

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Introduction: The treatment goal in patients with metastatic spine tumor (MST) should be the improvement of quality of life. Although radiotherapy has developed rapidly, surgical treatment is still important in some selective patients. Surgical treatment should be performed based on patients' conditions including their life expectancy. In patients with short predicted survival, the decision on surgical treatment is very difficult. Especially there is a debate on the surgical treatment for patients who diagnosed primary cancer with MST as an initial presentation and had short predicted survival. The purpose of this study was to investigate surgical outcomes in MST patients with short predicted survival and to analyze the prognostic significance of MST as an initial presentation.

Methods: Between 2011 and 2016, all consecutive patients who underwent surgical treatments for their symptomatic MST were included in this retrospective study. The life expectancy was based on the revised Tokuhashi scoring system. Patients with the revised Tokuhashi score of less than 9 was defined as those with short predicted survival. Among 103 patients, 76 patients had the revised Tokuhashi score of less than 9. Authors compared 28 patients (Group 1) who diagnosed primary cancer with MST as an initial presentation and 48 patients (Group 2) who identified MST during the treatment for their primary cancer. Baseline patient characteristics were collected from the database. Univariate and multivariate regression analysis were performed to examine the association between the time of MST diagnosis and prognosis including survival and the improvement of preoperative symptoms.

Results: The mean age was 58.9 years and 49 males and 27 females were included. The mean Tokuhashi score was 5.8. After surgery, the mean survival time was 7.9 months (0.5-33) and 17 patients survived more than 1 year (22.4%). The most common primary cancer was lung (n=35), followed by hepatobiliary (n=17), kidney (n=3). Group 2 had lower Tokuhashi score than Group 1 significantly (6.2 versus 5.1). On the contrary, survival analysis showed Group 2 had significantly longer postoperative survival than Group 1 (12.2 months versus 7.0 months, p=0.042). Multivariate regression analysis showed the time of MST diagnosis and preoperative performance status were significant prognostic factors (p=0.021, 0.008). The improvement of preoperative symptoms was significantly correlated with the time of MST diagnosis and preoperative ambulatory status (p=0.040, <0.001).

Discussion: Recent studies showed the revised Tokuhashi score may not predict actual survival because the cancer treatment has evolved. In this study, patients with the revised Tokuhashi score of less than 9 had actually longer survival than the predicted survival. The decreasing trend in Tokuhashi score accuracy over time will likely further reduce its utility. When patients with short predicted survival are considered surgical treatment for their MST, the time of MST diagnosis as well as their performance status should be considered.

Reducing mechanical stress restores the rounding deformity in a rat model of immature pediatric spondylolisthesis: Is a pediatric spinal deformity reversible condition?

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Introduction: The rounding deformity of sacrum associated is reported to be the most responsible risk factor for high grade slippage. To prevent high-grade slippage with L5 spondylolisthesis, the rounding deformity of sacrum should be restored by appropriate treatment. However, the pathomechanism of the restoration of rounding deformity is yet to be clarified. To confirm that endochondral ossification can be improved radiologically and histologically by reducing mechanical stress.

Methods: Spondylolisthesis model rats (4-week-old) were postoperatively divided into three groups, a control group, an immature tail suspension group, and a mature tail suspension group. Radiographs were acquired weekly for 6 weeks after destabilization surgery. The rats were then euthanized and lumbar spines were harvested and stained with hematoxylin-eosin (H&E) and Alcian blue for histology.

Results: Radiographs showed slippage and rounding deformity of the lower vertebrae after surgery. The rounding deformity progressed with time in the control group and the mature tail suspension group but not in the immature tail suspension group. Bony modification was observed at the anterior upper corner of the growth plates in the lower vertebrae in the immature tail suspension group; however, specific columns of the growth plate were unclear at the anterior upper corner in the control and mature tail suspension groups, both of which showed expansion of the cartilage layer and increased numbers of proliferative chondrocytes rather than hypertrophic chondrocytes. In the immature tail suspension group, the cartilage layer was almost normal and hypertrophic chondrocytes were clearly visualized.

Discussion: Reducing mechanical stress at the growth plate when the bone age is immature can restore the rounding deformity. Bone restoration at this site depends on bone maturity.

Selective Nerve Root Block for Lumbar Spine Disease

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Objective: It is considered to be effective therapy to perform selective nerve root block (SNRB) in a patient with lumbar spinal nerve root disorder with low back pain / lower extremity pain, typified by a lumbar disc herniation. However, it is not yet clear what kind of case it is effective, and what characteristics it has in the case of transition to surgery despite SNRB implementation. In order to clarify the characteristics of these patients, patients with SNRB undergoing lumbar nerve root injury were classified into two groups according to the difference in treatment process and are reported.

Methods: From August 2003 to July 2013, we examined 466 times of 258 cases in which SNRB was performed among patients who visited our hospital with lumbar nerve root injury. Based on the course of treatment, we classified them into con. Group which continued conservative therapy, op. Group which shifted to surgical therapy. Then, the disease, the presence or absence of steroid use, the number of SNRB enforcement, before SNRB <1> enforcement, <2> one hour after enforcement <3> One day after enforcement <4> One week after enforcement VAS, VAS improvement rate.

Results: 1) op. Group was 201 times in 90 cases and con. Group was 265 times in 168 cases. 2) There was no significant difference between the op. Group and the con. Group in the disease, presence or absence of steroid use. 3) Number of SNRB enforcement : op. Group 38 cases performed once, more than 2 times 52 cases. con. Group 104 cases performed once, more than 2 times 64 cases . 4) At the VAS of <3> <4>, the op. Group was significantly higher than the con. Group. 5) In the VAS improvement rate of <3> <4>, the op. Group was significantly lower than the con. Group.

Discussion: In the past we have reported that "There is no need to use steroids at the time of SNRB enforcement." Since there was no significant difference in the use of steroid between the op. group and the con. group, it seemed that this result proved this. "There was significantly more cases in which op. Group performed SNRB more than twice", it was thought that the possibility of surgery becomes higher if SNRB is performed more than twice. "In the VAS of <3> <4>, the op. Group was significantly higher than the con. Group. " "In the VAS improvement rate of <3> <4>, the op. Group was significantly lower than the con. Group " It was speculated that if the effect of SNRB disappears in 1 day, the possibility of surgery will increase.

Relationship between cervical balance and neck muscle degeneration

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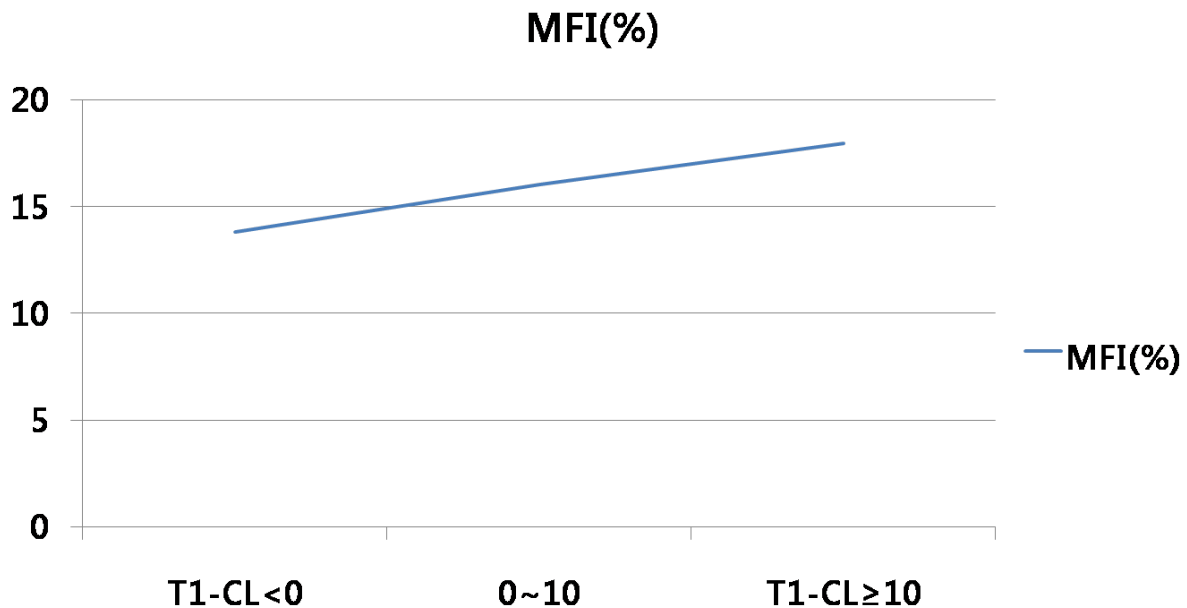
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Introduction: The T1 slope has been suggested previously as an important factor influencing overall spinal sagittal alignment. T1 slope minus C2-C7 lordosis, the cervical analog to pelvic incidence minus lumbar lordosis correlated positively with neck disability index after multilevel posterior spine fusion surgery. And it is known that sagittal imbalance is associated with back muscle degeneration in lumbar spine. But there was no study that reported relationship between cervical sagittal balance and neck muscle degeneration. The purpose of our study is to evaluate relationship between T1 slope minus cervical lordosis and neck muscle degeneration.

Methods: In this study, 100 patients who had taken cervical spine MRI in our orthopaedic clinic were recruited. Muscle fat infiltrate(MFI) was measure using pseudocolor technique in cervical multifidus at C6-7 level quantitatively. MFI between matched group(T1 slope minus cervical lordosis<10) and mismatched group(T1 slope minus cervical lordosis≥10). Correlations between MFI and the other parameters were analyzed.

Results: Average multifidus fat infiltrate of mismatched group was significantly higher than that of matched group(p=0.005). Average multifidus cross-sectional-area(CSA) of mismatched group was significantly larger than average CSA of matched group(p=0.030). Average multifidus CSA was significantly lager in male group than female group(p<0.001). And muscle fat infiltrate was not significantly different between male and female group. T1 slope minus cervical lordosis correlated positively with multifidus fat infiltrate(Pearson r=0.306, p=0.002). Age, body mass index and cervical lordosis were not correlated with multifidus fat infiltrate.

Discussion: It was reported that subjects with neck pain had significantly less cervical lordosis than normal controls. If the loss of cervical lordosis progresses, the axial load shifts anteriorly, resulting in cervical kyphosis. Furthermore, it has been suggested that disruption of ideal cervical spine biomechanics is correlated with spondylotic myelopathy, demyelination of the cord and neuronal loss, and neural degeneration. There was few study analyzing effect of cervical sagittal balance on neck muscle. T1 slope minus cervical lordosis represents sagittal alignment of cervical spine. In our study, mismatch of this parameter accelerate fatty degeneration of multifidus which stabilize cervical spine. And degeneration of neck muscle may contribute neck pain and disability.



Relationship among osteoporosis, sarcopenia, locomotive syndrome, and spinal kyphosis in elderly living in a local mountain area

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Introduction: Kyphosis is known to greatly reduce the quality of life of the elderly. Generally, kyphosis is easily diagnosed using the kyphosis index with a cutoff value of 15. Osteoporosis and sarcopenia are considered as factors causing kyphosis. The present study investigated the relationship among osteoporosis, sarcopenia, locomotive syndrome, and spinal kyphosis in the elderly living in a mountain area.

Method: This cross-sectional study enrolled general inhabitants living in a local mountain area of the 469 inhabitants who underwent medical checkup between 2014 and 2018, 361 inhabitants aging ≥ 65 (mean age: 75.0) years were included. Survey items included kyphosis index, body mass index, back pain prevalence, back pain visual analog scale score, Oswestry disability index, walking speed, grip strength, skeletal mass index, osteoporosis [% young adult mean (YAM)], LOCOMO 5 score, and presence of sarcopenia (Asian Working Group for Sarcopenia standard). The inhabitants were divided into the following three groups according to the kyphosis index: N group (kyphosis index: < 12 ; $n = 229$, 63.4%), M group (kyphosis index: 12 to < 15 ; $n = 99$, 27.4%), and K group (kyphosis index: ≥ 15 ; $n = 33$, 9.2%). Survey items were compared among these groups. P-value of < 0.05 was considered to indicate a significant difference. Logistic regression analysis was performed to association factor of kyphosis (kyphosis index: ≥ 15)

Results: Age and LOCOMO 5 score were significantly higher in the K group than those in the other two groups ($P < 0.05$), whereas %YAM and walking speed were significantly lower in the K group than those in the other two groups ($P < 0.05$). Significant differences were noted among other survey items. Multivariate analysis using age, LOCOMO 5 score, walking speed, and %YAM as explanatory variables showed that only %YAM (odds ratio: 0.20, 95% confidence interval: 0.04–0.96) was an independent factor associated with a kyphosis index of ≥ 15 . Age, LOCOMO 5 score, walking speed were not significantly related factors.

Discussion: Although it was anticipated that factors such as a decrease in the muscle mass and muscle strength would be associated with kyphosis, no such relations were noted. However, bone loss was found to be significantly related to kyphosis. A decrease in vertebral body height due to osteoporosis will be in the background.

Conclusion: Sarcopenia is not related to kyphosis, whereas osteoporosis is independently related to kyphosis in the elderly living in a mountain area.

Assessment of lumbar changes over 8 years in hemodialysis patients.

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Introduction: Cervical changes in hemodialysis patients have been reported; however, to the best of our knowledge, no trial has investigated lumbar changes in such patients. Using lumbar plain radiography, this study aimed to investigate whether hemodialysis patients develop lumbar destructive spondyloarthropathy (DSA).

Methods: A total of 103 (58 men and 45 women; mean age, 68.0± 9.2 years) patients who underwent hemodialysis at the Toranomon hospital in 2018 were retrospectively examined. Cervical and lumbar radiography were performed for all patients every year for more than 8 years. The latest radiographs were compared with the ones taken 8 years previously, and the incidence and grade of DSA as well as lumbar lordosis(LL) were analyzed. Moreover, the duration of dialysis (years), incidence of spinal operation, and DSA in the cervical vertebrae were analyzed. The analyzed DSA was classified based on the following four grades: Grade 0, normal features except for some spondylotic changes; Grade1, bony erosion at the anterior vertebral rim; Grade2, radiolucent lesions in the vertebral endplates along with narrowed intervertebral disc space; and Grade 3, absence of intervertebral disc space. Grades 2 and 3 were defined as DSA.

Results: According to the lumbar radiographs taken 8 years previously, 7 of the 103 included patients had DSA. According to the above mentioned classification, 94, 2, 6, and 1 patient were classified as having grade 0, 1, 2, and 3 DSA, respectively. Based on the latest radiographs, 66, 10, 12, and 15 patients were classified as having grade 0, 1, 2, and 3 DSA, respectively. Of the 103 patients, 27 exhibited DSA progression, and of the 96 patients, 20 who were not diagnosed with DSA 8 years previously had developed some grade of DSA. In the progression group, LL decreased from 27° to 17°, which led to kyphosis. In contrast, LL slightly decreased from 25° to 22° in the non-progression group; however, in the progression group, LL decreased significantly. The dialysis duration in taking latest radiographs was significantly greater for the progression group(23.6 years) than for the non-progression group(19.4 years). Of the 103 patients, 8 required spinal operations within the follow-up period. Of the 8 patients, 2 had DSA 8 years previously, 5 showed progression to DSA, and 1 did not show progression. A total of 41 patients had cervical DSA as per the latest radiographs; furthermore, of those 41, 22 (53.7%) had lumbar DSA.

Discussion: Greater the dialysis duration, higher the number of DSA patients in the follow-up period. Along with the presence of DSA, the patients exhibited local kyphosis, which caused lumbar lordosis. In the DSA group, the spinal operation was attributable to the DSA lesions, and the presence of DSA was a significant cause of spinal operations.

Development of the brief "Core Yellow Flags Index" (CYFI) for the baseline assessment of psychological status in patients undergoing spine surgery

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Introduction: Depression, anxiety, catastrophising thoughts, and fear-avoidance beliefs are some of the so-called "yellow flags" that predict a poor outcome in patients with spinal disorders. Many clinicians have difficulty assessing or detecting yellow flags and they rarely formally screen for them. This may be because of the complexity of existing instruments and time constraints in the consultation. A brief assessment tool would allow for the rapid evaluation of the core yellow flags on a more systematic basis. We aimed to develop such a tool for use in routine preoperative assessment.

Methods: First, we performed a secondary analysis of large sets of spine patients' data for 4 questionnaires: ZUNG depression (N=399); Hospital Anxiety and Depression Scale (Anxiety-subscale) (N=308); Pain Catastrophising (N=766); Fear Avoidance Beliefs (N=736). We selected the single item that best correlated with the full questionnaire score, had the lowest floor/ceiling effects, and made sense as a stand-alone item. These 4 items were coined the "Core Yellow Flags Index" (CYFI) (Fig 1) and were answered by 1'768 patients preoperatively; patients also completed a baseline Core Outcome Measures Index (COMI), to evaluate CYFI's construct validity, and a 3- and 12-month follow-up (FU) COMI to assess CYFI's ability to predict outcome. Reliability was assessed in 30 patients who completed CYFI twice, 6±7days apart.

Results: The individual flag items showed strong correlations with their corresponding full-length questionnaires: 0.71 (depression), 0.81 (catastrophising), 0.77 (anxiety), 0.83 (fear avoidance beliefs). The test-retest reliability was 0.6-0.8 for each of the 4 items and 0.83 for the set, considered good. Cronbach's α for the 4 items was 0.79. Fig 2 shows the output of structural equation modelling examining the associations between each of the flag items and the CYFI "construct", as well as the association between the CYFI at baseline and 1) COMI at baseline, 2) COMI at 3 mo FU, 3) COMI at a 12 mo FU. The CYFI explained a significant amount of the variance in COMI (patient-rated outcome) at 3 months' FU ($\beta=0.23, p<0.001$; 8% variance explained). The CYFI also added significantly to the prediction of COMI at 12 months FU ($\beta=0.20, p<0.001$), explaining more than 7 percent of the variance, over and above that explained by individual differences in COMI at 3 months' FU. The fit of the model was good (RMSEA=0.06, CFI=0.96, $\chi^2(18)=59.56, \chi^2/df=3.31$).

Discussion: The 4-item CYFI proved to be a simple, practicable, reliable and valid tool for routinely assessing key psychological attributes in spine surgery patients. The CYFI made a significant and clinically relevant contribution to the prediction of patient outcome after surgery. CYFI's items were similar to those in the "STarTBack screening tool", used in primary care to evaluate the risk of back pain chronicity, further substantiating its validity. The brevity of CYFI makes it a useful addition to the brief COMI in the self-assessment of baseline status before surgery. Its widespread use may assist in improving the accuracy of individual outcome predictions in predictive analytical models derived using spine registry data.

Fig 1: The Core Yellow Flags Index (CYFI)

The following list contains statements from people with back problems. Some of these statements may also reflect your own thoughts/feelings. Please tick the box that best describes the extent to which each statement reflects your own thoughts/feelings at the moment.

	Not at all	To a slight degree	To a moderate degree	To a great degree	Totally
It's terrible and I think it's never going to get any better.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I feel down-hearted, blue and sad.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Worrying thoughts go through my mind.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Physical activity might harm my back.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Fig 2: Results of structural equation modelling

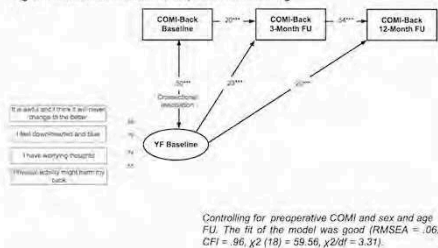
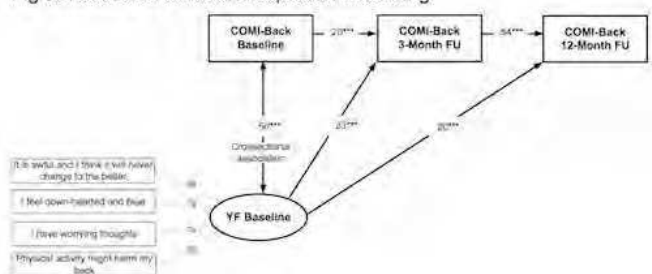


Fig 2: Results of structural equation modelling



Controlling for preoperative COMI and sex and age FU. The fit of the model was good (RMSEA = .06, CFI = .96, $\chi^2(18) = 59.56, \chi^2/df = 3.31$).

Lumbar spinal stenosis, knee osteoarthritis and loss of lumbar lordosis have an impact on quality of life: findings from the Katsuragi Low Back Pain Study

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Introduction: Musculoskeletal diseases and spinal malalignment are widely known to be associated with poorer quality of life (QOL) in the elderly. However, few general population cohort studies have been conducted to date focusing on these conditions together. Our objectives were to clarify the associations between musculoskeletal degenerative diseases and/or spinal malalignment with QOL measures in a group of Japanese older adults.

Methods: In this cross-sectional study, we analysed data from 334 individuals recruited from the local population (120 men, 214 women; mean age 62.7 years; range 40-75). Low back pain (LBP) was assessed by questionnaire, and lumbar spinal stenosis (LSS) was diagnosed using a validated lumbar spinal stenosis support tool. Knee osteoarthritis (KOA) was diagnosed by the presence of clinical knee pain plus radiographic KOA. Spinal radiographs were used to assess the degree of lumbar lordosis (LL) and sagittal vertical alignment (SVA). QOL assessment was performed using the Oswestry Disability Index (ODI). A score of 12 was used as a cut-point for poor quality of life.

Results: 107 (32.0%) participants had an ODI > 12 (cases) and the remaining 227 individuals were designated controls. LBP, LSS, KOA and lumbar lordosis (LL) were associated with an increased odds of poorer QOL, both in basic models and models adjusted for age, sex and BMI. Associations persisted after adjustment for the other musculoskeletal outcomes.

Conclusion: In a free-living Japanese population, the odds of poor quality of life are increased by LBP, LSS, KOA and certain spinal radiographic features, loss of LL and increased SVA. The odds of poor quality of life were greatest in those with the diagnoses of LSS or KOA. From spinal radiographs, decreasing LL and increased SVA were also predictors of poor QOL.

Examining the sport-specific impact on intervertebral disc degeneration: a cross-sectional analysis of 308 athletes

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Introduction: Athletes constitute a unique population to study the effect of loading and exercise on the body. At the spine, there is burgeoning evidence [1-3] that specific kinds of physical activity may have a beneficial effect on the intervertebral disc (IVD). To better understand if exercise may result in an anabolic effect on the IVD, we examined IVD characteristics across a range of sporting codes compared to non-athlete controls.

Methods: This cross-sectional study was performed as secondary analysis of an existing dataset [4] of 308 athletes (baseball, n=57; basketball, n=63; kendo, n=51; running, n=43; soccer, n=47; swimming, n=47) and 71 controls. A sagittal T2-weighted scan was performed and mid-sagittal slice selected for further analysis. All lumbar discs L1/2 to L5/S1 were measured. The following parameters were measured: (a) ratio of signal intensity in the nucleus versus that in the anterior and posterior annulus, (b) ratio of IVD height to vertebral body height and as a marker of IVD hypertrophy (c) degree of IVD degeneration as per the Pfirrmann scale. Current low back pain status (yes/no) was assessed by self-report questionnaire. Primary analysis considered data were averaged across all lumbar levels. Statistical analyses to compare athlete groups to controls were: (a) one-way analysis of variance (ANOVA) of all groups, and (b) analysis of variance of subjects matched based on low back pain status (yes/no) and height within 2 cm (n=22 per group; matched-ANOVA).

Results: The ANOVA showed, in comparison to controls, baseball players had a lower nucleus-annulus signal intensity ratio (-10%; P<0.001). The IVD/vertebral height ratio was higher in baseball (5.8%; P=0.004), basketball (10%; P<0.001), soccer (5.0%; P=0.018) and swimming (10%; P<0.001). Running (-11%; P=0.033) and soccer (-15%; P=0.003) were associated with a lower Pfirrmann score compared to controls. However, body height differed between groups (P<0.001; range of means, 164.9-175.9 cm). Body height correlated with IVD height to vertebral body height ratio (r=0.20; P<0.001) and Pfirrmann grade (r=0.25; P<0.001), but not with the nucleus-annulus signal intensity ratio (r=-0.05; P=0.340). We therefore also performed analyses using matched-ANOVA. Matched-ANOVA showed that soccer was associated with 9.7% (P=0.039) higher signal intensity ratio and basketball was associated with 11% (P=0.005) higher IVD/vertebral height ratio. Lower Pfirrmann scores were seen in basketball (-18%; P=0.012), running (-21%; P=0.007) and soccer (-28%; P<0.001).

Discussion: This study provides evidence of a positive effect of some, but not all, types of sport on the IVD in comparison to non-athletic controls. Specifically, we observed that basketballers, runners and soccer players (upright activities under body weight) had better IVD characteristics. In baseball players (rotational activities), there was some evidence of detrimental effects on the IVD, but this was not borne out after controlling for body height and back pain status. This cross-sectional study provides support to the notion that specific kinds of spinal loading may have beneficial effects on the IVD.

1. [1] Brisby et al (2010) Spine
2. [2] Belavy et al (2017) Scientific Reports
3. [3] Bowden et al (2018) J Orthop Res
4. [4] Hangai et al (2009) Am J Sports Med

Lumbar facet effusion and paraspinal edema in the patients with lumbar spondylodiscitis

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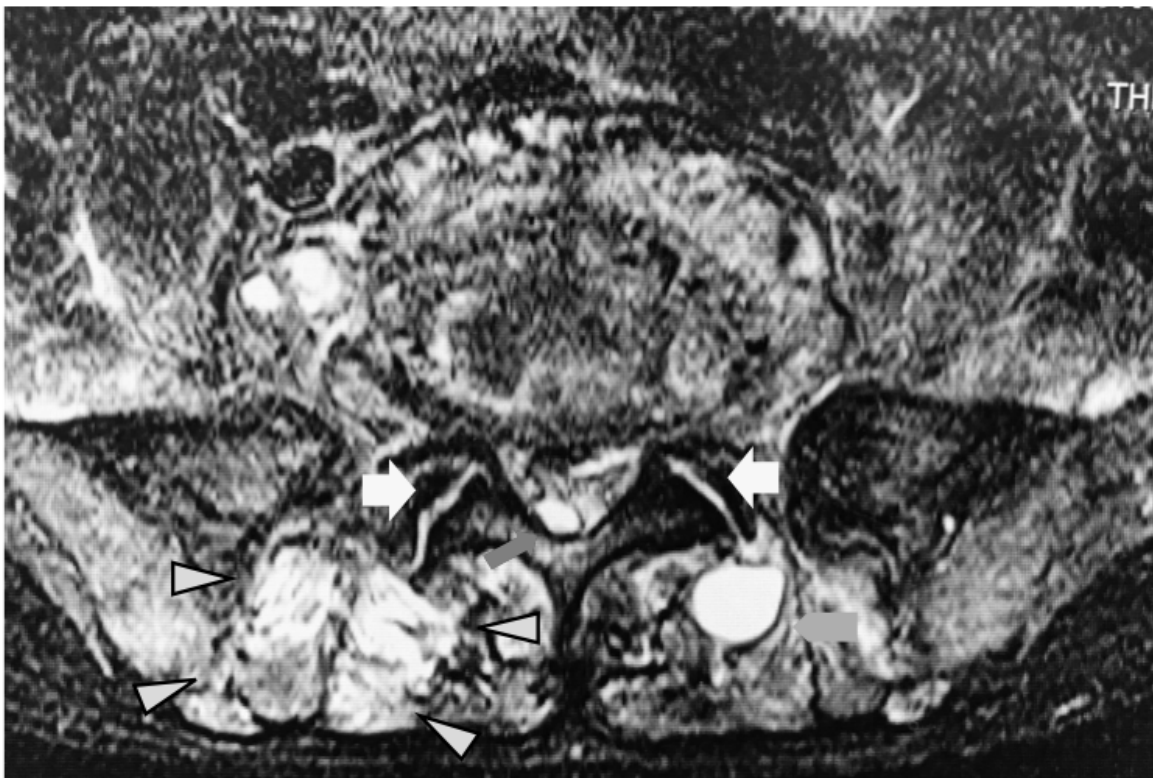
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Introduction: Pyogenic lumbar facet joint infection and paraspinal abscess are reported to be extremely rare. However, we occasionally find magnetic resonance imaging (MRI) showing lumbar facet effusion or paraspinal edema in the patients with lumbar spondylodiscitis. Therefore, we investigated the prevalence and characteristics of lumbar facet effusion and paraspinal edema associated with pyogenic spondylodiscitis.

Methods: We included consecutive 54 patients who were diagnosed as lumbar spondylodiscitis using MRI and treated in our hospital between April 2007 and March 2017. The mean age of the patients was age 69.3 ± 11.1 years old (38 males and 16 females). MRI was evaluated using staging classification reported by Uchida et al to know the pattern of extension (Uchida et al. 2010). The lumbar facet effusion was defined as presence of effusion of 1 mm or more in the largest distance between the apparent articular surfaces of facet joint in T2 weighted axial images of MRI. The paraspinal edema was defined as high signal change in multifidus muscle or longissimus muscle in s short T1 inversion recovery sequence, T2 weighted image or contrast enhanced T1 weighted image of MRI.

Results: The number of affected levels were 1 level in 43 cases, 2 levels in 9 cases and 3 levels in 2 cases. MRI stage classification were stage 1: 3 cases, stage 2: 7 cases, stage 3: 8 cases, stage 4: 15 cases, stage 5: 21 cases. MRI revealed lumbar facet effusion in 21 cases (39%), paraspinal edema in 12 cases (22%) and epidural abscess in 30 cases (56%). Epidural abscesses occurred in 17 of 21 (81%) patients with lumbar facet effusion, and lumbar facet effusion was associated with 11 cases (92%) of 12 patients with paraspinal edema. Paraspinal edema which was admitted in initial MRI at the time of admission turned into paraspinal abscess in following MRI in 2 patients.

Discussion: Although lumbar facet effusion and paraspinal muscle edema may be just reactive pathologies for pyogenic spondylodiscitis, they should be considered as initial lesions of pyogenic lumbar facet joint infection and paraspinal abscess. It is suggested that hematogenous dissemination of the infection may have progressed from intervertebral disc to epidural space, to facet joint and to paraspinal muscle. Lumbar facet effusion and paraspinal edema were highly associated with lumbar pyogenic spondylodiscitis with epidural abscess which is often indicated for surgery. Clinicians must be cautious about lumbar facet effusion and paraspinal edema especially when performing percutaneous pedicle screw fixation surgery for pyogenic spondylodiscitis.



An axial MR image of patient with pyogenic spondylodiscitis acquired by short T1 inversion recovery sequence. The image shows facet joint effusion (⇨), epidural abscess(⇨), paraspinal edema (⇨) and paraspinal abscess (⇨).

Development and enlargement of ossification of the ligamentum flavum in the thoraco-lumbar spine in Asian professional baseball players: comparison with age- and sex-matched control subjects

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Introduction: Ossification of the ligamentum flavum (OLF) is a pathologic condition that causes myelopathy or radiculopathy. The majority of surgical cases with OLF occur in middle-aged men, and younger individuals are rarely affected. However, among young, high-level Asian baseball players, some reports have indicated that repeated, localized mechanical stress influences the development of thoracic OLF causing myelopathy. The purpose of this cross-sectional study was to assess the prevalence and distribution of OLF in professional baseball players compared with age- and sex-matched control subjects.

Methods: Group B comprised 62 professional baseball players (29 pitchers and 33 fielders; mean age, 23.3 years; range, 18-33 years) with no previous systemic disorders or family history of treatment for OLF. Group C comprised 103 age- and sex-matched controls (103 males; mean age, 24.0 years; range, 18-30 years) who had undergone whole-spine computed tomography for examination of high-energy multiple injuries in the emergency department of our institute from April 2010 to November 2014. The subjects with previous thoracic spine surgery were excluded. The prevalence, distribution, and morphology of OLF were reviewed. The positive case of OLF was defined as a distinctive ossified plaque within the yellow ligament, but calcifications of the yellow ligament and facet osteophytes were excluded. Wilcoxon and chi-square tests were used for statistical analyses.

Results: No significant differences in the prevalence of thoracic and lumbar OLF were observed (Group B, 22.6%; Group C, 18.5%; $p=0.52$). The distribution of OLF peaked at T10-T11 in both groups. However, the prevalence of OLF was greater than or equal to 3 mm thick and was significantly greater in Group B (12.9%) than in Group C (1.0%; $p=0.001$). Moreover, only one fused central-type OLF was noted in Group B. three pitchers with thoracic OLF experienced neurological problems due to OLF (thoracic radiculopathy, $n=2$; myelopathy, $n=1$). No fielder with OLF experienced neurological problems due to OLF.

Discussion: Differences between professional athletes and non-athletes did not affect the prevalence or distribution of OLF, but lesion size was increased in the thoracic-lumbar junction among professional baseball players compared with age- and sex-matched controls. Symptomatic OLF existed at only pitchers who have over 10 years pitching training experience in our study. Longitudinal studies will be needed to clarify cause-effect relations among mechanical stress of pitching motion and development and enlargement of OLF in the thoracic-lumbar spine in young baseball players.

Physical and Mental Health Outcomes in a Randomized Controlled Trial of Yoga for Chronic Low Back Pain in Veterans

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Introduction: Military veterans experience higher rates of chronic low back pain (cLBP), with more psychiatric comorbidity. cLBP treatment options such as opioids have limited effectiveness and deleterious side effects. Hatha yoga has been shown to reduce pain and improve functioning in non-veteran populations with cLBP, but this hasn't been well studied among military veterans. Recently, we reported improved disability, pain intensity and opioid use in a randomized, controlled trial (RCT) of yoga for military veterans with cLBP¹. Here we present secondary outcomes which track physical and mental health changes in this RCT.

Methods: This was a 4-year RCT with Institutional Research Board approval, registered at www.clinicaltrials.gov. Participants were recruited at a large VA medical center. Eligible patients were randomized to yoga immediately or a delayed treatment group with usual care (UC). Yoga involved 60 minute sessions performed 2x/week for 12 weeks. Yoga home practice was strongly encouraged. Assessments were done at 0, 6, 12 and 24 weeks. UC during this time period commonly involved medications, physical therapy, and chiropractics.

Secondary outcomes included fatigue, depression, anxiety, sleep quality, and self-efficacy, quality of life (SF12 and EQ5D), flexibility, core strength, and balance, among others. Multivariable random effects models were used in intent-to-treat analyses of change by treatment group over time. Analysis of covariance was used to study the change in outcome scores between the two groups.

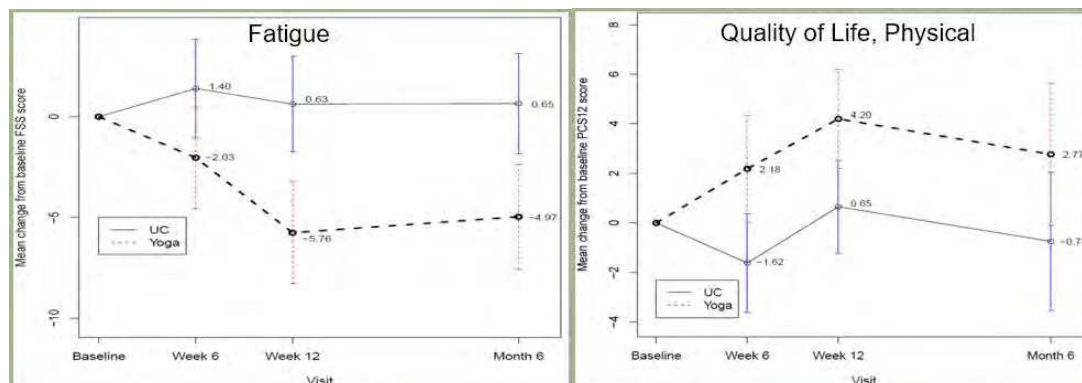
Results: 150 VA patients with cLBP were enrolled in 6 cohorts, with a mean age of 53.4 years; 26% were women, 51% non-White or Hispanic, 34% employed, 18% homeless within the last 5 years, 20% taking opioids, and 15.0 years was the mean cLBP duration. Completing the 6 month assessment were 57/75 yoga, and 55/75 UC group participants.

At 12-weeks, when compared to the UC control group, yoga participants reported significantly less fatigue ($p < 0.001$); higher QoL (PCS12, $p = 0.01$); and improved balance ($p=0.04$). At 6-months (3-months after the formal intervention ended), when compared to the usual care control, yoga participants reported significantly less fatigue ($p = 0.003$); greater global quality of life (EQ5D, $p = 0.04$); core strength ($p=0.04$), and improved balance ($p=0.01$). No significant differences were seen with depression, sleep quality, anxiety, self-efficacy, grip strength or flexibility (Table 1).

Discussion: The yoga group had larger improvements in fatigue, physical and global QoL, core strength and balance. The improvements in some outcomes were modest. Other outcomes, such as depression, anxiety and mental QoL were not significantly different between the two groups. These outcomes occurred within the context of lower than optimal adherence, and decreased pain medication usage among the study subjects. These mental health outcomes represent new findings in the field of yoga and cLBP research, not fully reported upon yet². This data can be used to pilot future studies, which are critically needed because of the high rates of mental health comorbidity seen among sufferers of cLBP. Additionally, this study points to physical outcomes (i.e. fatigue and balance), which might have an important role in the research of cLBP.

Table 1. Outcome Data

	12-weeks	6-months
Fatigue – FSS	$p < 0.001$	$p = 0.003$
Depression – CESD	ns	ns
Sleep Quality – PSQI	ns	ns
Anxiety – BAI	ns	ns
Self-Efficacy	ns	ns
QoL – PCS12 Physical	$p = 0.012$	ns
QoL – MCS12 Mental	ns	ns
QoL – global – EQ5D	ns	$p = 0.047$
Grip Strength	ns	ns
Core Strength	ns	$p = 0.045$
Flexibility	ns	ns
Balance	$p = 0.036$	$p = 0.010$



1. Groessl EJ, et al. Am J Prev Med, 2017.
2. Saper RB, et al. Ann Intern Med, 2017.

Changes in sagittal alignment in upslope or downslope: An insight into dynamic spinal stenosis symptomatology

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Introduction: Classical textbook description of symptomatic spinal stenosis is worsened symptoms while walking on a downslope and improved in upslope posture as a result of respective extension and flexion movements of the lumbar spine with resultant reduction and relative increased spinal canal diameter. However, these dynamic changes and resulting changes in sagittal alignment have not been studied. Hence, the aim of study is to analyze the changes in sagittal alignment with downslope and upslope positions to better understand the dynamic changes in the spine related to lumbar spinal stenosis.

Methods: Ten asymptomatic young adults without back pain, spinal disease or surgery were recruited. Whole body biplanar images were obtained at level ground standing, standing on 20 degrees downslope and 20 degrees upslope using an adjustable slant board. Sagittal parameters included spinopelvic parameters (lumbar lordosis (L1-S1), thoracic kyphosis (T5-12), pelvic tilt, sacral slope, pelvic incidence), lower limb parameters (posterior pelvic shift, knee flexion angle) and global balance parameters (sagittal vertical axis, C2-hip axis) were measured and evaluated.

Results: The lumbar alignment did not have significant changes in both downslope and upslope settings. Main compensatory changes occurred in the lower lumbar segments at L4/5 and L5/S1. The balancing mechanism in downslope setting were different in each individual but the net outcome was to maintain a balanced spine with little change in global alignment. The balancing mechanism in upslope setting favors translation of global alignment forward as evident by increased C2-Hip axis angle, sagittal vertical axis, C2-C7 sagittal vertical axis and sacral slope, along with decreased thoracic kyphosis.

Discussion: This study suggests that the overall balance and posture, especially lumbar lordosis do not change with different postures. The spine balance is maintained by compensatory mechanisms contributed by all segments including changes in cervical and thoracic alignments. Our findings of compensatory changes occurring more dramatically at L4/5 and L5/S1 suggest that in lumbar spinal stenosis, lower levels' spinal canal diameter may be affected more by dynamic postures than the upper levels. Symptoms occurring with different slope-walking may only be relevant to lower lumbar compressions.

Short time clinical outcome of Chondriase injection therapy for lumbar disc herniation

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Introduction: Chondriase that induces chemonucleolysis has been clinically approved for the treatment of lumbar intervertebral disc herniation in Japan. We aimed to assess the short time clinical effect of Chondriase injection therapy for the treatment of lumbar disc herniation.

Methods: Patients with lumbar disc herniation who underwent Chondriase injection in our department with at least a follow up of 1 month were studied. The level of herniation, herniation type, and clinical symptom were investigated. We also assessed the extent (degree) of disc degeneration by Pfirrmann grading and the change in herniation size using MRI before and 1 month after injection.

Results: The patients consisted of 9 males and 3 females with a mean age of 50 years old. The level of herniation was L2/3 in 1 patient, L3/4 in 1 patients, L4/5 in 5 patients, and L5/S in 5 patients. The herniation type was protrusion in 9 patients and transligamentous extrusion in 3 patients. All patients showed radicular pain and 1 patient showed bilateral lower extremity pain. Eleven out of 12 patients showed improvement in their pain within 1 month after injection. However, 1 patient had elevated pain due to the herniation enlargement and required operation. Among 12 cases, 2 were with severe comorbidities who could not go under general anesthesia, but both obtained successful pain relief.

Pfirrmann grading of disc was II in 1 patient, III in 7 patients, and IV in 4 patients, and 5 cases (42%) showed progression of Pfirrmann grade after Chondriase injection. The reduction of herniation size was observed in 5 cases (42%).

Discussion: Chondriase is the world first therapeutic agent for lumbar disc herniation which was approved in Japan. In most cases, sufficient pain relief was achieved even in case with inoperable condition. However, we should pay attention to neurological worsening caused by herniation enlargement. In MRI findings, progression of disc degeneration and reduction of herniation were observed in approximately half of cases which would require further observation.

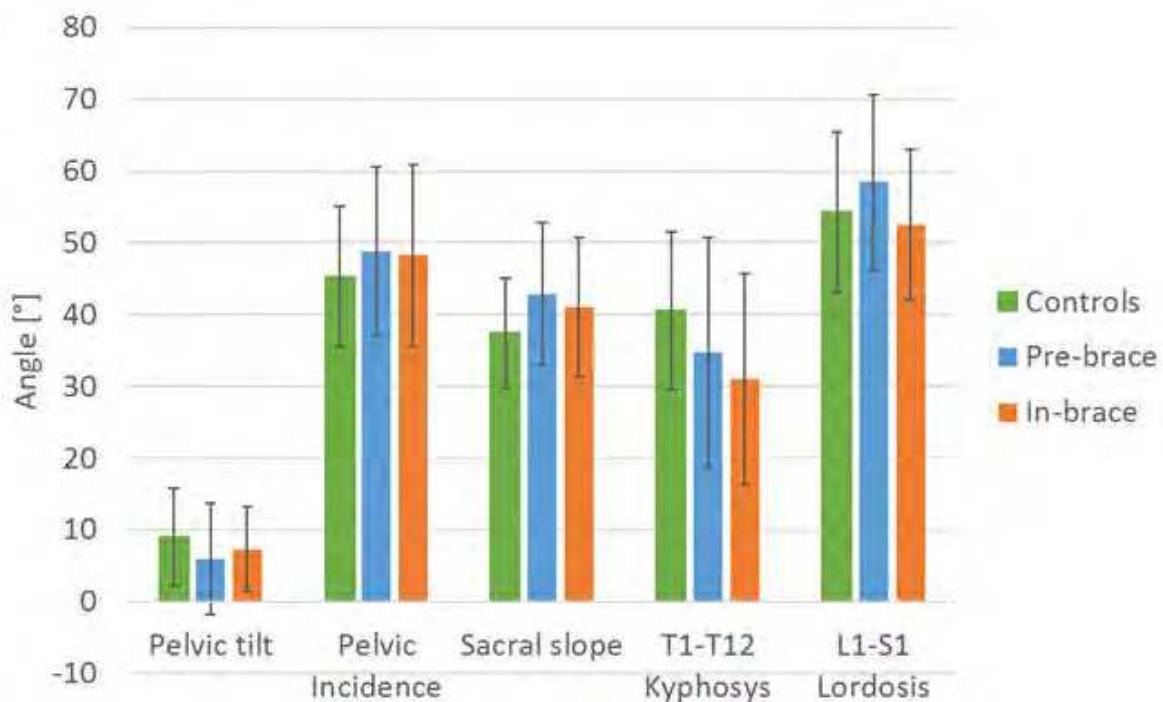
Effects of bracing on head and pelvis sagittal alignment in adolescent idiopathic scoliosis**Claudio Vergari¹, Isabelle Courtois², Eric Ebermeyer², Raphaël Pietton³, Houssam Bouloussa³, Raphael Vialle³, Wafa****Skalli¹**1. *Institut de Biomécanique Humaine Georges Charpak, Arts et Métiers ParisTech, Paris, France*2. *Unite Rachis, CHU - Hopital Bellevue, Saint-Etienne, France*3. *Department of Paediatric Orthopaedics, Armand Trousseau Hospital, Université Pierre et Marie Curie-Paris 6, Paris, France*

Introduction: Research on scoliotic deformities usually focus on the spine and the trunk; nevertheless, the “pelvic vertebra” is the first link of the compensatory chain that keeps the head upon the pelvis, and it is often neglected in the analysis of brace effect. This could be particularly important in adolescent idiopathic scoliotic (AIS) patients, since pelvic parameters can change during growth. Bracing should consider the physiological pelvic alignment of the patient, since altering it could lead to imbalance. The aim of this study was to assess the sagittal alignment of AIS patients from head to pelvis, compare it to healthy controls and determine the short-term effect of bracing.

Methods: Adolescent controls and AIS patients were included retrospectively and prospectively after ethical committee approval. All subjects underwent low-dose calibrated biplanar radiographies in free-standing position; AIS patients were imaged both at treatment decision (pre-brace) and in-brace between 0 (same day) and 9 months after. Validated methods were employed to reconstruct the 3D geometry of the spine, pelvis and odontoid process (OD) for each radiological exam. The following parameters were calculated: pelvic tilt (PT), pelvic incidence (PI), sacral slope (SS) T1-T12 kyphosis (TK), L1-S1 lordosis (LL) and the angle between the vertical and the line joining the OD and the center of the bicoxo-femoral axis (OD-HA angle). Differences between groups were analyzed with Kruskal-Wallis tests, and changes induced by bracing with paired Wilcoxon tests ($p < 0.05$). Results are reported as mean \pm SD.

Results: Eighty-three controls (14 \pm 3 years old) and forty-two AIS patients (13 \pm 2 years old, average Cobb angle 29° \pm 12°, ranging from 16 to 61°) were included. Prescribed braces were: 29 Boston and 13 night braces. Figure 1 shows the results for the three groups. PT and PI were similar between AIS and controls ($p > 0.05$) but bracing induced significant changes in PT: patients who had a PT $> 10^\circ$ decreased their PT by $-2.5 \pm 3.0^\circ$ ($p=0.005$), while the rest increased PT by $3.3 \pm 3.3^\circ$ ($p < 0.001$). SS was significantly higher pre-brace than in controls, while TK was lower ($p < 0.05$). LL was significantly lower in-brace than pre-brace and controls. OD-HA was the same in the three groups ($-2.0 \pm 2.6^\circ$) and it was not significantly affected by bracing.

Discussion: The short-term effects of bracing on head-to-pelvis sagittal alignment were analyzed in this study. AIS patients presented flat backs compared to controls, as expected, but bracing tended to exacerbate this phenomenon rather than restoring a normal sagittal alignment. Indeed, TK and LL decreased, and this was accompanied by changes in PT. These compensatory changes could aim at keeping the head upon the pelvis, since OD-HA angle was constant. Longer follow-up of patients under treatment would clarify what is the impact of pelvis realignment on the treatment outcome. Nevertheless, given the growing agreement on the importance of sagittal balance in scoliosis treatment, the changes observed in pelvic parameters suggest that the pelvic vertebra should be considered when designing the brace.



The influence of the low-level laser on polarization of bone marrow-derived macrophage

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Introduction: To investigate the influence of 810nm low-level lasers of different energy on the polarization of macrophage.

Methods: To culture the bone marrow macrophages derived from BALB/c-WT mouse with M-CSF conditioned cultural medium and examine the expression of F4/80 by flow cytometer for identification. To test lipopolysaccharide (LPS)-induced polarization status and the expression of iNOS, Arg1, CD86 of bone marrow macrophage by flow cytometry, reverse transcription PCR and Western blotting, respectively. To examine the cell viability, polarization of M1 macrophages and the expression of iNOS and Arg1 induced by 810nm low-level laser of different energies by immunofluorescent staining, MTT assay, reverse transcription PCR and Western blotting.

Results: According to the results of flow cytometry, we found that the rate of F4/80 positive cells cultured with M-CSF conditioned medium was 98%. The mRNA and protein level of iNOS and CD86 in macrophage cells were both significantly higher after induction by LPS- $\text{INF-}\gamma$. The viability of M1 cells was significantly decreased when the energy of the low-level laser was 4 J/cm^2 while the viability remained unchanged when energy was 1, 2 or 3 J/cm^2 compared with control. The amount of Arg1 positive cells that represent M2 macrophages was not significantly different from control when the irradiation doses were 1 or 2 J/cm^2 by immunocytochemistry analysis. However, the Arg1 positive cells were significantly increased and the iNOS positive cells that represent M1 macrophages were significantly increased when the irradiation doses were 3 or 4 J/cm^2 . When the irradiation doses were 1 or 2 J/cm^2 , the mRNA and protein level of iNOS and Arg1 remained unchanged compared with control. When the irradiation doses were 3 or 4 J/cm^2 , the mRNA and protein level of iNOS were significantly decreased and those of Arg1 were significantly increased.

Discussion: 810nm low-level laser with the energy of 1 or 2 J/cm^2 has no significant influence on the polarization and viability of macrophages. M1 macrophages can be polarized into M2 macrophages while there was no significant difference in the cell viability when the energy was 3 J/cm^2 . When the energy was 4 J/cm^2 , M1 cells polarized into M2 cells and the cell viability significantly decreased.

Impact of Total Hip Arthroplasty for Low Back Pain and Radiological Spinopelvic Sagittal Parameters in Patients with Hip Diseases

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Background: In patients with hip diseases, the spinal malalignment is frequently induced with changes of the inclination of the pelvis, inducing low back pain (LBP). At the progressive or end stage of hip disease, total hip arthroplasty (THA) is often performed, however, there are few reports on the impact of THA for spinopelvic sagittal alignment and LBP.

Purpose: We prospectively investigated the changes in LBP and sagittal spinopelvic alignment before and after THA, and examined the incidence and improvement of LBP. The correlation between LBP and spinopelvic alignment is also investigated.

Method: Consecutive 65 cases in half a year (15 males, 50 females, average 62.9 ± 1.3 years old) who underwent THA from July 2016 were examined. Patients included 60 cases of hip osteoarthritis, 4 cases of femoral head necrosis and 1 case of rheumatoid arthritis. We investigated Japan Orthopaedic Society hip score (JOA Hip score) and Oswestry Disability Index (ODI) before and 6 months after surgery. Also, spinopelvic sagittal parameters including sagittal vertical axis (SVA), pelvic tilt (PT), pelvic incidence (PI), and lumbar lordosis (LL), were measured in lateral plain X-ray in standing position. Over 30 mm of visual analogue scale (VAS) for LBP was defined as valid LBP, and incidence of LBP was evaluated. Statistics were performed with paired t-test and chi-square test, and p value <0.05 was defined as significant difference.

Result: The prevalence rate of LBP was 48% before THA, and decreased significantly to 17% in postoperative 6 months after surgery. VAS score for LBP was 34.5 mm before THA, and significantly improved to 15.4 mm after surgery. At 6 months after THA, LBP in 95% of patients had improved, and both JOA Hip score and ODI were significantly improved 6 months after THA. Among the spinopelvic parameters, only PT increased significantly (16.4° to 19.4°), but no statistically significant difference was noted in the other parameters.

Discussion: In patients after THA, LBP and lumbar spine function were improved after THA. In Japanese, there are many cases in which the pelvis is compensated forwardly due to the secondary degenerative hip osteoarthritis accompanied by acetabular dysplasia. Our results suggest that PT increased as a result of reduction of contracture in front of the hip joint as results of THA and postoperative rehabilitation, and a posterior inclination of the pelvis (which is increase of PT) was induced with compensatory mechanism was cancelled after THA. Previous evidence reported that activity of daily living depends on sagittal malalignment or imbalance. Our results indicated that LBP and lumbar spine function were improved as with hip pain and function after THA, but suggested that influence of spinal pelvic alignment was relatively low in THA patients.

The association between narrow cross-sectional area of lumbar dural sac and lower limb numbness in a Japanese population

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Introduction: In a super-ageing society, the prevalence of lumbar spinal canal stenosis (LSS) is increasing. LSS causes low back pain (LBP), lower limb pain (LP) and lower limb numbness (LN) and decreases patient's QOL. But, the relationship between symptoms of LSS and the cross-sectional area of the lumbar dural sac (CSA) remains unclear. The aim of this study was to clarify the relationship between symptoms of LSS and CSA using MRI in a Japanese population.

Method: A total of 106 individuals (Male: n=49, Female: n=57, 59.5±14.0 years old) who participated in the Iwaki Health Promotion Project 2016 were recruited. The participants underwent lumbar MRI. We measured the CSA of each lumbar intervertebral disc level (L1/2 – L5/S) and defined the minimum value of CSA as mCSA. The participants whose mCSA ≤ 100mm² were included in this study. They filled out self-administered questionnaires related to the symptoms of LSS: visual analog scale of LBP, LP and LN (VAS, 100 mm), and the Japanese Orthopedics Association back pain evaluation questionnaire (JOABPEQ; full score 100 points, with 0 as worst) which is the QOL score related to LBP. In the JOABPEQ, we evaluated lumbar function (LF), gait function (GF) and pain. Spearman's correlation test was performed. Multiple linear regression analyses were performed with VAS (LBP, LP and LN) and JOABPEQ as dependent variables, and age, sex, BMI and mCSA as independent variables.

Results: The mean of mCSA was 71.8±18.8 mm². The most frequent stenosis level was L5/S (42.5%). The percentage of other intervertebral levels were L4/5 (34.9%), L3/4 (18.9%), L2/3 (3.8%) and L1/2 (0%). In Spearman's correlation test, VAS (LN) and JOABPEQ (LF, GF) had relations with mCSA. In multiple linear regression analysis, VAS (LN) was related with mCSA (β -0.252, 95% CI -0.348–0.044, $p < 0.05$).

Discussion: In our study, mCSA was not related to LBP and LP, but was related to LN. The narrower the mCSA got, the worse the LN was. mCSA may be an indicator for LSS treatment, for example in decision making for decompression level, especially for LN. In the future, we would like to investigate the relationship between mCSA and the symptoms of LSS in a longitudinal study.

Intramuscular oxygenation of lumbar multifidus in different trunk positions in sitting

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Introduction: A deficiency in lumbar muscle blood circulation is supposed to be a major risk factor for nonspecific low back pain. A correlation between lumbar intramuscular pressure and intramuscular oxygenation was reported in previous researches. However, it is still unclear and the relationship between intramuscular oxygenation and trunk positions or the changes of the intramuscular oxygenation over time are also unclear. The aim of this study is to investigate changes in relative oxygenation over time on the lumbar multifidus in different postures in sitting.

Methods: Twelve healthy subjects (7 male, 5 female average age 20.9 years) without low back pain for past twelve months were recruited to this study. They received full explanation and all agreed to participate in this study. Near-infrared spectroscopy (NIRS) was used to non-invasively measure oxygenated hemoglobin (Oxy-Hb) of lumbar multifidus at L5-S1 segment. All measurements were obtained in neutral position, 60 degree of trunk flexed position and 20 degree of trunk extended position in sitting. Subjects were asked to move into either flexed or extended position from starting (neutral) position in 3 seconds timed by metronome and maintained these positions for 30 seconds. The angles of flexed and extended positions were measured with goniometer and self-aid devices were used to properly maintain these positions. All participants received education and practice time in order to be able to perform proper body movements and positions prior to assessment. The measurements of Oxy-Hb were compared at -3 seconds (neutral position), 0, 10, 20, and 30 seconds of in each flexed or extended position in sitting.

Results: In flexion, the Oxy-Hb of lumbar multifidus was significantly decreased from neutral position (-3 seconds) to flexed position (0 second) ($p=0.004$), however, there were no significant differences from 0 second up to 30 seconds in flexed position ($p=0.78, 0.59, 0.37$). In extension, the Oxy-Hb of lumbar multifidus was significantly increased from 0 second to 10 seconds ($p=0.001$) in extended position, however, there were no significant differences from neutral position (-3 second) to extended position (0 second) ($p=0.02$) and from 10 seconds to 30 seconds in extended position. ($p=0.93, 0.39$).

Discussion: The results of this study indicate that the Oxy-Hb of lumbar multifidus decreases immediately once trunk starts moving into flexed position in sitting. On the other hand, the Oxy-Hb of lumbar multifidus increases up to 10 seconds once trunk is in extended position. Therefore, it might be more beneficial for a person to teach to avoid flexed position and hold extended position up to 10 seconds for blood circulation purposes in sitting. Yet, these findings have to be verified in consecutive studies in people with low back pain, spinal deformity or different age groups in clinical practice.

Investigation for risk factor with spinal kyphosis Considerations based on medical examination of residents

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Introduction: Progression of osteoporosis, reduction in muscle mass, and other such changes are considered as risk factors of postural change. However, few studies have examined the causes of kyphosis progression over time. The purpose of this study was to assess the risk factors of kyphosis progression in local residents.

Methods: The study considered general inhabitants of Hino town in Tottori prefecture. Of 223 people who underwent medical checkup in 2014, 106 (mean age: 71.3 years) who also underwent medical checkup in 2018 were included. The kyphosis index was measured, and the change in the kyphosis index from 2014 to 2018 was assessed. Those who showed an increase were included in a progression group (n = 57), whereas those who did not show an increase were included in an invariant group (n = 49). The participants did not experience vertebral fracture during the study period. Age, sex, body mass index, low back pain visual analog scale (VAS) score, Oswestry disability index (ODI), kyphosis index, obesity (evaluated by body fat), walking speed (m/s), bone density [ultrasound % young adult mean (YAM)], grip strength (kg), limb muscle mass, and trunk muscle mass (corrected by the square of body height m): kg/m² were compared between the groups. The risk factors of kyphosis progression were examined using the increment of the kyphosis index as a dependent variable.

Results: The mean age was significantly higher in the invariant group than in the progression group (73.1 vs. 69.1 years, P < 0.05). The kyphosis index was significantly higher in the invariant group than in the progression group (11.7 ± 2.1 vs. 9.4 ± 3.0, P < 0.01). The low back pain VAS score and ODI were significantly lower in the invariant group than in the progression group (12.7 ± 20.7 vs. 19.2 ± 22.7, P < 0.05 and 7.5 ± 8.9 vs. 10.9 ± 9.3, P < 0.05, respectively). The limb muscle mass and trunk muscle mass were significantly higher in the invariant group than in the progression group (7.0 ± 0.9 vs. 6.5 ± 1.0, P < 0.01 and 9.4 ± 0.7 vs. 8.8 ± 0.8, P < 0.01, respectively). Grip strength was significantly higher in the invariant group than in the progression group. There were no significant differences in the other items. In logistic regression analysis, trunk muscle mass was identified as a risk factor of kyphosis progression (odds ratio: 0.23, 95% confidence interval: 0.06–0.89, P < 0.03).

Discussion: Trunk muscle mass was involved in kyphosis progression. Considering that age was lower in the progression group than in the invariant group, a decrease in muscle mass owing to aging is not conceivable is presumed that individuals, who are likely to develop a circle easily, have other factors that can cause a decrease in muscle mass.

Conclusion: A decrease in trunk muscle mass might be involved relatively early in kyphosis progression.

Analysis of the fracture patterns in imaging studies and risk factors for sacral insufficiency fracture: Are the sacral fractures seen in lumbosacral fusion insufficiency fractures or stress fractures?

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Introduction: Sacral insufficiency fractures occur when normal stresses are applied to bone with decreased density, most often due to osteoporosis. Sacral stress fractures are commonly misdiagnosed because their presentation is similar to that of other pathologies, such as degenerative disk disease, sacroiliac joint dysfunction, herniated nucleus pulposus, vertebral compression fractures, facet arthropathy, trochanteric bursitis, hamstring and lower-back muscle strains, and spondylolisthesis. This study examined the risk factors associated with the development of sacral insufficiency fractures to improve their diagnosis in clinical practice.

Methods: Consecutive patients who suffered sacral insufficiency fractures between June 2010 and December 2016 underwent radiological assessments. The study population was divided into lumbosacral fusion (n=16) and non-fusion (n=30) groups. The patient description, physical findings, medical treatment, imaging, follow-up, and risk factors were assessed. Patients were grouped using plain radiography, and at least one of the following diagnostic imaging procedures was performed to seek evidence of sacral insufficiency fractures: magnetic resonance imaging, computed tomography, bone scan, and/or single photon emission computed tomography.

Results: The study enrolled 46 patients treated for sacral insufficiency fractures (4 men and 42 women). The mean age at the initial visit was 72.1±10.6 years old and the mean body mass index was 22.8 kg/m². In the lumbosacral fusion group (n=16), fusion was performed for one, two, three, four, five, and seven segments in 5, 3, 4, 1, 2, and 1 patients, respectively. In nine patients, the fusion included the sacrum without using iliac screw fixation, while six underwent fusion including L5. The mean ages of the non-fusion and fusion groups were 75.8±9.8 and 66.6±9.1 years, respectively ($p=0.003$); their mean body mass index values were 21.4±3.8 and 24.6±3.34 kg/m² ($p=0.010$), the mean bone mineral densities of the spine were 0.788±0.134 and 0.996±0.202 g/cm² ($p=0.001$), and the mean T-scores were -2.55±1.23 and -1.16±1.59 ($p=0.007$). Overall, 21 patients were taking osteoporosis medication, 11 of 30 in the non-fusion group (10 on bisphosphonate and one on raloxifene) and 10 of 16 in the fusion group (nine on bisphosphonate and one on raloxifene). The mean dose-length of the osteoporosis medication was 3.45±3.08 and 8.1±5.04 years in the non-fusion and fusion groups, respectively, ($p=0.024$). There were no significant differences in the lower segment of fusion to the sacrum and L5.

Discussion: Sacral insufficiency fractures develop in patients who have undergone lumbosacral fusion. The fractures take about 10 years to develop after fusion. The use of osteoporosis medication did not differ between the patient groups. Sacral insufficiency fractures developed although the bone mineral density was statistically higher in lumbosacral fusion patients.

Relationship between hip muscle flexibility and low back pain during lumbar flexion and extension

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Introduction: Although nonspecific low back pain (LBP) is considered a multifaceted problem, much attention has been placed on hip muscle flexibility and its potential contributions to this condition. Decreased flexibility of hamstrings or hip flexors have been highlighted as possible causes of LBP. However, few studies have examined the influence of hip muscle flexibility on the development of LBP provoked by trunk movement. The purpose of the present study was to determine the flexibility of the hip muscles using clinical tests in patients with LBP during lumbar flexion and extension.

Methods: We included 50 patients with nonspecific LBP in this study. Patients were categorized into 2 groups: patients with LBP at lumbar flexion (group F; n = 20, 8 male and 12 female; age 66 ± 13.8 years (mean \pm SD)) and patients with LBP during lumbar extension (group E; n = 30, 9 male and 21 female; age 61 ± 17.0 years). The levels of flexibility of hip muscles were measured using the following 5 tests: a straight leg-raising test (SLR) for hamstring muscles, a GM-test for gluteus maximus, an Ober test for tensor fasciae latae, a modified Ely test for rectus femoris, and a modified Thomas test for iliopsoas. A positive result was defined as the inability to achieve the specified angle of hip range of motion in each test position, and indicated the presence of tightness of the targeting muscle.

Results: In group F, 55%, and in group E, 30% of the patients had a positive result for the SLR test, 15% and 20% of the patients had a positive result for the GM-test, 20% and 83% for the Ober test, 30% and 63% for the modified Ely test, and 20% and 60% for the modified Thomas test, respectively. The proportion of positive results for the Ober test, modified Ely test, and modified Thomas test was significantly higher in the patients in group E than it was in those in group F ($P < 0.05$).

Discussion: We found that patients with LBP during lumbar extension were more likely to have tight hip flexor muscles, than those with LBP at lumbar flexion. The tightness of the anterior hip region may induce excessive anterior pelvic tilt with resultant increased lumbar lordosis, leading to increased mechanical stress on the posterior elements of the lumbar spine, and contribute to LBP during lumbar extension. Research to evaluate the efficacy of stretching hip flexor muscles in patients with LBP during lumbar extension is warranted.

Does magnitude of dural tube compression induce fall? –A prospective one-year follow-up in the community–

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Purpose: In an aging society, it is well known that lumbar spinal stenosis (LSS) influences various health problem. Clinically diagnosed LSS is thought to induce fall. On the other hand, in degenerative spine disease, it is widely accepted that degenerative changes do not always cause symptoms. This means that dural tube compression is an anatomical cause for LSS; however, dural tube compression is not always symptomatic. The purpose of this study was to assess the relationship between magnitude of dural tube compression and the occurrence of fall within a year.

Participants and Method: This was a prospective cohort study of 459 participants who were received conventional MRI of the lumbar spine. One year later, 345 subjects (male 105, female 240, most frequent age: 70s, follow-up rate 64.9%) were assessed for the number of fall past one year (0, 1-2, 3 \leq). On MRI, transverse slices were aligned as parallel as possible to each intervertebral disc. The dural sac cross-sectional area (DCSA) of L1/2–L5/S1 on the T2-weighted image was measured using the conventional formula described by Hamanishi (1994). The number of intervertebral discs of which DCSA was less than 50 mm² (ranged 0-5) was analyzed. A multiple logistic regression analysis was performed with number of fall past one-year as the dependent variable, and age, gender, and the number of intrvertebral discs of which DCSA was less than 50 mm² as independent variables. A p value of less than 0.05 was considered statistically significant.

Results: Only the number of intrvertebral discs of DCSA less than 50 mm² affected the occurrence of fall (3 and more) (Odds ratio 5.647, 95%CI 1.357-23.494).

Discussion: We have already reported that LSS was associated with impairment of balance-function evaluated by stabilometer, and the occurrence of fall at retrospective and prospective one-year follow-up. From the present study, dural tube compression (anatomical LSS) with or without LSS symptoms has possibility of e an independent factor for the occurrence of fall in the community. In the aging society, LSS is very important to prevent fall and fracture.

Comparative analysis of sarcopenia and back muscle degeneration in back pain and new risk index of back muscle degeneration

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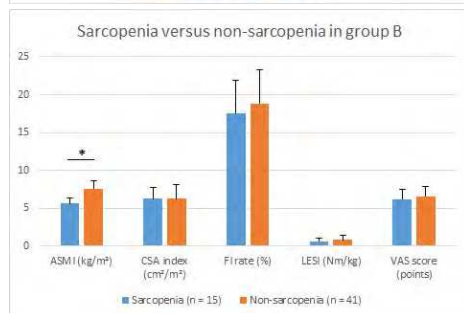
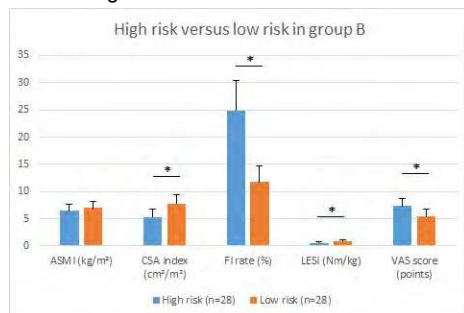
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Introduction: We aimed to investigate relationship between sarcopenia and back muscle degeneration and that between sarcopenia and back muscle degeneration in back pain, and develop a new risk index of back muscle degeneration. Sarcopenia is an age-related decline in muscle mass and function. The Asian Working Group for Sarcopenia recommends diagnosis of sarcopenia by handgrip strength, gait speed, and skeletal muscle mass. However, this criterion can barely represent back muscle degeneration.

Methods: Subjects were patients with back pain who answered a questionnaire during October 2016-May 2017. Appendicular skeletal muscle index (ASMI), cross-sectional area (CSA) index, fatty infiltration (FI) rate of the paraspinal muscle, and lumbar extensor strength index (LESI) were measured and compared between control (group A) and patient (group B) groups. Correlations between LESI and ASMI/CSA index/FI rate were analyzed. We muscle degeneration risk index using coefficients of LESI, CSA index, and FI rate. Group B was further divided using ASMI and back muscle degeneration risk index. Differences in ASMI, CSA index, FI rate, LESI, and VAS score between those groups were analyzed.

Results: ASMI, CSA index, FI rate, and LESI of groups A and B were all significantly different. LESI showed the highest correlation with FI rate. No significant difference on values of pain and back muscle degeneration was found according to the classification of sarcopenia and non-sarcopenia in group B. However, there was significant difference between the two groups when classified using back muscle degeneration risk index.

Discussion: Sarcopenia and back muscle degeneration might have no direct correlation, but both of them are related to some degree of back pain. However, back muscle degeneration is more associated with back pain. Back muscle degeneration risk index, which reflects both back muscle morphology and function, could be useful evaluation parameter for back pain and back muscle degeneration.



Therapeutic effects of gefitinib-encapsulated thermosensitive injectable hydrogel in intervertebral disc degeneration

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Intervertebral disc (IVD) degeneration is one of the most widespread musculoskeletal diseases world- wide, which remains an intractable clinical challenge. The aim of this study is to investigate the therapeutic potential of the small molecule gefitinib (an epidermal growth factor receptor (EGFR) inhibitor) in ameliorating IVD degeneration. Aberrant EGFR activation levels were detected in both human and rat degenerative IVDs, which prompted us to investigate the functional roles of EGFR by utilizing inducible cartilage-specific EGFR-deficient mice. We demonstrated that conditional EGFR deletion in mice increased nucleus pulposus (NP) extracellular matrix (ECM) production and autophagy marker activation while MMP13 expression decreased. These outcomes are comparable to the use of a controlled-release injectable thermosensitive hydrogel of gefitinib to block EGFR activity in a puncture-induced rat model. We also conducted a case series study involving patients with non-small cell lung cancer and IVD degeneration who received gefitinib treatment from 2010 to 2015. Gefitinib-treated patients displayed a relative slower disc degenerating progression, in contrast to control subjects. These findings thus provide evidence that suppression of EGFR by the FDA-approved drug gefitinib can protect IVD degeneration in rats, implying the potential application of gefitinib as a small molecule drug for treating IVD degeneration.

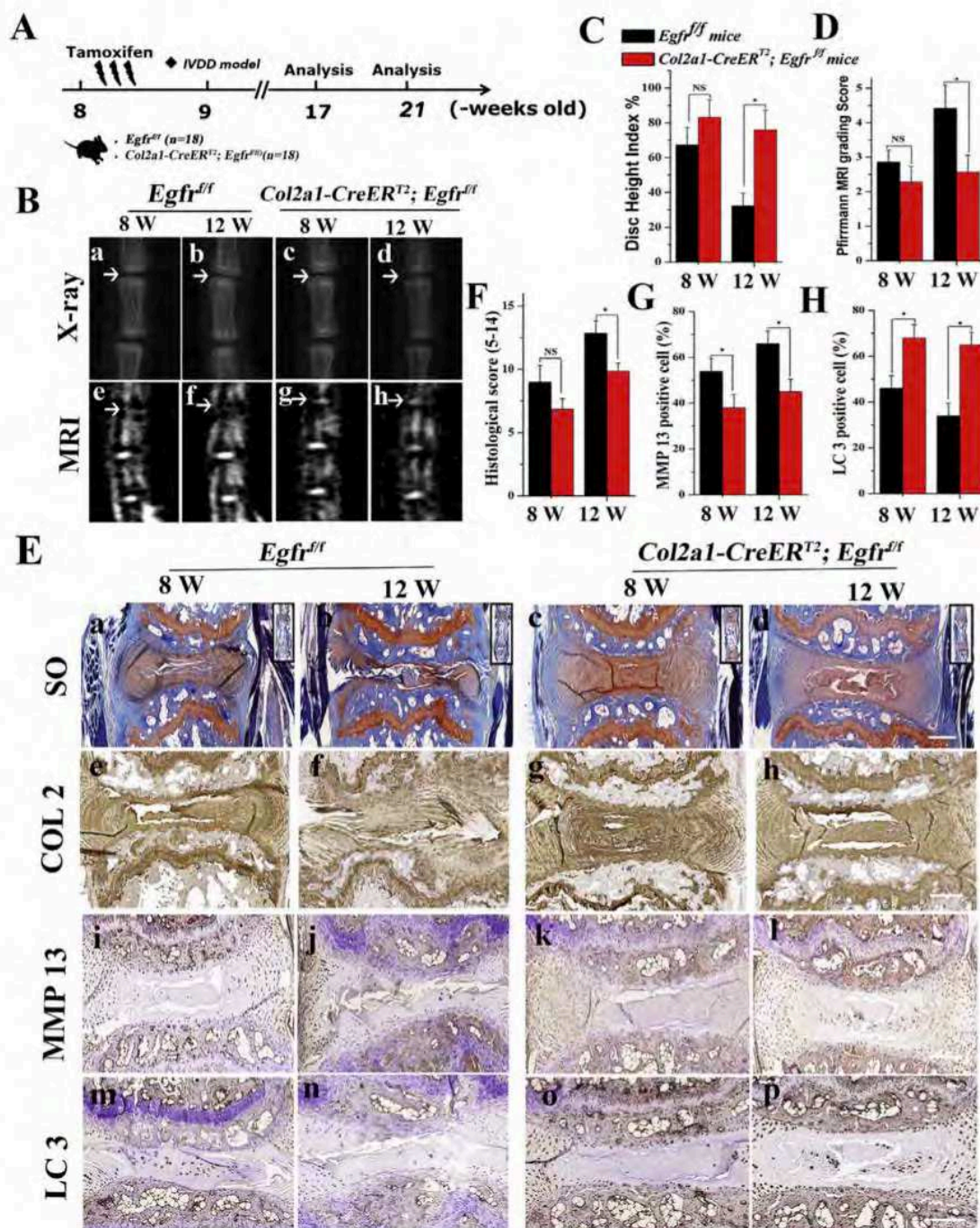


Fig. 1. Delayed IVD degeneration and increased autophagy level in *Col2a1-CreERT2; Egfr^{fl/fl}* mice.

The effect of total hip arthroplasty on the low back pain and lumbar spine function in hip patients with or without scoliosis in lumbar spine.

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Background: In patients for whom total hip arthroplasty (THA) is indicated, low back pain (LBP) is often noted specially in cases with scoliosis in lumbar spine. However, there are few reports that evaluated how LBP, the lumbar spine function, and the lumbar scoliosis change after THA in patients with and without scoliosis.

Aim: To evaluate LBP, lumbar spine function, and X-ray images before and after THA in hip patients and compare them between patients with and without scoliosis.

Patients and Methods: We targeted 50 consecutive cases (Males 10 cases, Females 40 cases, mean age 62.7 years) conducted THA from 2016 in half a year. Cobb angle was measured in X-ray images before and 6 months after THA. The preoperative Cobb angle of 10 degrees or more was defined as scoliosis group and the angle less than 10 degrees as control group. Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), Oswestry Disability Index (ODI) and Visual Analogue Scale (VAS) for LBP were compared between two groups.

Results: There were 16 cases in scoliosis group and 34 cases in control group. Before THA, walking function domain in JOABPEQ was significantly lower (32.1 vs. 58.1) and VAS for LBP was significantly higher (46mm vs. 26mm) in scoliosis group. In scoliosis group, Cobb angle improved 15.2° after surgery from preoperative 24.3°. In JOABPEQ, all domain, which are pain (55.3 to 74.9), lumbar spine function (59.8 to 65.1), walking function (32.1 to 68.3), social life (50.3 to 66.6), and psychological disturbance (44.3 to 59.9) improved after surgery. ODI (34.5 to 16.8) and VAS for LBP (46mm to 20mm) were significantly improved. In control group, Cobb angle was 4.7° before surgery and 3.7° after surgery. In JOABPEQ, all domain, which are pain (71.4 to 83.6), lumbar spine function (66.2 to 77.3), walking function (58.1 to 81.2), social life (52.6 to 72.4), and psychological disturbance (47.7 to 57.7) improved after surgery. ODI (33.6 to 14.7) and VAS for LBP (26mm to 13mm) were significantly improved.

Discussion: In the scoliotic group, walking function was significantly lower and preoperative VAS was significantly larger. Pain relief and gait function were significantly improved in scoliotic group. These results suggested that the leg length difference induced by hip disorder was corrected by THA and that the LBP and gait function improved due to the load reduction in lumbar spine with improvement of scoliosis.

Caudal Epidural Block for Lumbar Spine Disease

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Objective: It is considered to be effective therapy to apply caudal epidural block (CB) to patients with low back pain / lower extremity pain. Epidural steroid injection into chronic low back pain cases has been reported to have moderate or higher evidence for short-term pain relief and long-term pain relief. We report on the effectiveness of CB for patients with low back pain / lower extremity pain this time, so we report them.

Methods: The subjects were from November 2005 to March 2015, 177 cases of low back pain / lower extremity pain 477 times. They were classified into (-) and (+) according to ID numbers and blocked. (-): 1% xylocaine 5 ml + saline 5 ml, (+): 1% xylocaine 4 ml + dexate 3.3 mg + physiological saline 5 ml. Then we have reviewed (1) (2) (3). (1) VAS between (+) (-) group and before CB (a - 1), 1 week after (b - 1), the number of enforcement, treatment course. (2) It was classified into two groups, an acute phase group (A) within 4 weeks after symptoms and a non acute phase group (C) after 5 weeks. VAS between (A) (C) group and before CB (a - 2), 1 week after (b - 2), the number of enforcement. (3) Classification was divided into two groups of symptomatic group with low back pain (L) and group not accompanied by group (I). VAS between (L) (I) group and before CB (a - 3), 1 week after (b - 3), the number of enforcement.

Results: 1) (-) was 234 times in 86 cases and (+) was 243 times in 91 cases. There was no significant difference between VAS and number of enforcement and treatment course, but both (-) (+) and (b - 1) Was significantly lower than (a - 1). 2) (A) was 180 times in 99 cases, and (C) was 297 times in 78 cases. The VAS of (b-2) and the number of enforcement are significantly lower than (A) in (A) Both (b - 2) were significantly lower than (a - 2). 3) (L) was 161 times in 69 cases, and (I) was 108 times in 31 cases. The VAS in (b-3) is significantly lower in (L) than in (I) -3) was significantly lower than (a-3).

Discussion: From the results 1) ,it was considered that CB is effective for mild to medium-term pain relief regardless of steroid use, in cases with back pain and lower extremity pain. Moreover, from the results 2), regardless of the timing, CB is effective for mild to medium-term pain relief in cases with low back pain and lower extremity pain, but it was thought that it is more effective to perform it in the acute phase. Furthermore, from the results 3), CB was effective for relieving mid to long term pain, but it was thought to be more effective for low back pain than symptoms of lumbar spine disease.

Pelvic incidence: computed tomography study evaluating correlation with sagittal sacropelvic parameters

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Introduction: Pelvic incidence is widely used as a determinant of ideal spinal alignment. While understanding that the position and orientation of the sacral endplate in relation to the bicoxofemoral axis influence the pelvic incidence, the contribution by pelvic and sacral anatomy to the pelvic incidence have not been explored. Understanding how sacropelvic anatomy varies with pelvic incidence offers an opportunity to further understand spinopelvic alignment. We aimed to determine correlation of sacropelvic parameters with the pelvic incidence on computer tomography

Methods: Computed tomography scans performed for trauma were identified over a 1-year period. Patients aged over 16 were included. Pelvic incidence (PI), sacral anatomic orientation (SAO), sacral table angle (STA), sacral kyphosis (SK), pelvic thickness (PTH), femorosacral pelvic angle (FSPA), pelvisacral angle (PSA), sacropelvic angle (PRS1) were measured. Additional novel measures including crest-to-pubis distance (CPD), crest-to-sacrum distance (CSD), inlet distance (ID), outlet distance (OD) and inlet-outlet angle were taken. Scans were excluded if there was any destructive pathology that prevented accurate measurement.

Results: 177 scans were analysed. Mean age 44.3 years; 62% male. Intraclass coefficient values were as follows: PI 0.959; SAO 0.918; FSPA 0.973; inlet distance 0.824; outlet distance 0.745; inlet-outlet angle 0.817; CPD 0.964, and; CSD 0.985.

The mean PI was 50.1 (s.d. 10.8; range 29-87). SK (r=0.769), inlet-outlet angle (r=-0.533), PTH (r=-0.370), CSD (r=0.290), STA (r=-0.276) all significantly correlated with PI. Full results from correlation analysis are shown in Figure 1.

Multivariate analysis developed a predictive equation of: $PI = 101.45 - (0.52 \times STA) + (0.67 \times SK) - (0.34 \times \text{Inlet-outlet angle})$, with an adjusted R² 0.734, F-statistic of 163 (p<0.001).

Conclusions: A number of known measures correlated with the PI. Novel measures including the CSD and Inlet-Outlet angle correlated significantly with the PI. Measures that represent the sacral morphology, particularly sacral kyphosis, and the position of the sacrum in space correlated strongly with the Pelvic Incidence and contributed strongly to a predictive equation. Further study will allow us to understand how sacral anatomy contributes to the Pelvic Incidence.

Variables	Age	Gender	CPD	CSD	SAO	PI	PSA	PTH (mm)	PRS1	FSPA	STA	SK	Inlet (mm)	Outlet (mm)	In/Out angle
Age	1	0.001	-0.126	-0.010	-0.192	0.084	-0.083	-0.002	-0.111	0.136	0.040	0.013	-0.128	0.057	-0.016
Gender	0.001	1	0.197	0.138	0.085	0.105	-0.099	-0.005	-0.071	0.118	0.073	0.037	0.357	0.309	-0.282
CPD	-0.126	0.197	1	0.028	0.029	0.143	-0.136	0.262	-0.124	0.198	0.118	0.128	0.530	0.314	-0.211
CSD	-0.010	0.138	0.028	1	0.098	0.290	-0.296	0.162	-0.318	0.137	-0.284	0.174	0.335	0.277	-0.314
SAO	-0.192	0.085	0.029	0.098	1	-0.704	0.706	0.235	0.705	-0.615	0.139	-0.644	0.187	0.039	0.345
PI	0.084	0.105	0.143	0.290	-0.704	1	-0.998	-0.370	-0.979	0.802	-0.276	0.769	-0.141	0.056	-0.553
PSA	-0.083	-0.099	-0.136	-0.296	0.706	-0.998	1	0.374	0.982	-0.801	0.281	-0.771	0.146	-0.048	0.549
PTH (mm)	-0.002	-0.005	0.262	0.162	0.235	-0.370	0.374	1	0.393	-0.397	-0.007	-0.243	0.680	0.120	0.252
PRS1	-0.111	-0.071	-0.124	-0.318	0.705	-0.979	0.982	0.393	1	-0.798	0.316	-0.767	0.168	-0.046	0.575
FSPA	0.136	0.118	0.198	0.137	-0.615	0.802	-0.801	-0.397	-0.798	1	0.321	0.804	-0.148	0.024	-0.509
STA	0.040	0.073	0.118	-0.284	0.139	-0.276	0.281	-0.007	0.316	0.321	1	0.060	0.032	-0.034	0.102
SK	0.013	0.037	0.128	0.174	-0.644	0.769	-0.771	-0.243	-0.767	0.804	0.060	1	-0.091	-0.244	-0.425
Inlet (mm)	-0.128	0.357	0.530	0.335	0.187	-0.141	0.146	0.680	0.168	-0.148	0.032	-0.091	1	0.321	-0.073
Outlet (mm)	0.057	0.309	0.314	0.277	0.039	0.056	-0.048	0.120	-0.046	0.024	-0.034	-0.244	0.321	1	-0.332
In/Out angle	-0.016	-0.282	-0.211	-0.314	0.345	-0.553	0.549	0.252	0.575	-0.509	0.102	-0.425	-0.073	-0.332	1

Characteristics of neuropathic pain due to lumbar spine disorders: Relationship with recognition of pain, psychiatric problems, and HR-QoL

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Introduction: Mechanism-based treatment is very important when treating musculoskeletal pain. Neuropathic pain (NeP) is regarded as pathological pain in which the symptoms do not improve even after the source of pain has been removed, and its presence greatly influences the treatment of spinal disorders. We previously developed a screening tool for NeP caused by spinal disorders, called the Spine pain *DETECT* Questionnaire (SPDQ) (PLoS One 2018). The purpose of this study was to determine the prevalence of NeP with lumbar spine disorders using a short-form version of SPDQ (SF-SPDQ), and to examine the correlation between NeP and recognition of pain, psychiatric factors, and health-related quality of life (HR-QoL).

Methods: We recruited 118 patients, aged 20 years or older, with neuropathic pain caused by lumbar spine disorders persisting for ≥ 3 months and with a NRS score of ≥ 1 . The diagnosis of neuropathic pain due to lumbar spine disorders was confirmed by certificated orthopaedic spine surgeons. We calculated descriptive statistics for general scores using the SF-SPDQ. Subjects were divided into NeP+ and NeP- groups based on general SF-SPDQ scores. The other measurements for assessment of factors that correlate with NeP included pain intensity, the pain catastrophizing scale (PCS), the Brief Scale for Psychiatric Problems in Orthopaedic Patients (BS-POP), and the 36-Item Short Form Health Survey (SF-36).

Results: 1. Ninety-one subjects had an element of NeP (NeP+ group). The prevalence of NeP with lumbar spine disorders was 70.5%. 2. Pain intensity was 6.3 in the NeP+ group and 6.7 in the NeP- group, indicating no statistically significant differences between the two groups. 3. The general score of the PCS in the NeP+ group was statistically significantly higher than in the NeP- group. 4. The incidence of abnormal BS-POP scores was 47.3% in the NeP+ group and 36.8% in the NeP- group, indicating a statistically significantly higher rate of abnormality in BS-POP in the NeP+ than the NeP- group. 5. The mean deviation score of all components of the SF-36 questionnaire in the NeP+ group was lower than that in the NeP- group.

Discussion: Patients with lumbar spine disorders with an element of NeP have a strong tendency for catastrophizing pain, psychiatric problems, and lower HR-QoL as compared with patients without NeP, even if the pain intensity is equivalent in both groups. This tendency for catastrophizing and the associated psychiatric factors should be remembered when treating patients with lumbar spine disorders and NeP.

A new classification of micro-damaged cartilaginous endplates in the degenerative discs

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Introduction: Tidemark avulsions or irregularities at the disc-vertebra interface are closely related to low back pain(LBP) and intervertebral disc degeneration. However, histological features of micro-damaged cartilaginous endplates(CEPs) filled with vessel, nucleus pulposus or CEP tissues are currently rare. It limits our understanding the back pain mechanisms, and even interferes with the associated treatment. This study presented the types of micro-damaged cartilage endplate from clinical surgical specimens, and summarized a new classification of micro-damaged CEPs, providing more histological and imaging evidence for the treatment of low back pain.

Methods: Firstly, human lumbar cartilaginous endplate specimens were collected from patients with lumbar vertebral burst fractures or LBP who underwent anterior vertebral body excision and fusion surgery. All the CEP specimens were extracted, fixed, sectioned, and stained for histologic evaluation. Then, histological types were determined using Hematoxylin-eosin staining, safranin O fast green and alcian blue staining. MMP13 and type 2 collagen(Col II) of CEPs were stained to evaluate the properties of disc degeneration. Protein gene product-9.5 (PGP9.5) was detected by immunohistochemistry to observe the in-growth nerve in the CEP associated with LBP. Finally, a histological classification with six major categories of micro-damaged CEPs was created.

Results: The features of micro-damaged cartilaginous endplates were hardly observed based on the magnetic resonance imaging(MRI). Slices of the specimens showed the more microscopic structure of CEPs. Here, we presented the six major types of micro-damaged CEPs with fissure, node, blood vessel, filled NP tissue, filled NP+CEP tissue or filled CEP tissue. Further, they were verified by safranin O fast green and alcian blue staining. As expected, the MMP13 were elevated in these specimens while the Col II was decreased. PGP9.5-positive cells were detected on micro-damaged CEP with fissure, blood vessel, filled NP+CEP tissue or filled CEP tissue.

Discussion: When the CEPs were micro-damaged, it was difficult to observe on MRI because of the poor resolution. We discovered the several types of micro-damaged CEP:1, fissure; 2, node(trauma); 3, blood vessel; 4, filled NP tissue;5, filled NP+CEP tissue;6, filled CEP tissue. Although the exact anatomic position of specimens could not be confirmed, they were collected from the degenerative disc except the node(trauma) types. We also verified the damaged patterns by more than 3 slices of every specimen, safranin O fast green and alcian blue staining. The in-growth nerves in the CEP showed that it was more likely to occur LBP on patients with micro-damaged CEPs. So far, six major categories might not include all the types of micro-damaged CEPs, but these findings provided the essential histological evidence for the treatment of IVD diseases.

Function of MMP12 In Myofibroblastic Differentiation of NP Cells And Disc Degeneration

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Introduction: Intervertebral disc degeneration (IDD) is one of the major contributors for low back pain, of which disc fibrosis is characterized by the presence of myofibroblastic nucleus pulposus (NP) cells [1] and consequently an elevated expression of the profibrotic markers of connective tissue growth factor (CTGF), collagen I and III, and fibronectin [2, 3].

MMP12, typically as a macrophage marker, is also expressed in myofibroblasts. MMP12 deletion could suppress the profibrotic genes expression (e.g. Egr1, Cyr61) and protect mice from tissue fibrosis [4]. Recently, MMP12 was detected in smooth muscle actin (SMA)-expressing NP cells in IDD [1]. In this study, we aim to characterize the MMP12 implication in NP fibrosis. We hypothesize that MMP12 is essential to myofibroblast differentiation of NP cells and consequently NP fibrotic remodeling.

Methods: Myofibroblast differentiation assay: Human NP cells from scoliosis (ND-NP, n=4) and degenerative lumbar discs (D-NP, n=6) were re-plated as monolayer after 7-day alginate encapsulation and treated by TGF β for myofibroblast differentiation. MMP12 expression was assessed by immunoblotting and RT-PCR. Mouse IDD model: Tail disc-puncture was adopted on 3-month old C57bl/6j (WT) and Mmp12 knockout mice (MMP12^{-/-}, B6.129X-Mmp12tm1Sds/J from Jackson Lab). Disc height was evaluated for assessing the degeneration progression. FAST staining and collagen III immunostaining was performed to examine matrix organization and NP fibrosis. Statistics: p values were calculated via two-way ANOVA with Bonferroni post-test by GraphPad Prism.

Results: Both ND- and D-NP cells exhibited an up-regulation of FAP1- α and SMA after TGF β treatment at protein (Fig. 1a) and mRNA (Fig. 1b) levels. Nuclear localization of MMP12 was found in D-NP cells irrespective of TGF β treatment or not. In contrast, MMP12 expression was hardly detectable in ND-NP cells but markedly increased after TGF β treatment. In Mmp12 knockout mice, disc height exhibited a faster rate of decrease within 4 weeks after puncture injury (Fig. 2a). Safranin-O positivity was noted in the punctured discs in wild type mice but barely observed in Mmp12 knockout mice (Fig. 2b).

Discussion: To our knowledge, this is the first study for assessing MMP12 function in context of IVD degeneration. Myofibroblastic differentiation of NP cells in response to TGF β was built, where MMP12 nuclear localization might be involved. Furthermore, we found that MMP12 deficiency may accelerate puncture-induced disc degeneration. Absence of Safranin-O may imply either attenuated matrix deposition or remodeling. Examining aggrecan and collagen III may address this in future. Above all, our findings suggest a functional implication of MMP12 in disc fibrosis.

Figure 1: Assessment of MMP12 expression in myofibroblastic differentiation of non-degenerative (ND-) and degenerative (D-) NP cells.

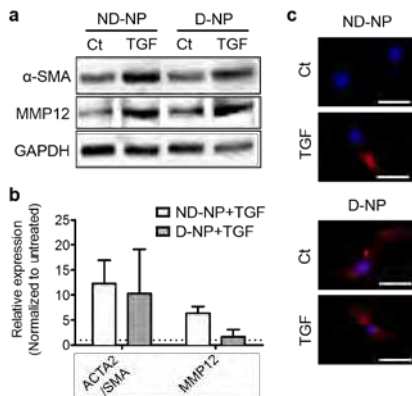
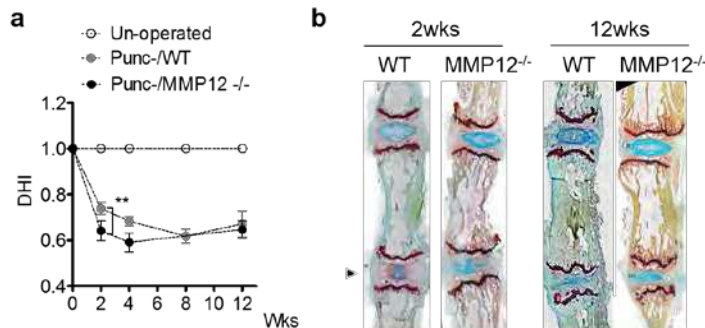


Figure 2. Annulus puncture in Mmp12 deficient mice. (a) Disc height measurement. (b) Assessment of matrix changes by FAST staining. Two-way ANOVA with Bonferroni post-test, ** p<0.01.



1. Lv FJ, Peng Y, Lim FL, Sun Y, Lv M, Zhou L, Wang H, Zheng Z, Cheung KMC, Leung VYL: Matrix metalloproteinase 12 is an indicator of intervertebral disc degeneration co-expressed with fibrotic markers. *Osteoarthritis Cartilage* 2016, 24(10):1826-1836.
 2. Tran CM, Markova D, Smith HE, Susarla B, Ponnappan RK, Anderson DG, Symes A, Shapiro IM, Risbud MV: Regulation of CCN2/connective tissue growth factor expression in the nucleus pulposus of the intervertebral disc: role of Smad and activator protein 1 signaling. *Arthritis Rheum* 2010, 62(7):1983-1992.
 3. Leung VY, Aladin DM, Lv F, Tam V, Sun Y, Lau RY, Hung SC, Ngan AH, Tang B, Lim CT et al: Mesenchymal stem cells reduce intervertebral disc fibrosis and facilitate repair. *Stem Cells* 2014, 32(8):2164-2177.
- Matute-Bello G, Wurfel MM, Lee JS, Park DR, Frevert CW, Madtes DK, Shapiro SD, Martin TR: Essential role of MMP-12 in Fas-induced lung fibrosis. *Am J Respir Cell Mol Biol* 2007, 37(2):210-221.

A Resource Efficient Novel MRI Post Processing Technique for the Assessment of Intervertebral Disc Degeneration - Correlation with Histological Grading in a Rabbit Disc Regeneration Model.

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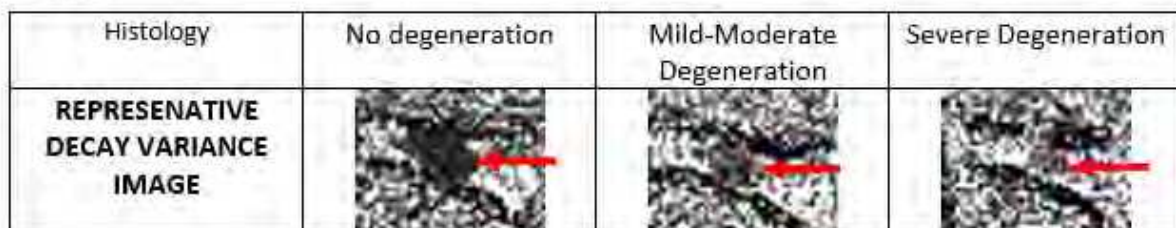
Introduction: The extent of disc degeneration, when visualised on an MR scan is mostly described using qualitative grades in clinical practice.[1,2] Quantification of disc degeneration on MRI scans using T2* and T1- ρ techniques have made rapid advances recently, but their clinical adoption remains a challenge due to the time consuming nature of image acquisition and post processing. Here we present a resource efficient novel image-processing technique for the quantitative assessment of disc degeneration using a multi-echo T2-MRI sequence. We hypothesised that the variability in the rate of signal decay over a multi-echo MRI sequence encodes information that could separate different tissue states in a degenerate and healthy disc.

Methods: As part of a prior study, 25 New Zealand white rabbits underwent annular puncture to induce disc degeneration in 50 non-contiguous lumbar discs.[3] The 25 intervening intact discs were used as controls. At four weeks, the punctured discs were injected with various doses of a recombinant protein or phosphate buffered saline; making available 75 discs, with varying degrees of degeneration, for this MRI technique development study. At 16 weeks, the animals underwent multi-echo T2 MRI scanning using a 7-Tesla BioSpec 70/30 and were subsequently euthanised. The discs were stained and examined histologically. Quantitative T2-relaxation maps were prepared using the non-linear least squares method. Decay variance maps were created using a novel technique of aggregating the deviation of each echo signal from the expected intensity based on the previous rate of decay. The time taken to generate each T2-relaxometry and decay variance map was recorded. Once these maps had been generated each disc was selected by manual segmentation and a score for each technique was generated by aggregating the pixel values contained within. All calculations were performed in MATLAB with 32Gb of accessible RAM and 8 Intel Corei7-7700K processor cores at 4.2GHz. These scores were correlated with the histologically confirmed degree of degeneration as a gold standard. Sensitivity and specificity at all possible cut-off values for each technique.

Results: Decay variance maps showed a clear and well demarcated dark nucleus pulposus in healthy discs that became progressively less dark with increasing degeneration (Figure 1). Decay variance maps required less than 1/1000th of the computational time to generate compared with traditional T2-Relaxometry maps. Histology scores correlated strongly with Decay variance scores ($r=0.83, p<0.05$) and weakly with T2 signal intensity ($r=0.32, p<0.05$) and Quantitative T2-Relaxometry ($r=0.39, p<0.05$). Decay Variance had superior sensitivity and specificity for the detection of degenerate discs when compared to T2 signal intensity or Quantitative T2 mapping, with no crossing of the ROC curves.

Discussion: Our results show that using multi-echo T2 MRI sequence, decay variance can quantitatively assess degeneration more accurately and with less image-processing time than quantitative T2-relaxometry in a rabbit disc puncture model. The technique is a viable candidate for quantitative assessment of disc degeneration on MR scans. Further validation on human subjects is needed, but if the trend exists, the implementation of this technique in clinical practice will allow for objective and accurate assessment of disc's health

Figure 1. Representative Decay Variance maps of intervertebral discs with different severities of degeneration. The dark nucleus pulposus in the healthy disc is progressively lost with more severe degeneration.



1. [1] C.W.A. Pfirrmann et al. (2001), Spine, 26(17): p1873-78.
2. [2] J.P. Thompson, et al. Trans Orthop Res Soc. 13 (1988).
3. [3] S. Miyazaki et. al., Eur. Spine J. Off. Publ. Eur. Spine Soc. Eur. Spinal Deform. Soc. Eur. Sect. Cerv. Spine Res. Soc. 27 (2018) 739–751. doi:10.1007/s00586-018-5488-1.

Pathological and MR Imaging Evaluation of Articular Cartilage Degeneration in the Human Zygapophysial Joint

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Introduction: The aim of this study was to evaluate the ability of T2 mapping to characterize morphologically and quantitatively of degenerated cartilage in zygapophysial joint.

Methods: 20 patients (lumbar spondylolisthesis L2/3,1;L3/4,5;L4/5,14;males, 9;females,11) underwent PLIF. The mean age at the time of surgery was 69.2±8.5 years (range, 51-82). 40 joints were examined by axial T2 mapping MRI. Regions of interest (ROIs) for the zygapophysial joints were drawn across both articular surfaces at the same time on each side. Histopathological Evaluation During the operation, each side of the intervertebral joints with spondylolisthesis was collected as a single mass. The histology sections were prepared and stained with hematoxylin and eosin (HE) and were immunohistochemically stained (for type 1 collagen, type 2 collagen and aggrecan core protein) to evaluate the severity of cartilage degeneration. The histopathological grading system of Pritzker et al. was used. The staining intensity was calculated using the formula: absorbance in the target area - background absorbance / background absorbance and the obtained values were expressed with arbitrary units (u).

Results: The average T2 value from a total of 40 joints was 88.49 ± 10.99 msec. The severity of degeneration: The values from the ventral, central and dorsal parts from the superior articular process were 3.55 ± 0.51, 2.6 ± 0.50, 3.3 ± 0.73. The values from the ventral, central and dorsal parts from the inferior articular process were 4.05 ± 0.51, 3.15 ± 0.75, 3.9 ± 0.45. The staining intensity values for type 1 collagen from the ventral, central and dorsal parts from the superior articular process were 0.45 ± 0.17 u, 0.45 ± 0.18 u and 0.44 ± 0.19 u. The values from the ventral, central and dorsal parts from the inferior articular process were 0.48 ± 0.2 u, 0.47 ± 0.18 u, 0.47 ± 0.21 u. The staining intensity values for type 2 collagen from the ventral, central and dorsal parts from the superior articular process were 1.01 ± 0.27 u, 1.11 ± 0.22 u, 1.02 ± 0.24 u. The values from the ventral, central and dorsal parts from the inferior articular process were 0.90 ± 0.17 u, 0.98 ± 0.19 u, 0.91 ± 0.04 u. The staining intensity values for aggrecan core protein from the ventral, central and dorsal parts of the superior articular process were 0.82 ± 0.15 u, 0.89 ± 0.13 u, 0.83 ± 0.04 u. The values from the ventral, central and dorsal parts from the inferior articular process were 0.77 ± 0.04 u, 0.85 ± 0.05 u, 0.78 ± 0.03 u. The Correlation Between the T2 Values and the Staining Intensity of Extracellular Matrix Components Strong negative correlations between the T2 values and type II collagen staining intensity ($r = -0.839$, $p < 0.001$) and between the T2 values and aggrecan core protein staining intensity ($r = -0.78$, $p < 0.001$).

Discussion: In this present study localization of zygapophysial joint cartilage degeneration was determined using histopathological evaluation. The decrease in extracellular matrix component levels was well correlated with an elevation in T2 values. The extracellular matrix component levels could possibly be assessed by MR imaging findings.

Involvement of ATG5-dependent autophagy in the maintenance of rat intervertebral disc homeostasis *in vitro* and *in vivo*

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Introduction: The intervertebral disc is the largest avascular, low nutrient organ. Autophagy is an important cell survival mechanism by self-digestion and recycling damaged components under stress, primarily nutrient deprivation. However, the involvement and roles of autophagy in the disc have not been uncovered. Our objective was to elucidate the involvement of autophagy in rat disc homeostasis through the RNA interference (RNAi) technique.

Methods:

In-vitro study: Disc nucleus pulposus (NP) cells harvested from seven 12-week-old Sprague-Dawley rats were used. Cells were cultured in DMEM with or without 10% FBS to simulate nutrient deprivation. Small interfering RNA (siRNA) to knock down an autophagy-essential gene ATG5 was applied by using the reverse transfection method. Three different ATG5 siRNA sequences were used to exclude the off-target effect. In the control group, nonspecific sequences were used. Cells were evaluated 24 hours after transfection. Expression of an autophagy marker LC3-II and substrate p62/SQSTM1 as well as ATG5 was measured by Western blotting to assess RNAi knock-down efficacy and autophagy levels. Cell viability was also assessed by using the Cell Counting Kit-8 (CCK-8). Then, cells were cultured in serum-free DMEM with 10 ng/ml of interleukin-1 beta (IL-1 β) for 24 hours. Apoptosis and senescence levels were determined by Western blotting based on expression of cleaved PARP and caspase-9 (apoptosis) and p16/INK4A (senescence).

In-vivo study: Eight 12-week-old Sprague-Dawley rats were used. Control siRNA and ATG5 siRNA were injected into intervertebral discs of individual rats. 48 hours after injection, rat disc NP tissues were harvested, homogenized using a bead-beating disrupter, and applied for Western blotting to assess ATG5 knock-down efficiency and autophagy levels based on LC3-II and p62/SQSTM1 expression.

Results:

In-vitro study: In rat disc NP cells, ATG5 protein expression significantly decreased by ATG5 RNAi (vs control: 37.6%, $P<0.05$). In addition, ATG5 RNAi facilitated decreased LC3-II and increased p62/SQSTM1 ($P<0.05$), indicating autophagy inhibition. ATG5 RNAi significantly decreased viability of cells cultured in DMEM without FBS (vs control: 86.3%, $P<0.05$). Pro-inflammatory IL-1 β stimulation induced the increases in apoptotic cleaved PARP and caspase-9 and senescent p16/INK4A expression ($P<0.05$). Then, ATG5 RNAi developed additional increases in IL-1 β -induced apoptosis and senescence ($P<0.05$).

In-vivo study: In rat disc NP tissues, ATG5 protein expression significantly decreased by ATG5 RNAi ($P<0.05$). In addition, ATG5 RNAi decreased LC3-II and increased p62/SQSTM1 ($P<0.05$), consistent with autophagy inhibition *in vivo*.

Discussion: This study demonstrates the involvement of ATG5-dependent autophagy in rat disc NP cell and tissue homeostasis, which potentially plays protective roles against apoptotic cell death and senescent cell aging. Autophagy is a potent new molecular therapy target for intervertebral disc disease.

The potential role of stromal cell-derived factor 1 α in promoting recruitment and chondrogenic differentiation of nucleus pulposus-derived stem cell via SDF-1/CXCR4 axis for intervertebral disc regeneration

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Introduction: Intervertebral disc (IVD) degeneration is considered as one of the major causes of low back pain. Recent evidence suggests that the chemokine stromal cell-derived factor 1 α (SDF-1 α) is upregulated in the injury sites and plays an important role in recruiting circulating or residing stem cells through interaction with its cognate receptor CXCR4. Many researchers have also demonstrated the presence of nucleus pulposus (NP)-derived stem cells (NPSCs) in the IVD contribute to normal regeneration of IVD. The purpose of the study was to investigate the effects and mechanism of SDF-1 α on repairing the degenerative IVD by recruiting endogenous NPSCs and promoting their chondrogenic differentiation.

Methods: We performed real-time RT-PCR and enzyme-linked immunosorbent assay (ELISA) to examine the synthesis and secretion of SDF-1 α in nucleus pulposus cells (NPCs) after treatment with pro-inflammatory cytokines, and immunohistochemical analysis to compare the expression of SDF-1 α between the degenerative and normal rat coccygeal IVDs. The migration capacity of NPSCs regulated by SDF-1 α was evaluated using wound healing and transwell migration assays *in vitro*, the nucleotomized bovine caudal IVD culture model *ex vivo*, and chemotaxis assay in rat coccygeal degenerative IVD model *in vivo*. To determine the role of SDF-1 α on chondrogenic differentiation of NPSCs, we conducted cell micromass culture and examined the expressions of Sox-9, Aggrecan, and Collagen II using histological analysis. Moreover, the role of SDF-1/CXCR4 axis on the migration and chondrogenesis differentiation of NPSCs were analyzed by immunofluorescence, immunoblotting, and real-time RT-PCR.

Results: We found that SDF-1 α was significantly up-regulated in the native disc cells cultured in interleukin (IL)-1 β or tumor necrosis factor- α (TNF- α) *in vitro* mimicking degenerative settings ($P < 0.05$) (Fig. 1a and 1b). Immunohistochemical staining also showed that the level of SDF-1 α was higher in the degenerative group than in the normal group (Fig. 1c). SDF-1 α enhanced migration capacity of NPSCs in a dose-dependent manner *in vitro* (Fig. 2). SDF-1 α significantly increased the number of NPSCs migrating into the nucleotomized bovine IVD *ex vivo* ($P < 0.05$) (Fig. 3). After systemic delivery of exogenous PKH-labelled NPSCs into rats, there were significant differences in the distribution of migrated cells between the normal and degenerative IVDs *in vivo* ($P < 0.05$) (Fig. 4). In addition, SDF-1 α induced chondrogenic differentiation of NPSCs, evidenced by the increased expression of chondrogenic markers using histological analysis ($P < 0.05$) (Fig. 5). Real-time RT-PCR, immunoblotting, and immunofluorescence showed SDF-1 α not only increased CXCR4 expression but also stimulated translocation of CXCR4 from cytoplasm to membrane, accompanied by cytoskeletal rearrangement (Fig. 6). Furthermore, blocking CXCR4 with AMD3100 suppressed SDF-1 α -induced migration and differentiation capacities (Fig. 6 and 7).

Discussion: In summary, the current research demonstrated a novel role of SDF-1 α , pathogenically accumulated in the damaged or degenerative IVD, in effectively promoting NPSCs migration and chondrogenic differentiation. These findings support that the SDF-1/CXCR4 chemotaxis signal might be involved in spontaneous repair during the early stage of IDD owing to maintaining the bioactivity of the stem cell resources within the degenerative IVD and also could enhance the efficiency of stem cell-based therapy for IVD regeneration.

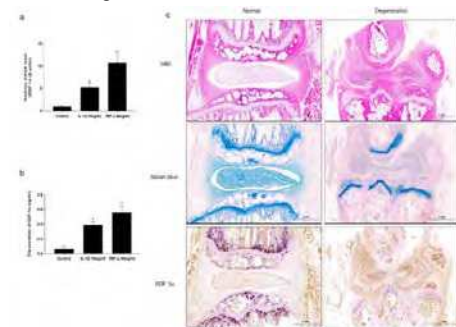


Fig. 1 The expression of SDF-1 α in the condition of the degenerative disc.

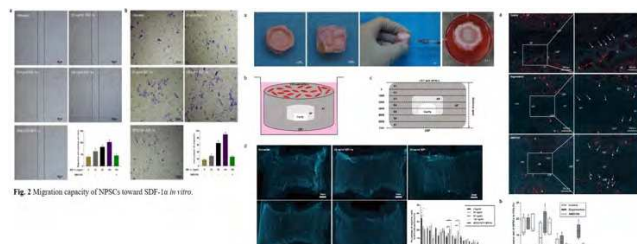


Fig. 2 Migration capacity of NPSCs toward SDF-1 α *in vitro*.

Fig. 3 NPSCs recruitment toward SDF-1 α in an *ex vivo* IVD organ culture model.

Fig. 4 Exogenous NPSCs migration in a degenerative rat coccygeal IVD model *in vivo*.

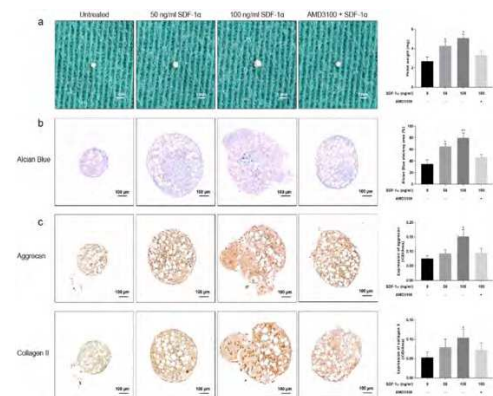


Fig. 5 Effects of SDF-1/CXCR4 axis on chondrogenesis differentiation of NPSCs using cell micromass culture.

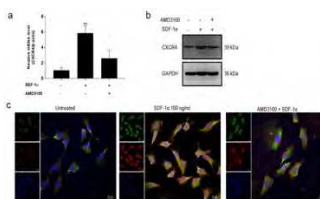


Fig. 6 CXCR4 expression affected by SDF-1 α in NPSCs.

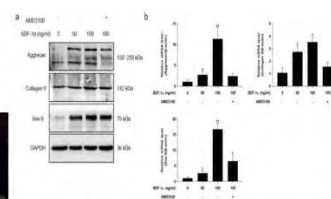


Fig. 7 Effects of SDF-1/CXCR4 axis on chondrogenesis differentiation of NPSCs *in vitro*.

The effect of GDF6 in reducing intervertebral disc degeneration and inflammation-related pain in a rat model

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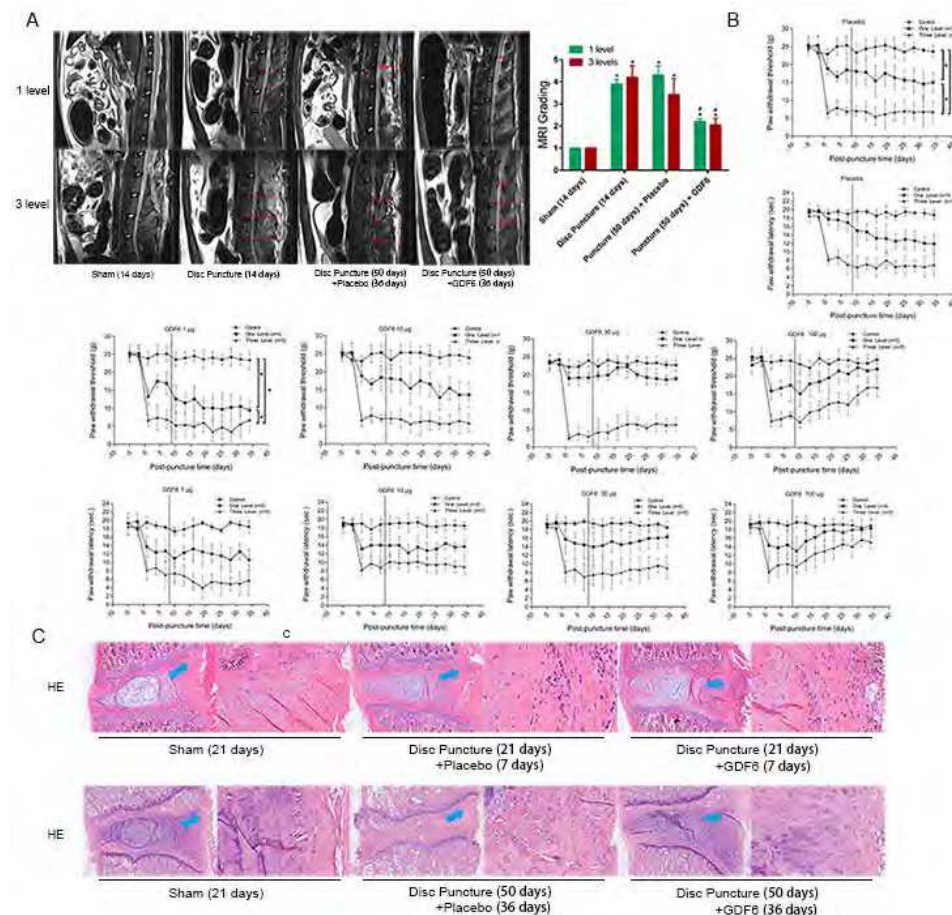
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Introduction: Degeneration of intervertebral disc (IVDD) is a significant cause of chronic back pain. The potential for new therapies that arrest or even reverse degenerative disc progression is sought by clinicians. We have identified a potential therapeutic agent, growth differentiation factor 6 (GDF6), which may have the capability to relieve or alleviate the pain occurs during disc degeneration, while promoting disc regeneration.

Methods: After the IVDD model in rat was established through the posterior disc puncture protocol similar to our previous study, GDF6 was intradiscal injected to IVDD rat. The effects of GDF6 on IVDD were measured by MRI and histological analyses, and the effects of GDF6 on dorsal root ganglion (DRG) inflammation and pain development were analyzed by IHC staining and animal behavioral tests, respectively. Furthermore, discs were excised and cultured. Cytokine secretion from discs was evaluated with protein arrays.

Results: Degenerative discs were confirmed by MRI (fig. 1A). Only a large dose (100ug) injection of GDF6 reduced the degeneration of the disc in the IVDD model. HE staining, Safranin O-fast green staining, Massion staining and Sirius red staining demonstrated decreased disc height, shrunk NP, disorganized collagen fibers and significant inflammatory cell infiltration 7 days after disc puncture. And the overall structure of the disc was destroyed, the nucleus pulposus disappeared with the signs of bone fusion showed up 50 days after disc puncture. While in GDF6-treated group, the collagen fibers showed slight disorganization, the NP remained its original height and less inflammatory cell infiltration showed up around the AF (fig. 1B). High dose GDF6 injection in IVDD rat reduced the number of CGRP+ cells and SP+ cells to a relative low level. A significant loss of aggrecan and Type II collagen with increased IL-1beta displayed in the IVDD discs through IHC staining. In contrast, GDF6 surprisingly weakened this effect. Regarding the results of animal behavioral tests, the paw withdrawal threshold and latency decreased dramatically within 5 days after 1 and 3 levels disc puncture, and then remained at the low level until 36 days post-surgery. The GDF6-treated group showed a temporarily decreased threshold at 5 days after surgery, which started to recover and finally returned back to normal at days 36 (fig. 1C). Discs were cultured 2 weeks after disc puncture. As indicated in the heat map, the puncture caused a greater overall increase in proinflammatory cytokine secretion, which negatively regulated through GDF6-treatment. We therefore examined disc tissue to quantify levels of clearly decreased proinflammatory cytokine in GDF6-treated group like IL-1 alpha (29.3 pg/ml [CI: 6.9, 51.7] vs 10.4 pg/ml [CI: 2.1, 18.7]), FGF BP1 (243.1 pg/ml [CI: 76.9, 409.3] vs 193.4 pg/ml [CI: 103.1, 283.7]), CXCL12 (15.3 pg/ml [CI: 3.4, 27.2] vs 5.9 pg/ml [CI: -3.7, 21.4]).

Discussion: The data suggests that intradiscal injection of GDF6 reduces disc degeneration and inflammatory reaction, which results in discogenic pain relief. It may become a therapeutic agent for the control of inflammation-related pain associated with IVDD.



Potential Involvement of Semaphorin 3A in Maintaining Tissue Homeostasis of Intervertebral Disc

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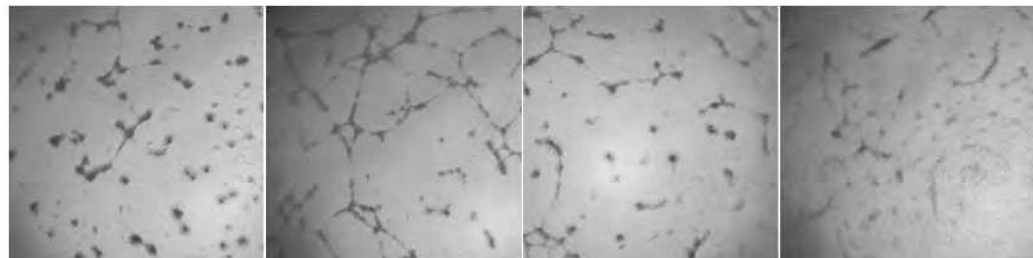
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Introduction: Although the healthy intervertebral disc (IVD) is avascular, there is ingrowth of blood vessels into outer regions of the IVD during developing degeneration. Previous studies have demonstrated that vascular endothelial growth factor (VEGF), one of the most potent angiogenic factors, is overexpressed in human degenerative IVD and potentially involved in the pathogenesis of IVD degeneration. VEGF165, one of VEGF isoforms, is known to bind to the neuropilin 1 (NRP-1) complex on the cell membrane, where NRP-1 strengthens the VEGF signal. On the other hand, NRP-1 serves as a receptor for semaphorin 3A (Sema3A), a secreted protein that was originally characterized as a chemorepulsive factor for growing axons in the developing nervous system. However, the function of Sema3A in the IVD is not fully understood. In the present study, our aim was to elucidate the potential involvement of Sema3A in maintaining tissue homeostasis of avascular IVD.

Methods and Results: We investigated whether the expression of Sema3A was also decreased in a rat IVD degeneration, in which degenerative changes were artificially induced by puncturing the IVDs. RT-PCR showed the mRNA expression of Sema3A was significantly suppressed in Tx group. To investigate the mechanisms for regulation of Sema3A expression in IVD degeneration, we treated the cultured rat AF cells with inflammatory cytokines which played potential roles for IVD degeneration. Both RT-PCR and western blot analysis clearly showed that the expression of Sema3A was significantly reduced by treatment of cytokines including TNF- α , IL-1 β , and IL-6. Next, we treated the cultured rat AF cells with SM345431, a Sema3A inhibitor, and evaluated the mRNA expression level of IL-6, MMP-3, ADAMTS-4, aggrecan, and collagen type 2. We found that the mRNA expression level of IL-6, MMP-3, and ADAMTS-4 was significantly increased by treatment of SM345431 at a dose-dependent manner, whereas that of collagen type 2 was significantly decreased. Conversely, recombinant Sema3A significantly reduced the expression levels of the transcripts for IL-6 and MMP-3 and induced those for aggrecan and collagen type 2 in the IL-6-treated cells. Western blot analysis clearly showed that phosphorylation of STAT 3 was reduced by treatment of recombinant Sema3A in the IL-6 treated AF cells. Finally, tube formation assay was performed by using recombinant Sema3A. FCS-mediated induction of tube length was significantly abolished by treatment of recombinant Sema3A at dose dependent manner (Figure).

Discussion: To the best of our knowledge, this is the first study to show the potential involvement of Sema3A in the maintenance of tissue homeostasis in IVD. We showed that the expression of Sema3A was down-regulated in rat degenerative IVDs through overexpression of inflammatory cytokines, and that Sema3A significantly inhibited angiogenesis and reduced catabolic shift in AF cells. Notably, we found that Sema3A played a potential inhibitory role in IL-6/JAK/STAT pathway which is involved in the pathogenesis of IVD degeneration. Despite some limitations, the present study sheds a novel light on the biology of IVD degeneration and suggests that pharmacological treatment of Sema3A may be a potential therapeutic option for treating patients with IVD degeneration.

FCS		+	+	+
Sema3A	-	-	250ng/ml	500ng/ml



Autophagy in an extruded disc compared to the remaining disc after lumbar disc herniation in the same patient

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Introduction: To investigate autophagy in an extruded disc, and to compare this with the status of the remaining disc after lumbar disc herniation in the same patient.

Methods: In total, 12 patients (females 4, males 8) with the extruded type of lumbar disc herniation (LDH) were surgically treated. Their mean age was 54.3±15.8 years (range: 29–78 years). The mean interval from the occurrence of symptoms to the operation was 9.8 ± 9.4 weeks (range: 2–24 weeks). The extruded discs were excised, and the remaining disc material removed, to prevent recurrence of herniation. Immediately after specimen collection, all tissues were stored in liquid nitrogen at -70°C prior to analysis. Autophagy was assessed immunohistochemically and via Western blotting for Atg 5, Atg 7, Atg 12, Atg12L1, LC3, and Beclin-1. Crosstalk with apoptosis was assessed via correlation of autophagy genes with cleaved caspase-3.

Results: The expression levels of autophagic markers were significantly increased in the extruded discs compared to the healthy discs within the same patients. The mean expression levels of Atg 5, Atg7, Atg12, Beclin-1, and LC3II in extruded discs were statistically significantly higher than those in the contained discs (P=0.0037, P<0.0001, P=0.0024, P=0.0001 and P=0.0323 respectively) Differential interference contrast microscopy revealed Atg5 and Atg 7 stained cell number is higher in extruded disc than remained disc. Statistically significant positive correlation in autophagy gene with cleaved caspase-3 were found.(Atg 5: R=0.47, P=0.02 ; Atg7: R=0.69, P=0.0002; Atg12: R=0.44, P=0.03; Beclin-1: R=0.54, P=0.01; LC3II: R=0.51, P=0.01)

Discussion: The autophagic pathway was more active in extruded disc material than in healthy disc material within the same patient. Autophagy may play a role in spontaneous resorption of the extruded disc after LDH

Promoting nucleus pulposus progenitors-like differentiation from mesenchymal stem cells via MAP kinase coupled chondrogenic induction

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Introduction: Depletion of extracellular matrix producing nucleus pulposus (NP) cells in intervertebral disc (IVD) degeneration limits the self-repair ability *per se*. Currently, tyrosine kinase receptor 2 (Tie2) and disialoganglioside 2 (GD2) expressing progenitor cells were identified in human adult NP tissue based on *in vitro* clonogenicity and *in vivo* self-renewal ability. [1] By microarray analysis of the transcriptome in rat primitive NP and costal cartilage, we identified preferential expressions of *Cdh2*, *Krt19* and *Car3* in rat primitive NP. Further *in silico* analysis of signaling pathways suggested rat primitive NP exhibiting low TGF- β and MAP kinase activities. Mesenchymal stem cells (MSCs) were demonstrated to differentiate into NP-like cells via TGF- β stimulation. Here, we hypothesized that MSCs could differentiate into NP progenitor-like cells by MAP kinase interference coupled chondrogenic induction (MICCI). To this end, we characterized protein expression of defined molecular markers in Colonies Formation Units-Spherical (CFU-S) from human NP cells. Thereafter, we evaluated gene expression of these markers in MSC micro-pellets after MICCI.

Methods: CFU-S assay was performed by culturing 1×10^3 human NP cells / 1ml of methylcellulose medium (*Stem Cell Technologies*) for 14 days. The CFU-S were immuno-stained with (*Santa Cruz*): anti-Tie2, anti-Krt19, anti-Car3; (*abcam*): anti-Cdh2, anti-CD24, anti-type II collagen (COL2), anti-aggrecan (AGC1); and (*BD biosciences*): anti-GD2 antibodies. Human bone marrow MSC micro-pellet culture were chondrogenic induced with 10ng/ml TGF- β 1 and treated with/without 10 μ M MEK 1/2 inhibitors (PD98059) for 14 days. Quantitative PCR (QPCR) was performed using Taqman probes (*Thermo Fisher scientific*): *TEK* (HS00945746_m1); *CDH2* (HS00983056_m1); *AGC1* (HS00153936_m1); and normalized by *GAPDH* (HS02758991_g1).

Results: Immunostaining detected the expression of Tie2, GD2, aggrecan, and collagen II in human NP derived CFU-S. CDH2, but not for KRT19, CAR3 and CD24, were detected in CFU-S (Fig. 1). QPCR showed strong upregulations of *TEK1* and *CDH2* at Day 1 and *AGC1* at Day 14 in MEK1/2 inhibitor treated MSC micro-pellets. MEK1/2 inhibitor treatment also resulted in higher level of proteoglycan deposition indicated by safranin-O staining (Fig. 2).

Discussion: CFU-S study suggests *Tie2*, *CDH2* and *AGC1* are markers of disc progenitors. MEK1/2 inhibition in TGF- β mediated chondrogenic differentiation of MSC micro-pellets could induce these marker expression along with enhanced proteoglycan deposition, implicating a function of MAP kinase in promoting NP cell-like differentiation in MSCs.

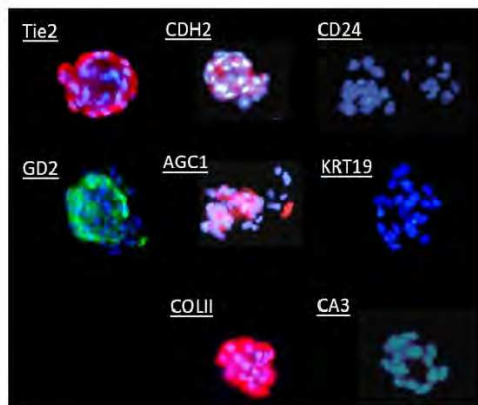


Fig. 1 Expression of putative molecular markers in human NP progenitors.

Human NP progenitors were identified as proliferative suspended spheroid colonies formation units (CFU-S) (numbers of cells ≥ 10) in methylcellulose suspension culture. By Immunostaining, Tie2; CDH2; AGC1; COL2 (represented in red colour) and GD2 (represented in green colour) were detected in NP derived CFU-S. Cell nuclei was stained by DAPI staining (represented in blue colour).

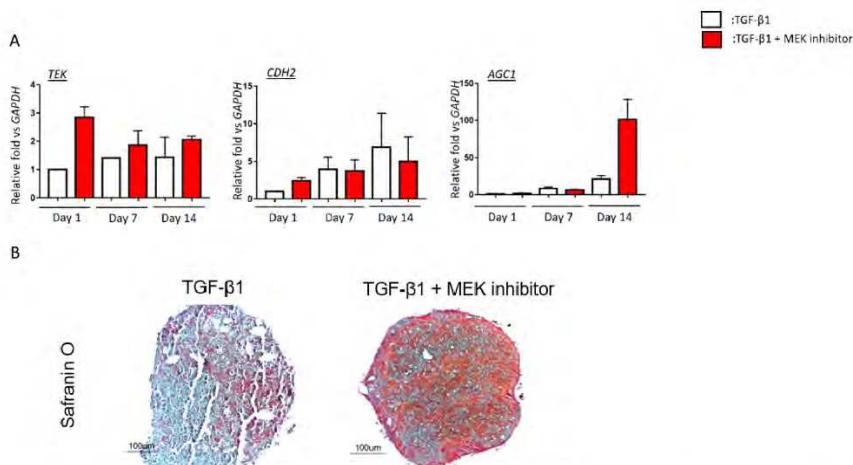


Fig. 2 Expression of NP progenitor-like molecular markers in MAP kinase interference coupled chondrogenic induction (MICCI) of MSCs.

(A) Induction of *TEK* and *CDH2* gene expressions were detected at Day1, whereas induction of *AGC1* gene expression was observed at Day 14 of MICCI of MSCs. (B) Safranin O staining (represented in orange colour) shown enhanced proteoglycan deposition was detected in MICCI of MSCs.

Scaffold-Free Tissue Engineering with Aligned Bone Marrow Stromal Cells Sheets to Recapitulate the Microstructural and Biochemical Composition of Annulus Fibrosus

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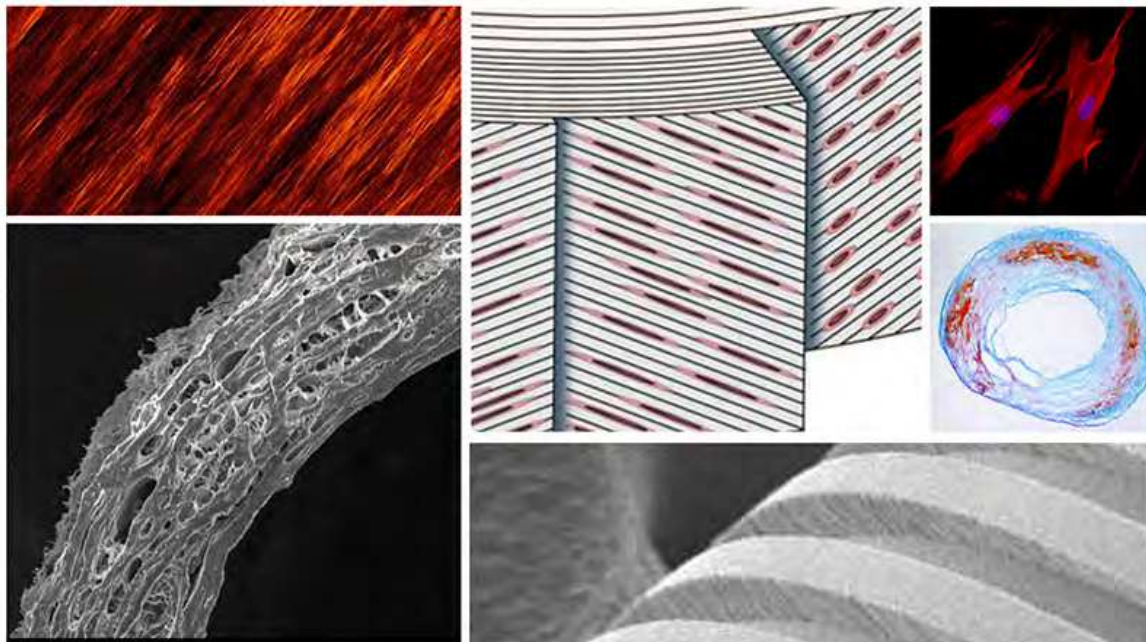
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Introduction. Degeneration of intervertebral disc (IVD) remains a predominant cause of low back pain, leading to huge socioeconomic impact on the healthcare resources. While surgical invention aims to eliminate the pain, it does not address the underlying biological problem nor restore the biological function. Current tissue engineering strategies focus on restoring the biological function of the native disc, but fail to recapitulate the complex three-dimensional microarchitecture and biochemical composition of the native annulus fibrosus (AF) within the IVD. Considering limited access to healthy annulus fibrosus cells from patients and the drawbacks in scaffold-based tissue engineering, we explore the potential of integration of bone marrow stromal cells (BMSC) into multi-layered micropatterned cell sheet technologies to produce a novel scaffold-free multilamellar annulus fibrosus-like tissue.

Methods. BMSC sheet with parallel collagen fibers aligned at $\sim 30^\circ$ with respect to their longitudinal dimension were first developed by culturing BMSC on a microgroove-patterned PDMS substrate. PDMS substrate with flat surface was used as a control. Two sheets were then stacked together in alternating directions to form an angle-ply bilayer tissue, which was then rolled up and sliced to form individual multi-lamellar angle-ply tissue before culturing them in a customized medium. Development of annulus fibrosus-like tissues was evaluated by histological, gene expression and microscopic analysis.

Results. BMSC cultured on microgroove-patterned PDMS substrates exhibited an elongated morphology with aligned actin filaments. On the other hand, BMSC cultured on the flat surface showed a polygonal morphology with randomly aligned actin filaments. Furthermore, BMSCs cultured on micro-grooved patterned substrate facilitated the formation of an aligned BMSC sheet with enhanced expression of parallel collagen fibrils. These BMSC sheets were assembled into multi-lamellar angle-ply tissues that resembled the microstructural features of the native disc. Histological analysis revealed the presence of AF-associated extracellular matrix within the AF-like tissue constructs which was expressed significantly higher in the AF-like tissues constructed with the aligned BMSC sheets when compared to the non-aligned BMSC sheets.

Discussion. The present study provides a new annulus fibrosus tissue engineering methodology to develop a scaffold-free AF-like tissue that resembles the microarchitecture and biochemical attributes of a native AF tissue. This is achieved by developing aligned BMSC sheets on a microgroove-patterned surface as the building block of the three-dimensional AF-tissue constructs. The alignment of BMSC was demonstrated to be a crucial determinant in enhancing cell behaviour and forming parallel arrays of collagen fibrils. Furthermore, manipulating the BMSCs morphology and cytoskeleton in BMSC sheet was shown to be critical in facilitating production of AF-associated extracellular matrix during tissue development. This novel scaffold-free approach avoids issues of rapid progressive degradation of scaffold in the scaffold-based therapy. Further investigation with this invention may potentially lead to a promising avenue for advancing BMSC mediated AF regeneration towards future clinical applications.



SCAFFOLD-FREE AF TISSUE ENGINEERING

Possible regulation of nerve growth factor by M1 and M2 macrophages following intervertebral disc injury in mice

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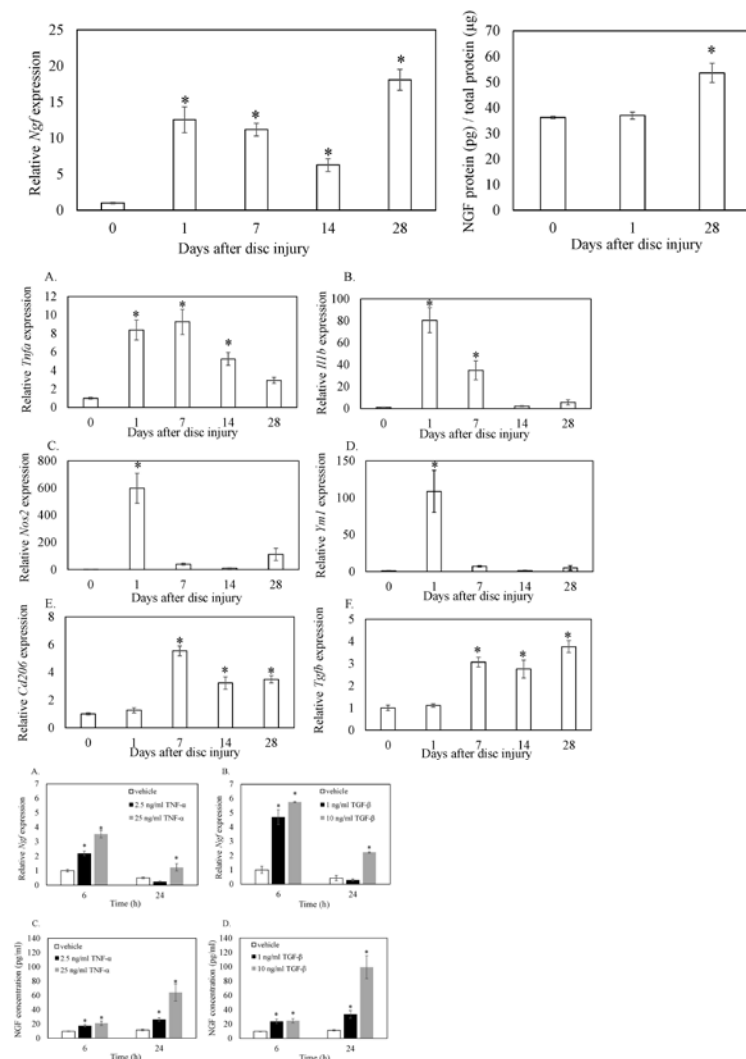
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Introduction: Recent evidence indicates that NGF is increased in intervertebral discs (IVDs) after disc injury and that anti-NGF therapy improves low back pain in humans.^{1,2} M1 and M2 macrophage subtypes were recently reported to play a role in degenerative IVD injury.³ We examined the possible regulation of nerve growth factor (NGF) by M1 and M2 macrophages following IVD injury in mice.

Methods: We divided the mice into two groups as follows: 20 of 90 mice comprised a control group in which IVDs were left intact (day 0); and the remaining 70 comprised a punctured IVD injury group in which coccygeal (Co) 5-6 and Co 6-7 IVDs were punctured 10 times with a 27-gauge needle. On days 0, 1, 7, 14, and 28, discs were extracted from the control and IVD injury groups and evaluated M1 and M2 macrophage markers and NGF and cytokine expression using real time PCR (n=10 for each time point), and macrophage population using flow cytometric analysis (n=5 for each time point). On days 0, 1 and 28, discs were extracted from the control and IVD injury groups and analyzed NGF protein level using enzyme-linked immunosorbent assay (ELISA) (n=5 for each time point).

Results: *Ngf* mRNA expression increased 1 day after injury in injured compared to control mice, and persisted for up to 28 days. Flow cytometric analysis demonstrated that F4/80+CD11b+ cells were significantly increased from 1 day after injury for up to 28 days in injured compared to control mice. mRNA expression of M1 macrophage markers *Tnfa*, *Il1b*, and *Nos2* was significantly increased 1 day after injury in injured compared to control mice, before gradually decreasing. At 28 days, no significant difference was observed in M1 markers. The M2a marker, *Ym1*, was significantly increased 1 day after injury in injured compared to control mice, while M2a and M2c markers *Tgfb* and *Cd206* were significantly increased 7, 14, and 28 days after injury. TNF- α and TGF- β stimulate *Ngf* mRNA and NGF protein expression in IVD cells.

DISCUSSION: A recent study showed that M1 macrophages were increased in degenerative human IVDs compared to healthy controls.³ Here, the number of macrophages and TNF- α expression immediately increased following disc injury. In addition, TNF- α stimulation induced *Ngf* mRNA and NGF protein production. Our findings suggest that M1 macrophages may stimulate NGF production in the inflammatory phase after IVD injury. Like M1 macrophages, increases in M2c macrophages have been observed in degenerative IVDs in humans.³ Several studies have demonstrated that M2 macrophages, in particular the M2c subtype, produce TGF- β .⁴⁻⁷ Here, the increase in *Tgfb* expression was consistent with that of the M2a and M2c marker *Cd206* but not the M2a marker *Ym1*, and TGF- β stimulation promoted *Ngf* mRNA expression and NGF protein production, suggesting that non-inflammatory M2 macrophages, in particular the M2c subtype, may stimulate NGF production via TGF- β production. M1 and M2c macrophages may contribute to NGF production via TNF- α and TGF- β , respectively, following IVD injury. Our results may be useful for developing treatments for IVD-related LBP pathology.



Repetitive Changes in Hydrostatic Pressure at High Osmotic Pressure Have a Potential to Reproduce Homeostasis in Human Nucleus Pulposus

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Introduction: Nucleus pulposus (NP) and notochordal (NC) cells are exposed to change in hydrostatic pressure (HP) due to weight bearing and spinal motion, as well as to change in osmotic pressure (OP) due to negatively charged extracellular matrix (ECM) within the intervertebral disc (IVD). We think studies in homeostasis, regeneration, and degeneration in NP should incorporate these changes. Our latest study indicated a combined change in cyclic HP and high-OP had a potential to stimulate synthesis of ECM with bovine NP cells (J Orthop Res, *in press*). Additionally, constant HP has a potential to retain ECM. NP tissue has a capability to absorb water resulting in increasing swelling pressure within IVD compartment. This swelling pressure without externally loaded HP behaves as intrinsic HP. We speculated constant HP at 0.2 MPa represented intradiscal pressure during resting time. We hypothesized repetitive combined changes in HP and OP reproduce homeostasis in NP *in-vitro*. In order to reproduce homeostasis, we thought both anabolic metabolism and ECM accumulation need to be synchronized. This study was designed to clarify characteristics of human NP cells exposed to chosen algorithm of changes in HP and OP from series of experiments using bovine NP cells.

Methods: We harvested NPs from bovine caudal joints and porcine thoracic and lumbar spine purchased from a local abattoir (USDA approved), and isolated discarded NPs from the subjects undergoing lumbar discectomy (IRB approved). We enzymatically isolated NP cells/clusters from bovine and human NP and NC cells/clusters from porcine NP, and enclosed them within semi-permeable membrane pouches (500 KD cut-off MW) respectively. The pouches were divided into 2 test groups: 1) repetitive HP, cyclic HP (0-0.5 MPa, 0.5 Hz) for 2 days followed by constant HP (0.2 MPa) for 1 day, repeating this algorithm twice; pouches were placed in a pressure-proof chamber to load HP. 2) no HP; pouches were in a cage and the medium was spun for sufficient medium infiltration. The OP of culture medium was set at 450 mOsm with additional NaCl (4.6 g/L) in the medium with 10% FBS. We measured the gene expression of Aggrecan core protein (AGG) as an anabolic marker and Brachyury as a notochordal marker. Relative quantity (RQ) was analyzed. We also stained the NP/NC cells/clusters with an antibody against keratan sulfate proteoglycan (KS).

Results: The expression of Brachyury was suppressed under repetitive HP compared to no HP in bovine NP, porcine NC and human NP. On the other hand, the expression of AGG did not decrease under repetitive HP compared to no HP in bovine, porcine and human. Immunohistological staining also revealed as much accumulation of KS within NP/NC cells/clusters under repetitive HP as under no HP.

Discussion: Changes in cyclic and constant HP mimicked daily physiological loading in IVD with our culture system. Lower expression of Brachyury may lead degenerative changes seen *in-vivo*. Repeating combined cyclic and constant HP has a potential to reproduce homeostasis in NP, whereas suppressing the expression of Brachyury.

Role of DUSP1 on the regulation of NGF and MMPs in human intervertebral disc cells

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Introduction: Nonphysiological nerve invasion into degenerated intervertebral disc (IVD) due to aging or inflammation is considered as a molecular mechanism of discogenic low back pain. Matrix metalloproteinases (MMPs) and nerve growth factor (NGF) play important role for IVD degeneration and nerve invasion, respectively. We reported that selective COX-2 inhibitor enhanced MMPs and NGF expression, and on the contrary, PGE2 suppressed MMPs and NGF expression. However, the mechanisms of regulating MMPs and NGF are not clear. In this study, we focused on the mitogen-activated protein kinases (MAPKs; ERK, P38, JNK), which are intracellular signaling pathways of inflammation, and dual-specificity phosphatase (DUSP) 1 (dephosphorylating enzyme of MAPKs) to investigate the regulatory mechanism of MMPs and NGF in human IVD cells.

Methods: Human IVD cells isolated from the tissue obtained during lumbar surgery were used for following experiments. Firstly, the involvement of MAPKs was examined by adding inhibitors for ERK (U0126), p38 (SB203580) and JNK (SP600125) were added prior to stimulation with the proinflammatory cytokine interleukin-1 (IL-1). Secondly, involvement of DUSP1 was investigated using DUSP1 knocked-down cells. DUSP1 knocked-down cells were prepared by transfecting DUSP1 siRNA into IVD cells. The cells were then stimulated with IL-1. The phosphorylation of MAPKs (p38, JNK, ERK) was sequentially evaluated by Western blotting using phospho-specific antibodies for each MAPK. MMPs, NGF and DUSP1 expressions were examined by real-time PCR and the proteins of those were examined by Western blotting.

Results: MMPs expression was suppressed when ERK or JNK were inhibited. NGF expression was suppressed only when p38 was inhibited. DUSP1 gene was significantly suppressed about 70% ($p < 0.01$) by DUSP1 siRNA. While phosphorylation of MAPKs by IL-1 stimulation was transient in untransfected cells, enhanced and sustained phosphorylation was observed in DUSP1 knocked-down cells. In addition, NGF and MMPs expressions were exaggerated in the DUSP1 knocked-down cells.

Discussion: MAPKs were involved in MMPs and NGF expression, and it was revealed that ERK and JNK are important for MMPs expression and p38 is important for NGF expression in IVD cells. DUSP1 dephosphorylates MAPKs in intracellular signaling of IL-1 stimulation in IVD cells, and it was found to be an important molecule involved in NGF and MMPs regulation. DUSP1 can be a new target molecule in conservative therapy for discogenic low back pain.

Endplate cartilage avulsion during percutaneous endoscopic discectomy: presence in herniated disc, associations with Modic changes and endplate defects.

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Objective: Herniated disc tissue obtained at surgery contains nucleus pulposus, annulus fibrosus, hyaline cartilage and even some bone. There is little evidence to clarify the proportion of patients who have disc herniation with endplate cartilage avulsion. Besides, associations between cartilage avulsion and Modic changes as well as endplate defects remain unknown. This study was aim to determine the presence of endplate cartilage avulsion in herniated disc and its association with age, gender, Modic changes and endplate defects.

Methods: All patients underwent percutaneous endoscopic discectomy due to disc herniation were included between Jan 1st 2014 and Aug 30th 2017 at the Department of Orthopedic Surgery, The First Affiliated Hospital, Zhejiang University. The demographic data, such as age, sex, the level of disc herniation, and the chief complaints, were collected and analyzed. The type of disc herniation was classified as contained and non-contained using magnetic resonance images and confirmed by endoscopy. If the disc herniation was classified as contained while spinal endoscopy confirmed that there is a break in the annulus. Then the disc herniation was classified as non-contained. The presence of Modic changes and endplate defects were identified using lumbar MRI. Endplate cartilage avulsion was first examined under the endoscopic observation, and then confirmed by detailed inspection if there was hard and semi-transparent cartilage attached to the disc. The endplate cartilage avulsion was visually classified as yes or no. Furthermore, the associations between cartilage avulsion and Modic changes as well as endplate defects were explored.

Results: In total, 315 patients were included in our study. The mean age was 48.0 year (range from 15 to 78), there were 190 men and 120 women. For the type of disc herniation, there were 148 cases classified as non-contained disc herniation. Among all the patients, endplate cartilage avulsion were observed in 116 (44.1%) patients. The presence of cartilage avulsion was more frequently observed in non-contained disc herniation ($P=0.0002$). The age of the patients with non-contained disc were older than patients with contained disc (48.9 ± 1.0 vs 45.5 ± 1.2 , $P=0.03$). Men were more likely to have non-contained disc herniation as compared to women ($P=0.04$). Furthermore, the presence of Modic change (odds ratio=2.14, $P=0.002$) and endplate defects (odds ratio=1.72, $P=0.022$) were associated with the presence of endplate cartilage avulsion. However, no associations were observed between cartilage avulsion and age as well as sex.

Conclusions: Cartilage avulsion always co-exists with disc herniation at lumbar spine, especially non-contained disc herniation. Cartilage avulsion may play an important role in the disc herniation. Furthermore, the positive associations between endplate cartilage avulsion and Modic changes as well as endplate defects indicates that cartilage avulsion may play a important role in disc degeneration. Further studies are needed to be conducted to explore the mechanisms of cartilage avulsion in disc herniation, Modic changes and endplate defect.

DUSP1 regulates autocrine positive feedback loop of interleukin (IL)-1 in human intervertebral disc

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Introduction: Degeneration of intervertebral disc (IVD) by matrix metalloproteinases (MMPs), which degrade collagen (major extracellular matrix of IVD tissue), is considered as an essential step for developing discogenic low back pain. Pain-related molecules such as prostaglandin E2 (PGE2) generated by inducible cyclooxygenases (COX)-2 and nerve growth factor (NGF) that induces non-physiological nerve invasion into degenerated IVD are involved in the cause of pain. Interleukin (IL)-1 is a cytokine that induces various inflammatory proteins including COX-2, NGF and MMPs in IVD cells, and is recognized as a key molecule for the pathogenesis of discogenic low back pain. However, the regulation of endogenous IL-1 expressed by IVD cells are largely unknown. In the present study, we investigated the mechanism of regulation of endogenous IL-1 expression induced by exogenous IL-1 by focusing on intracellular signaling molecules, mitogen-activated protein (MAP) kinases (ERK, p38, JNK) and their endogenous phosphatase, dual-specificity phosphatase (DUSP) 1.

Methods: Isolated human IVD cells were stimulated with IL-1 in the presence of MAP kinases inhibitors. For some experiments, DUSP1 was knocked-down by transfecting DUSP1 siRNA into IVD cells. Phosphorylations of MAP kinases after IL-1 stimulation were evaluated by the Western blotting. The expression of endogenous IL-1 and DUSP1 was analyzed by realtime PCR.

Results: Endogenous IL-1 expression was induced by exogenous IL-1 stimulation. This expression was suppressed by JNK inhibitor (SP600125) and ERK inhibitor (U0126) in a concentration-dependent manner, while it was enhanced by p38 inhibitor (SB203580). Knocking down of DUSP1 by siRNA (~70% inhibition) resulted in exaggeration of the phosphorylations of p38, ERK and JNK compared to untransfected cells. The expression level of endogenous IL-1 after IL-1 stimulation was significantly higher in the DUSP1 knock-down cells compared to untransfected cells.

Discussion: Because the IVD disc tissue is avascular and mainly composed of IVD cells, inflammatory cytokines, including IL-1, are thought to be produced by the IVD cells. Our results demonstrated that there is a mechanism by which exogenous IL-1 stimulates the endogenous IL-1 which may stimulate the same or neighboring cells in an autocrine manner. This positive feedback loop may cause prolonged local inflammation in IVD tissue. The intracellular signaling was complex in which JNK and ERK pathways positively while p38 pathway negatively regulated the IL-1 induction. However, ERK and JNK may dominate in the induction of IL-1, since IL-1 expression was enhanced in DUSP1 knock-down cells. Our study suggests that DUSP1 would be a novel targeting molecule for managing discogenic low back pain.

Crocin exhibits anti-inflammatory effects by suppressing the activation of JNK in IL-1 β treated human annulus fibrosus cells.

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Introduction: Symptomatic disc degeneration is an important cause of chronic intractable lumbar pain. Painful symptomatic discs seem to result from inflammatory reactions associated with abundant macrophages in the outer annulus fibrosus (AF). Recent studies have suggested that the interleukin (IL)-1 β released from macrophages may promote inflammation and degeneration of the intervertebral disc (IVD). Among the extracts of saffron, crocin is the main constituent responsible for the multifarious activities of saffron. Previous studies have reported that crocin has various pharmacological activities, such as antioxidant, anti-cancer, anti-atherosclerotic, anti-hyperlipidemic and neuroprotective effects. It has earned a universal acceptability as a phytotherapeutic drug because of its history of safe and zero side effects. In the present study, the anti-inflammatory effects of crocin on human AF were analyzed in vitro.

Methods: Human AF cells were isolated from the disc tissues during elective surgery for degenerative spinal disease (Pfirrmann degenerative grades II–III). Confluent AF was treated with various concentrations of crocin in the presence or absence of IL-1 β (10 ng/ml) for 24 h. Subsequently, RT-qPCR and enzyme-linked immunosorbent assay were carried out to measure the expression levels of catabolic enzymes, pro-inflammatory factors and the components of the extracellular matrix (ECM). In addition, western blot analysis was also used to investigate the related signaling pathways.

Results: Compared with unstimulated cells, IL-1 β -stimulated AF cells produced significantly higher levels of MMP-1, MMP-3, MMP-13, IL-6, IL-8, COX-2, and VEGF, and lower levels of TIMP-1 and TIMP-2. Crocin significantly inhibited the IL-1 β -induced overexpression of catabolic enzymes [matrix metalloproteinase (MMP)-1, MMP-3, MMP-13], pro-inflammatory factors [IL-6, IL-8, and COX-2] in a concentration-dependent manner. Notably, crocin partly prevented the down-regulation of aggrecan and type II collagen. Moreover, crocin inhibited IL-1 β -induced activation of the JNK, but not ERK, to repress NF- κ B activation and inflammation induction.

Discussion: Crocin effectively suppressed the degeneration-related inflammation and catabolism in human AF in vitro, suggesting that crocin has a potential for use as a therapeutic strategy in the treatment of LBP.

Selective mTORC1 inhibition by temsirolimus protects human disc nucleus pulposus cells through Akt and autophagy induction

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Introduction: The mammalian target of rapamycin (mTOR) is a serine/threonine kinase that plays a central role in cell growth and protein synthesis. We previously reported protective effects of mTORC1 inhibitor—temsirolimus on human disc cells. However, it remains unknown which signal(s) substantially provides beneficial effects of mTOR suppression. Therefore, a human disc-cell study was designed to identify the most suitable mTOR inhibitor and its plausible mechanistic explanation to treat disc disease. An additional mechanistic investigation using a dual mTORC1 & mTORC2 inhibitor—INK-128, a dual PI3K & mTOR inhibitor—NVP-BEZ235, and an Akt inhibitor—MK-2206 was also conducted to clarify which signal(s) substantially provides beneficial effects of mTOR suppression.

Methods: Human disc nucleus pulposus cells were isolated from 28 patient specimens undertaking lumbar surgery (65.0±13.8 years; male:female=12:16; Pfirrmann degeneration grade, 3.4±0.5). Cells were cultured in DMEM with and without serum to simulate nutrient deprivation. Also, 10-ng/ml IL-1β was applied to simulate inflammation. Temsirolimus, INK-128, NVP-BEZ235, and MK-2206, were applied. Cell viability was investigated by using the Cell Counting Kit-8 (CCK-8). Expression and phosphorylation of mTOR and its down-stream effector p70/S6K and up-stream regulator Akt were assessed by Western blotting. Autophagy marker LC3-II and substrate p62/SQSTM1 were also evaluated. Apoptotic cleaved PARP, cleaved caspase-9, and senescent p16/INK4A in cell lysates and catabolic MMPs and anti-catabolic TIMPs in culture supernatants were analyzed similarly.

Results: Temsirolimus, INK-128, NVP-BEZ235, and MK-2206 showed dose-dependent decreases in CCK-8 dehydrogenase activity (temsirolimus, INK-128, and NVP-BEZ235: $P<0.01$ in $>1 \mu\text{M}$, MK-2206: $P<0.01$ in $>10 \mu\text{M}$). Based on the CCK-8 findings, 100 nM in temsirolimus, INK-128, and NVP-BEZ235, and 5 μM in MK-2206 were selected as an effective but non-toxic concentration. Western blotting showed that temsirolimus decreased mTOR and p70/S6K but increased Akt phosphorylation ($P<0.05$). Temsirolimus increased LC3-II and decreased p62/SQSTM1 ($P<0.05$), consistent with autophagy induction. Western blotting showed that temsirolimus suppressed IL-1β-induced increases in apoptotic cleaved PARP and caspase-9 and senescent p16/INK4A expression ($P<0.05$). Furthermore, temsirolimus suppressed IL-1β-induced release in MMPs and TIMPs ($P<0.05$). Then, in mechanistic examination, administration of MK-2206 increased Akt phosphorylation induced by temsirolimus ($P<0.05$). Unlike temsirolimus alone, combination of temsirolimus and MK-2206 developed additional increases in IL-1β-induced apoptosis and senescence ($P<0.05$). Moreover, IL-1β-induced MMP production was suppressed by temsirolimus but enhanced by combination of temsirolimus and MK-2206. Meanwhile, INK-128, and NVP-BEZ235 decreased p70/S6K and Akt phosphorylation ($P<0.05$) without enhancing autophagy and suppressing apoptosis, senescence, and matrix catabolism ($P<0.05$). These findings highlighted the importance of Akt in this signaling pathway.

Discussion: Pharmacological inhibition of mTORC1 but mTORC2 protects against inflammation-induced apoptosis, senescence, and matrix catabolism in human disc cells. This primarily depends on Akt and autophagy induction. Temsirolimus has an improved water solubility, allowing intravenous/local administration. Thus, temsirolimus has a potential therapeutic application to human disc disease.

The Role of Periostin in Osteoporosis

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Introduction: Periostin (PN) is a secreted extracellular matrix protein associated with the thickening, fibrosis and ossification of tissues. Recently, several reports have explored the association of PN and osteoporosis, but no detailed investigations have been performed. The purpose of this study was to investigate the role of PN in osteoporosis.

Methods: The subjects were 79 male and 48 female spine surgery patients with an average age of 70 years (range, 17 to 93). Patients with allergic disease, hemodialysis, tumor and infectious disease were excluded from the study. We measured the bone metabolism marker (P1NP, TRACP-5b) and the bone density (%YAM) before surgery. We examined the presence of vertebral and proximal femoral fracture and diffuse idiopathic skeletal hyperostosis (DISH) using whole spine-pelvic computed tomography. According to the Resnick definition, DISH was defined by the presence of a bone bridge at three successive levels (involving four contiguous vertebrae). Enzyme-linked immunosorbent assay (ELISA) kits were used to measure the serum PN (sPN), and the relative expression of PN mRNA in the vertebral arch cortical bone (bPN) was measured using a reverse transcription quantitative polymerase chain reaction (RT-qPCR) analysis. Human peripheral blood and vertebral arch cancellous bone were obtained as discards from patients undergoing spine surgery. We examined the relationships among the parameters. The significance of the differences in the parameters between the two groups (DISH+ vs. DISH-) were evaluated by Student's *t*-test. The correlations between each parameter were calculated using Pearson's correlation coefficient. P values of <0.05 were considered to indicate statistical significance.

Results: The sPN of the DISH+ group was significantly higher than that of the DISH- group ($P < 0.05$). Furthermore, significant correlations were found between the bPN and the TRACP-5b, P1NP level ($P < 0.01$). In addition, the sPN was correlated with bone bridging intervertebral number and %YAM ($P < 0.05$). The sPN and bPN showed no significant correlation with any other parameters.

Discussion: These findings suggest that PN affects osteoporosis, that bPN and TRACP-5b, P1NP are correlated. Furthermore, the high expression PN may prevent the progression of osteoporosis and maintain homeostasis of the bone. The high sPN in the DISH+ group and the correlation between sPN and bone bridging intervertebral number suggests that PN may not be very involved in the DISH pathophysiology.

Involvement of autophagy in human lumbar spine degenerated and herniated disc diseases

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Introduction: Intervertebral disc pathologies can cause back pain and neurological complications. The disc is the largest avascular organ in the body. Disc cells are expected subject to limited nutrition. Autophagy, the intracellular process by self-digestion and recycling damaged components, is an important cell survival mechanism under stress, primarily nutrient deprivation. We thus hypothesized that resident cells may utilize autophagy to cope with the harsh disc environment. However, clinical relevance of disc cellular autophagy is unknown. Therefore, an *in-vivo* study was designed to elucidate the involvement of autophagy in human lumbar spine degenerated and herniated disc diseases.

Methods: Human disc nucleus pulposus (NP) and annulus fibrosus (AF) tissues of 32 patients who underwent lumbar interbody fusion surgery for degenerative disc disease (age, 54.8 ± 19.2 [22–83] yr; male 16, female 16; Pfirrmann degeneration grade 4, 3.4 ± 0.8 [2–5]) and 12 patients who underwent micro-endoscopic discectomy for lumbar disc herniation (age, 49.3 ± 19.0 [21–85] yr; male 8, female 4; degeneration grade, 3.1 ± 0.9 [2–4]) were carefully dissected for protein extraction. Western blotting for an autophagy marker, LC3-II, and autophagy substrate, p62/SQSTM1, was performed. The α -tubulin was used as a loading control. Age-, degeneration severity-, and disease-dependent expression of autophagy-related LC3-II and p62/SQSTM1 was analyzed.

Results: First, we assessed expression of autophagy-related proteins based on the severity of human disc degeneration. In 12 patient samples of grades-2, -3, -4, and -5 disc NP tissues, expression levels of autophagic LC3-II and p62/SQSTM1 were both highest in discs with the Pfirrmann grades 3 and 4 ($P=0.049$ in LC3-II between grades 2 versus 4).

Next, to understand roles of autophagy in human disc aging, we analyzed 20 consecutive patient samples of grades-3 and -4 disc NP and AF tissues. Human disc NP tissues in varying ages showed that LC3-II and p62/SQSTM1 expression transiently increased in middle ages of 40–70 but subsequently decreased in older ages of >70 (LC3-II $R^2=0.424$, $P<0.01$; p62/SQSTM1 $R^2=0.392$, $P=0.01$). Human disc AF-tissues presented a similar trend (LC3-II $R^2=0.546$, $P<0.01$; p62/SQSTM1 $R^2=0.614$, $P<0.01$).

Finally, to find disease-specific characteristics of autophagy in human disc degeneration and herniation, we compared age- and degeneration severity (grades 2, 3, and 4)-matched 12 patients with unstable degenerated discs requiring fusion surgery and 12 those with symptomatic herniated discs requiring discectomy. Unexpectedly, there were no significant differences in LC3-II and p62/SQSTM1 expression levels between degenerated and herniated discs.

Discussion: This is the first report to demonstrate that autophagy is clinically involved in intervertebral disc degeneration and herniation. Autophagy levels transiently increased in human middle-aged and moderately degenerated discs, potentially by stress response. However, autophagy levels subsequently decreased in human older-aged and severely degenerated discs, cells of which might lose the reaction potential of autophagy. In this study, disc cellular autophagy was age- and degeneration severity- but not disease-dependent. This suggests that age and degeneration grade are important in the patient selection for autophagy-modulating molecular therapy. Autophagy modulation could be suitable for treating grades-3 and -4 disc disease in middle-aged patients.

Hepatocyte growth factor promotes nucleus pulposus cell proliferation with HIF-1 α expression.

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Introduction: Hypoxia inducible factor 1 alpha(HIF-1 α) showing anabolism has been identified as the primary regulatory factor responding to variations in O₂ levels, is reported to maintain the homeostasis of nucleus pulposus(NP) cells and play an important role in intervertebral disc(IVD) degeneration. We reported that hepatocyte growth factor(HGF) and c-Met, its specific receptor, promotes cell proliferation and protects NP cells through anti-apoptotic and anti-inflammatory activities. However, the mechanism has not been clarified in detail. In this study, we elucidated the mechanism by which HGF promotes proliferation of NP cells focusing on HIF-1 α expression.

Method:

The NP cells were isolated from Japanese white rabbits IVD and cultured as a monolayer. NP cells were sub-cultured in a 96-well plate and treated with recombinant human HGF (0, 100 ng/ml) and PD98059 (0, 10 μ M), which is an inhibitor of the MAPK pathway, in DMEM/F12 medium supplemented with 10% FBS under 2% or 20% O₂. Cell proliferation was measured for 1, 3, 5, or 7 days after administration of HGF using a Cell Counting Kit-8(WST-8 method). Cells were sub-cultured in a PLL-coated, 35-mm dish. After attachment, the medium was changed to serum-free DMEM/F12 overnight. The cells were then treated with HGF (0, 100 ng/ml) and PD98059 (0, 10 μ M) for 24 h in serum-free DMEM/F12 medium under 2% or 20% O₂. The protein expression of pERK and HIF-1 α was evaluated by western blotting.

Result: In experiments conducted without HGF treatment, cell proliferation increased under 2% O₂, compared to that observed with cells grown under 20% O₂. Under hypoxic condition, HGF treatment significantly increased cell proliferation at culture days 5 and 7, compared to that observed in no-HGF treatment control cells. In addition, PD98059 significantly inhibited cell activity at culture days 5 and 7, compared to that observed in HGF treatment control cells under 2% O₂(Figure 1). HIF-1 α expression was induced by hypoxic stimulation and further enhanced by HGF. PD98059 reduced pERK expression in NP cells, and suppressed HIF-1 α expression which is enhanced by hypoxia and HGF(Figure 2).

Discussion: In this study, it was demonstrated that HGF promoted NP cell proliferation with HIF-1 α expression under hypoxia. We also revealed that the MAPK pathway was involved in NP cell proliferation and HIF-1 α expression induced by HGF. These results showed that IVD degeneration could be treated by regulating HIF-1 α expression in NP cells through HGF/c-Met signal. Therefore, it is necessary to analyze the molecular pathway in further detail concerning apoptosis and extracellular matrix metabolism.

Significance: To our knowledge, we, for the first time, report the effects of HGF on NP cell proliferation under hypoxic condition focusing on HIF-1 α expression. Our study proposed that the therapy targeting to regulation of HIF-1 α expression by HGF might be useful for IVD degeneration.

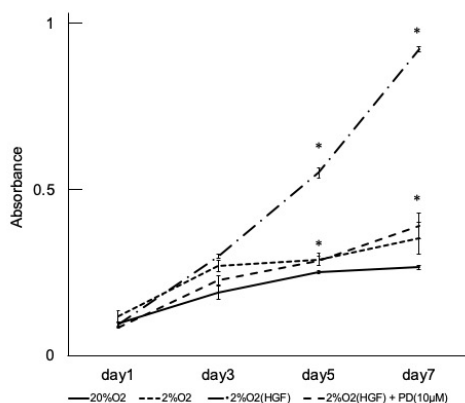
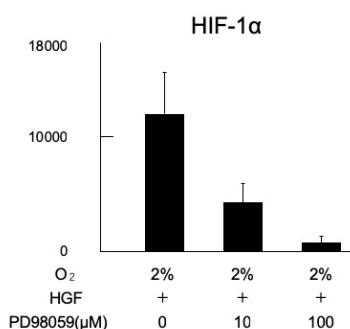


Figure1. NP cell proliferation which was promoted by HGF or hypoxic condition but inhibited by PD98059.

B



A

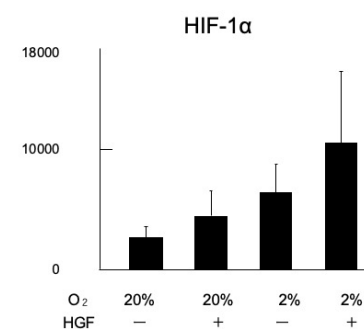
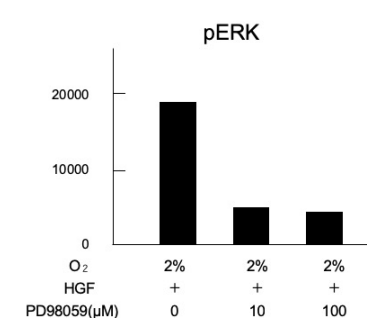


Figure2. HIF-1 α expression which was promoted by hypoxic stimulation and further enhanced by HGF(A). Protein expression of HIF-1 α and pERK which was suppressed by PD98059(B,C).

C



Shox2 inhibits inflammatory response in nucleus pulposus cells and intervertebral disc degeneration associated pain behavior in vivo

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Introduction: Proinflammatory mediators play a vital role in the pathogenic processes of low back pain underlying painful intervertebral disc degenerative diseases. Objective: This study was to evaluate the role of Shox2 in the regulation of inflammatory factors release of nucleus pulposus (NP) cells, and it's regulation on discogenic pain.

Methods: The expression of TNF- α , IL-1 β , IL-6, COX2, PGE2 and NGF, chemokines(CCL2/3) and VEGF in painless and painful discs was detected. The involvement of the NF- κ B and MAPK signaling pathway on the regulation of Shox2 expression was also studied by lenti-virus mediated knockdown. The effect of Shox2 on cytokines expression induced by TNF- α in NP cells was also studied by lenti-virus mediated knockdown or over-expression. Effect of Shox2 on the migration of macrophages was measured by cell migration assay. The effect of Shox2 on the inflammatory response in the IVD and DRG was studied in IVDD rat model in vivo.

Results: RT-PCR showed the expression of TNF- α , IL-1 β , IL-6, COX2, NGF and CCL2/3 increased in painful discs compared with painless discs, representing a statistically significant difference ($P < 0.05$). Lenti-viral delivery of sh-p65 and sh-IKK β significantly decreased cytokine dependent change in Shox2 expression. Besides, MAPK signaling showed an isoform-specific control of Shox2 expression. Inhibition of Shox2 significantly enhanced the effect of TNF- α on cytokines induction in human NP and macrophages with promoted chemotactic migration of macrophages, while Shox2 over-expression counteracts the up-regulation of cytokines. In vivo, inhibition of Shox2 accelerated the progress of IVDD, while Shox2 over-expression can down-regulated this process. Moreover, inhibition of Shox2 enhanced the inflammatory response and pain development in rat models, while Shox2 over-expression suppresses the inflammatory response and pain development.

Discussion: Our results suggest that painful degenerated IVDs release increased quantities of cytokines which can regulate by Shox2 expression. Moreover, Shox2 over-expression can suppress degenerative processes, together with inhibited inflammatory responses in IVD and DRG and pain behavior.

A link of disc degeneration to increased myofibroblast and fibrocyte-like activity

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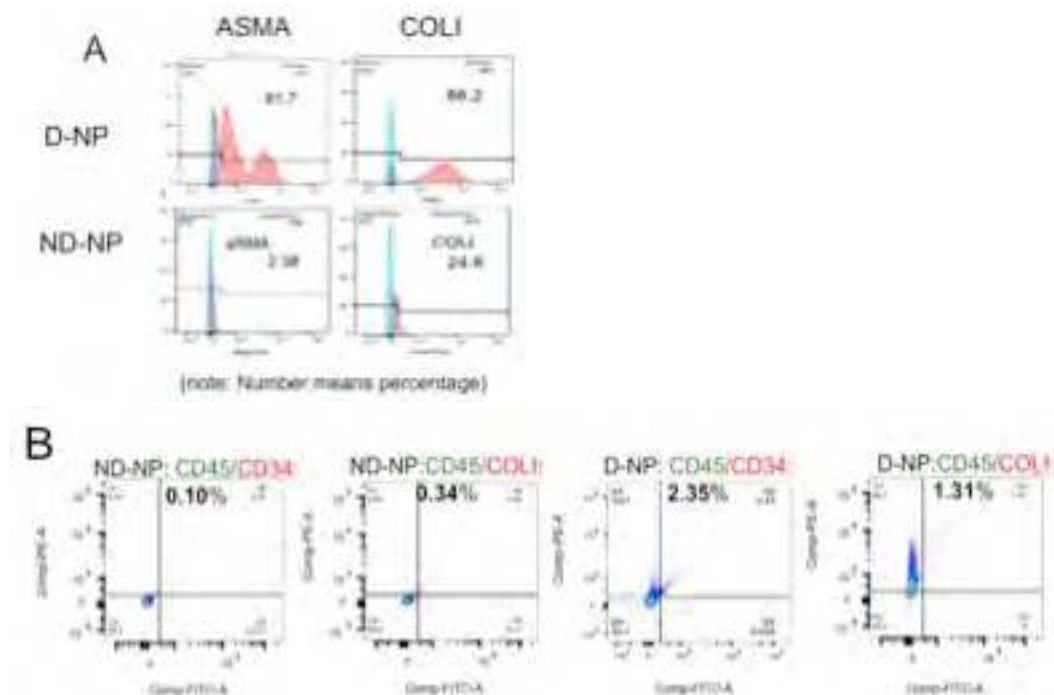
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Introduction: Intervertebral disc degeneration (IDD) is associated with low back pain and considered as a chronic disorder. We previously demonstrated the presence of fibrotic events in the nucleus pulposus (NP) in human degenerative disc samples and animal models of IDD. We proposed that such fibrous transformation might be a major cause of biomechanical changes and responsible for the progression of IDD. Tissue fibrosis is a pathological condition associated with an elevated activity of myofibroblasts. Previous studies suggest that tissue fibrosis may involve an activation of fibrocytes (monocytes descendent cells that characterized by expression of CD34, CD11b/CD45 and collagen I) into contractile myofibroblasts. We hypothesized that IDD is linked to an activation of myofibroblast activity from fibrocytes, which leads to the fibrous events in NP.

Methods: Immunostaining was performed on human degenerative NP (D-NP) and non-degenerative (ND-NP) control disc samples (n=3) to assess the expression of the myofibroblast marker aSMA (alpha smooth muscle actin) and collagen I. Similar marker expression analysis was conducted in corresponding cell culture (n=3) using flow cytometry. A rat-tail disc perturbation model was generated by intradiscal injection of bleomycin (2ul, 2mg/ml) and the induction of myofibroblast marker expression and fibrosis was evaluated. Dual staining of typical fibrocytes CD34/CD45, and CD45/COLI were performed on both human and animal samples to investigate the presence of fibrocyte-like cells. Co-Staining of aSMA with CD34 was performed to test if the fibrocyte-like cells exhibit a myofibroblast phenotype.

Results: Immunostaining showed that human D-NP samples presented an increased amount of aSMA positive cells than ND-NP samples. Flow cytometry in the D-NP cell culture demonstrated that aSMA positive cells account for 81.7% of total disc cells (figure A). In the bleomycin-injected rat model, we observed features of disc degeneration including a decrease in %DHI and alcian blue positive matrix. Consistent with the findings in the human specimens, aSMA positive cells were induced in the NP during the degeneration progression from 2 to 8 weeks, with a frequency peaked at 70.6% by 8 weeks. Human D-NP samples and degenerative rat discs showed an increased number of CD34+CD45+ and CD45+COLI+ cells, although at a low quantity as shown by flow data (figure B), suggesting IDD might involve fibrocyte-like cells. An aSMA+ sub-population was also positive for CD34, implicating a possible transition between the fibrocyte-like and myofibroblast-like phenotypes.

Discussion: Results from the human disc samples and the rat model support an increase of myofibroblastic cells in the NP during IDD. Moreover, our data imply that a sub-population of these myofibroblastic cells carry a fibrocyte-like phenotype. Further understanding of this hierarchy in future may provide important insights into the cause of NP fibrosis in IDD.



TSCmKO kyphosis mice model – muscle loss induced intervertebral disc degenerationWing Moon Raymond Lam¹, Hwee Weng Dennis Hey¹, Elisa Marie Crombie², Simon Cool³, Ling Liu^{1,4}, Shih-Yin Tsai²,Hee Kit Wong¹

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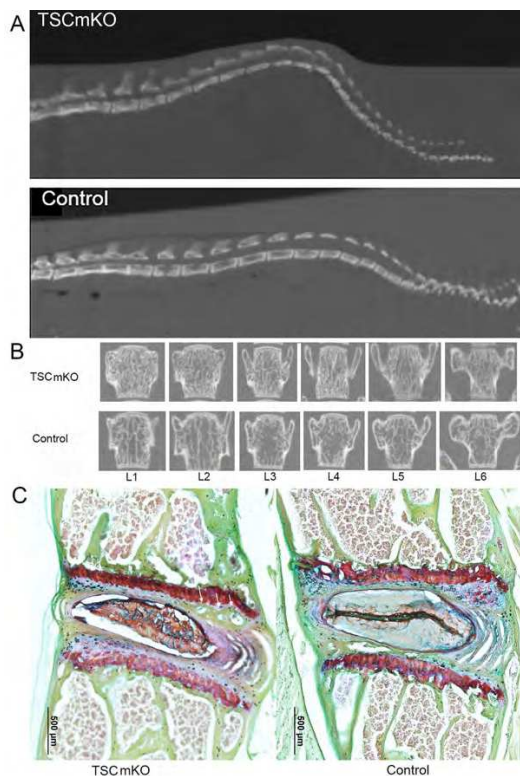
Introduction: Sarcopenia is defined as a progressive age-related loss of muscle mass, strength and function; it is a significant global public health problem, especially in the developed world. Muscle weakening by reduced autophagy reduce stability of the spine, reduce extension force of lumbar which can lead to hyperkyphosis (1). Hyperkyphosis may negatively impact several aspects of an afflicted individual's health; for example, excessive mechanical load applied to the spine can accelerate disc degeneration. Previously, intervertebral disc stabbing to induce trauma has been used as a disc degeneration model; however, this differs from the process occurring in human aging populations induced muscle loss. Therefore, an animal model with gradual muscle loss may allow for better understanding of a disc degeneration during ageing.

The TSCmKO mouse is a sarcopenia model with a shortened lifespan, exhibiting kyphosis in the late stages (2)(9-12 months of age); at this stage, muscle force is lost by 50%, which has some similarity to elderly humans with sarcopenia (1). We hypothesize that TSCmKO mice develop intervertebral disc degeneration due to muscle loss-induced overload in L5-6 vertebra level. The aim of the present study is to determine whether muscle loss can induce intervertebral disc degeneration in the TSCmKO mouse model.

Methods: All animal-related procedures were approved by the institutional ethics committee. Eight mice were divided into two groups: Group 1, 9 months old, TSCmKO (n=4); and Group 2, age-matched control mice (n=4). Cobb Angle was measured by microCT at low resolution mode, post-mortem. For bone histomorphometry, disc height, and vertebral length, L1 to L6 vertebra were scanned at 20- μ m spatial resolution by Spectrum FX micro-tomography. Bone histomorphometry parameters such as Bone volume/tissue volume (BV/TV), Bone Surface/Tissue Volume(BS/TV), Bone Surface/Bone Volume(BS/BV), Trabecular Thickness(Tb.Th), Trabecular Separation (Tb.Sp) and Trabecular Number(Tb.N) were calculated by CTan software. After microCT imaging, specimens were fixed by paraformaldehyde and decalcified by Moses solution, embedded in paraffin. Section were stained by Fast staining. Degree of intervertebral disc degeneration was evaluated by histological method.

Results Cobb Angle of TSCmKO (56.8 \pm 12.7) was higher than age matched control mice (35.2 \pm 12.5). Intervertebral disc heights in TSCmKO mice were lower than those in age matched control mice (L4-5 205 \pm 63mm vs 233 \pm 17mm), (L5-6 209 \pm 45 vs 248 \pm 32mm). Vertebra length in TSCmKO mice was reduced at L1-L6, with a significant reduction at L4 (2940.8 \pm 216.3mm vs 3238.2 \pm 72.6mm, p=0.04). From histomorphometry analysis, TSCmKO mice had significantly higher BV/TV (23.34 \pm 8.01 vs 15.84 \pm 3.11, 0.04) and trabecular thickness than the control group (98.8 \pm 18.1 vs 80.5 \pm 5.3mm, p= 0.03). From fast staining histology, L4-5 and L5-6 intervertebral discs of TSCmKO mice had lower GAG content, with endplate ossification observed at the anterior side.

Discussion: The TSCmKO mouse showed an increased Cobb angle. In the present study, higher intervertebral disc degeneration at L4-5 and L5-6 provide evidence towards our hypothesis. These results are consistent with elderly patients with muscle weakness and intervertebral disc degeneration. This study showed the potential of TSCmKO model for disc degeneration study.



1. Kasukawa Y, et al. (2017) Age-related changes in muscle strength and spinal kyphosis angles in an elderly Japanese population. *Clinical interventions in aging* 12:413-420.
2. Castets P, et al. (2013) Sustained activation of mTORC1 in skeletal muscle inhibits constitutive and starvation-induced autophagy and causes a severe, late-onset myopathy. *Cell metabolism* 17(5):731-744.

MSCs secretome decreases matrix degrading activity of anulus fibrosus cells under mechanical loading and an inflammatory environment

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Introduction: In the last years, cell-based therapies for low back pain and intervertebral disc (IVD) degeneration have been emerging specially using Mesenchymal Stem/Stromal Cells (MSCs), despite the poor knowledge on their full mechanism of action. As failure of the AF is often associated with IVD herniation and inflammation, the objective of the present study was to investigate if the secretome of MSCs influences AF cells exposed to mechanical loading in a pro-inflammatory environment.

Materials/Methods: Human IVD biopsies were isolated from patients with scoliosis (age 16±2; 4M/2F) or IVD degeneration (age 65±11; 5M/1F) by microdissectomy, after Hospital's ethical approval and patients' informed consent. AF was separated from NP and endplates by macroscopic analysis and digested using Collagenase I. AF cells were expanded in DMEM with 5% FBS, osmolality adjusted to 400 mOsm, in 6% O₂ environment². AF cells (passage 3-4) were exposed to physiological cyclic tensile strain (CTS) (2%, 1Hz, 3h/day) during 72h in a custom-made device³ with or without the presence of IL-1β (10 ng/mL). Unstimulated AF cells were used as controls. AF cells stimulated with CTS and IL-1β were then treated with MSCs secretome (1:1 dilution in culture medium) produced in basal conditions or following cells pre-conditioning with 6% O₂ and IL-1β (10 ng/mL) during 48h. Metabolic activity and gene expression of AF cells (Bax1, IL-6, IL-8, COL1, Elastin, Fibrillin, MMP1, MMP3) were evaluated by rezasurin conversion and real-time PCR, respectively. In the supernatant, PGE₂ production and MMPs activity were evaluated by ELISA and gelatin zymography, respectively.

Results:

Similar gene expression profile, metabolic activity and apoptosis of AF cells from patients with scoliosis and IVD degeneration were observed, despite different age range and pathology. CTS stimulation up-regulated COL1, while IL-1β significantly stimulated the expression of IL-6, IL-8, MMP1, MMP3 and PGE₂ production, and down-regulated COL1 gene expression (p<0.05). Furthermore, the combination of CTS+IL-1β had a similar outcome as IL-1β alone, accompanied by a significant up-regulation of Elastin (p<0.05). MSCs secretome did not influence inflammatory gene profile of CTS+IL-1β-stimulated AF cells, but reduced MMP1 and MMP3 gene expression, particularly when MSCs were pre-conditioned. This result was confirmed by gelatin zymography, in which MSCs secretome reduced MMP2 and MMP9 activity of CTS+IL-1β-stimulated AF cells.

Discussion: The gene expression profile of AF cells from patients with distinct spine pathologies is similar in cell passages 3-4. AF cells inflammatory profile is stimulated mostly by IL-1β, that up-regulates MMPs gene expression, while a CTS+IL-1β synergistic effect is observed only in the up-regulation of Elastin expression. Interestingly, MSCs secretome revealed an important role in down-regulating gene expression of MMPs and metabolic activity of AF cells, in the presence of CTS+IL-1β. The results obtained demonstrate the impact of the inflammatory milieu on the human AF, evidencing a novel aspect of MSCs mechanism of action in degenerated IVD that consists in the modulation of MMPs activity by AF cells, which could have an impact in AF tissue weakening and consequently in IVD herniation.

Funding: German Spine Foundation, Humboldt Foundation, Ulm University (L.SBN.0157) and DAAD/CRUP.

Figure 1

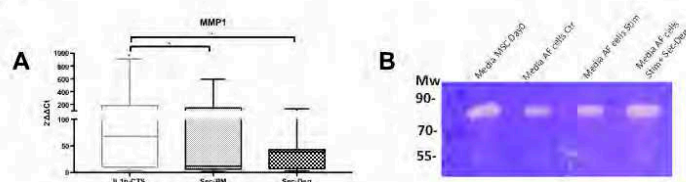


Figure 1: AF matrix degrading enzymes gene expression (A) and activity (B), stimulated by IL-1β+CTS and treated with MSCs secretome.

Sensory innervation of the lumbar intervertebral disc in mice: nerve types, origins, and differences with rats

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Introduction: Over the years, most biological studies related to back pain focused on disc degeneration. It is well known that there are nerve terminals at the outer layers of the annulus fibrosus. Little is known about the neural pathways of back pain. In fact, neuronal distribution and constitution patterns of the lumbar discs remain unclear, particularly in mice. Earlier studies suggested that the L5/6 disc in rats was mainly innervated by L1 and L2 dorsal root ganglions (DRGs). Despite mice are more commonly used than rats in back pain related research, patterns and origins of sensory nerve terminals in the lumbar discs of mice remain unknown. Using disc microinjection and nerve retrograde tracing techniques, the current study aims to characterize the nerve network and neuropathway of the lumbar discs in mice and rats.

Methods: Five adult C57BL/6 mice and Sprague-Dawley rats (males, 8-12 weeks) were used. Using an anterior peritoneal approach, the L5/6 disc was exposed to perform disc microinjection. Using a glass micropipette and a nano-electronic microinjection pump, 100 nl and 1 μ l 4% fluorogold (FG) was injected into the L5/6 disc for mice and rats, respectively. The spine and bilateral T13-L6 DRGs were harvested 10 days after injection. Immunohistochemistry staining with different nerve markers was used to identify types of nerve terminals in the annulus, including anti-neurofilament 160/200 (NF160/200, the marker for A β fibers), anti-calcitonin gene-related peptide (CGRP, for A δ and C fibers), anti-parvalbumin (PV, for proprioceptive fibers), and anti-tyrosine hydroxylase (TH, for sympathetic nerve fibers and some C-low threshold mechanoreceptors). T13-L6 DRGs were further stained with aforementioned neuronal markers and numbers of FG⁺ neurons among different levels of DRGs were counted.

Results: For both mice and rats, there were at least 3 types of nerve terminals in the outer layers of L5/6 annulus, including NF160/200⁺, CGRP⁺, and PV⁺ nerves. No TH⁺ nerve was noticed in either. For mice, FG⁺ neurons were identified in T13-L6 DRGs, but predominantly in T13 (19.9% in total FG⁺ neurons), L1 (26.2%), and L5 (18.8%) DRGs. For rats, most FG⁺ neurons were identified in L1 and L2 DRGs but only a small percentage of FG⁺ neurons disseminated in L3-L6 DRGs. Co-immunofluorescent staining of DRG neurons revealed that while FG⁺ neurons were co-localized with NF160/200, CGRP, and PV, no FG⁺TH⁺ neurons were identified in the DRGs of mice and rats.

Discussion: In mice and rats, the lumbar intervertebral discs were innervated by multiple neurofilaments from multi-segmental DRGs, including A β fibers, A δ fibers, C fibers, and proprioceptive fibers, suggesting that the lumbar disc annulus may sense various stimuli. No sympathetic nerve fiber was observed in the lumbar disc annulus. Different from the nerve network of L5/6 disc in rats which was mainly innervated by L1 and L2 DRGs, the L5/6 disc in mice was multi-segmentally innervated by the T13-L6 DRGs (mainly T13, L1 and L5 DRGs). There is an intricate nerve network in the lumbar discs, which may be species-specific, complicating studies of neuropathology of back pain.

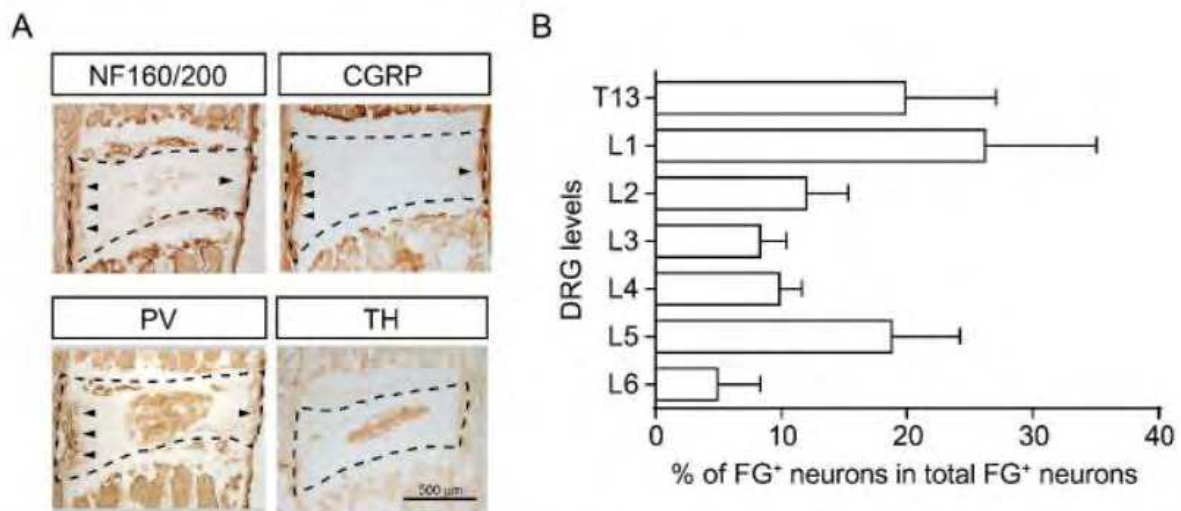


Figure 1. Sensory innervation of the L5/6 disc in mice. (A) NF160/200⁺, CGRP⁺, and PV⁺ nerve terminals (arrowheads) but no TH⁺ nerve terminals innervated the outer layers of annulus fibrosus. (B) FG⁺ neurons were identified in T13 to L6 DRGs but predominantly in T13, L1 and L5 DRGs after FG injection into the L5/6 disc of mice.

Evaluation of Gait Characteristics Using Acceleration Sensor for Patients with Lumbar Spinal Stenosis

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Introduction: In gait analysis for patients with lumbar spinal stenosis (LSS), the force plate method and 3-D motion analysis are established techniques to assess gait characteristics, however, they have been difficult to apply in a clinical setting as they require expensive large-scale facilities and a longer measurement time. Wireless, triaxial accelerometers are being widely used recently for gait analyses as they are simple and inexpensive to use and do not require a laboratory setup. Moreover, there are few reports evaluating gait characteristics associated with intermittent claudication while walking in patients with LSS. Therefore, the aim of this study was to assess gait characteristics in patients with LSS using accelerometers.

Methods: Twenty patients (11 males and 9 females, mean age=67.6±7.8years) with LSS who had limited walking abilities were enrolled. The control cohort included 20 healthy volunteers (10 males and 10 females, mean age=65.4±10.7years). The subjects continued walking for six-minutes. Root mean square (RMS), stride regularity (SR), step symmetry (SS), and flatness, which is the standard error of SR (S.E. SR) and SS (S.E. SS), were analyzed using the triaxial accelerometer. We compared the evaluated parameters between the two groups using an independent t-test. Association between the gait distance, The Japanese Orthopedic Association's evaluation system for lower back pain syndrome (JOA score) and gait characteristics were evaluated using Pearson's r correlation coefficient.

Results: The gait distance was significantly different between the patients with LSS (359.5±108.3m) and the control subjects (540.5±52.7m) ($p=0.00007$). The vertical SR and SS were significantly different between the patients with LSS (0.35±0.15) and (0.39±0.11), and the control subjects (0.52±0.092) and (0.50±0.12), with $p=0.04$ and $p=0.006$, respectively. S.E. SR, S.E. SS and RMS were significantly different in all directions between the patients with LSS and the control subjects. In Patients with LSS, the gait distance was significantly correlated with S.E. SR ($r=-0.62$, $p=0.04$) and S.E. SS ($r=-0.60$, $p=0.04$) in medio-lateral, S.E. SR ($r=-0.61$, $p=0.03$) in vertical, and RMS [in medio-lateral ($r=-0.72$ $p=0.005$), in vertical ($r=-0.74$ $p=0.005$), in antero-posterior ($r=-0.59$ $p=0.04$) and in synthesis of triaxial ($r=-0.75$, $p=0.003$)]. JOA score was significantly correlated with S.E. SS ($r=-0.63$, $p=0.04$) in medio-lateral. In the control subjects, the gait distance was significantly correlated with S.E. SR ($r=0.61$, $p=0.03$).

Discussion: In contrast to the control subjects, the gait of patients with LSS was irregular and asymmetrical in the vertical plane with a short gait distance. With respect to the associations between gait parameters and distance, patients with LSS had a shorter gait distance and lower flatness. Altogether, the gait distance, postural sway during walking, stride regularity, step symmetry, and flatness were inferior in the patients with LSS. These results indicate disrupted gait parameters, with respect to decrease in flatness indicating variations in SR and SS, characteristics to patients with LSS, which may not be present in healthy individuals. These results also suggest that gait analysis using accelerometry can be used to assess the gait characteristics and that SR, SS and flatness parameters are good indicators of gait characteristics in patients with LSS.

Changes in Adjacent Segment Kinematics After Lumbar Decompression and Fusion are Patient-Specific

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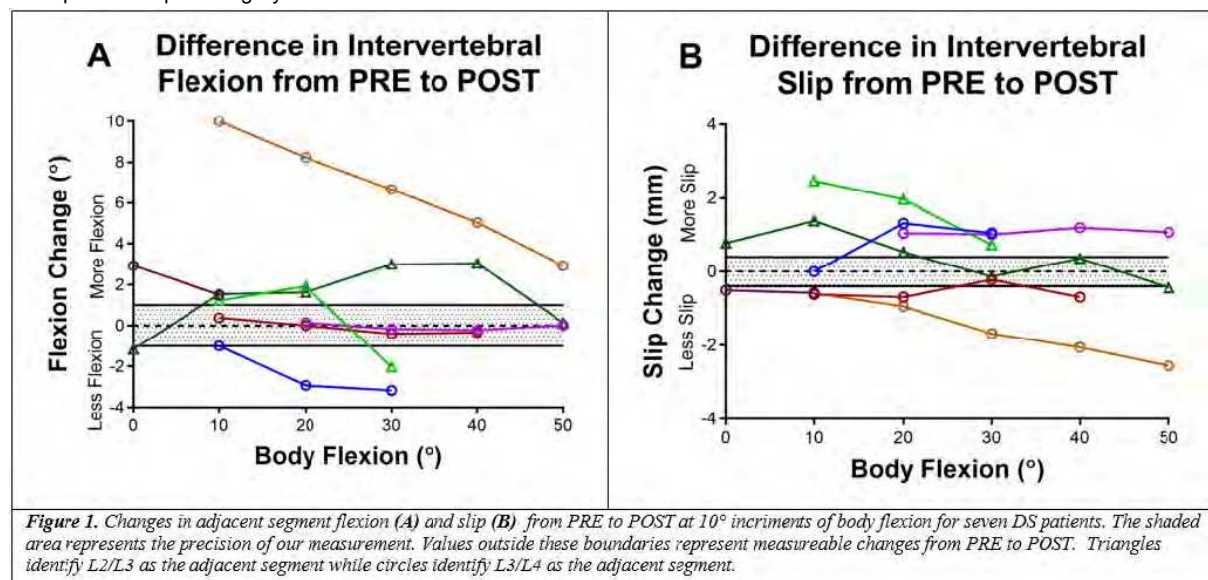
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Introduction: The pathogenesis of lumbar adjacent segment disease (ASD) is thought to be secondary to altered biomechanics resulting from fusion^[1]. Direct *in vivo* evidence for altered biomechanics following lumbar fusion is lacking. Currently, the gold standard for measuring motion is static end-range flexion and extension lateral radiographs^[2, 3] which are not able to assess the midrange motion that comprises the majority of activities of daily living. This study's aim was to describe *in vivo* kinematics of the superior adjacent segment relative to the fused segment before and after fusion in the lumbar spine. We hypothesized that flexion and AP translation of the superior adjacent segment are increased post-fusion.

Methods: Seven patients with symptomatic lumbar degenerative spondylolisthesis (DS) (5 M, 2 F; age 65±5.1 years) were positioned within a biplane radiographic imaging system and performed two to three trials of continuous flexion of their torso according to established protocols^[4]. Images were acquired at 30 images per second one month before (PRE) and six months after (POST) spinal decompression and fusion surgery at one or two levels between L3 and the sacrum. A previously validated volumetric model-based tracking process was used to track the position and orientation of vertebrae in the radiographic images^[4]. Intervertebral flexion/extension and AP translation (slip) at the superior adjacent segment were calculated over the entire dynamic flexion activity. Data from multiple flexion trials was averaged across all trials during a test session^[4]. Surface markers were tracked using conventional motion analysis and used to determine torso flexion. PRE to POST differences were considered measurable if they were more than twice the validated uncertainty in our measurement system (0.5° for flexion/extension and 0.2 mm for slip)^[4].

Results: There were no consistent trends in adjacent segment kinematics after lumbar fusion. Two patients had increased intervertebral flexion at all measured body flexion angles POST compared to PRE, while one patient had decreased intervertebral flexion at all measured body flexion angles (Figure 1A). Two patients had no measurable change in intervertebral flexion at all body flexion angles POST compared to PRE (Figure 1A), while the remaining two patients had either more or less intervertebral flexion POST compared to PRE, depending on body flexion angle. Three patients had consistently more slip at all body flexion angles POST compared to PRE (Figure 1B), whereas two had consistently less slip (Figure 1B). The remaining two patients saw increases and decreases in slip at different body flexion angles (Figure 1B).

Discussion: Changes in adjacent segment kinematics varied across patients between pre- and post-operative states, with some having increased motion and others decreased. These findings are similar to a previous report of increased adjacent segment mobility in some patients, with decreased mobility in others^[2]. The current results suggest that kinematic changes at the superior adjacent segment after lumbar fusion appear to be patient-specific. Future work will focus on long-term changes in adjacent segment kinematic and evaluating where the lost motion from the fused segment is being transferred, as total torso flexion appears to be preserved post-surgery.



1. Tobert et al., Clin Spine Surg, 2017.
2. Wiltse et al., J Spinal Disord, 1999.
3. Axelsson et al., Spine, 1997.
4. Dombrowski et al., Eur Spine J, 2018.

Personalized regenerative medicine in spine surgery: stem cells from vertebral body

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Introduction: The use of spinal fusion procedures has increased over the last decades; however, failed fusion still remains an important problem. The availability of tools and treatments that promote spinal fusion in patients undergoing surgery for degenerative spine disease is a relevant clinical need. Recently, our group has shown that mesenchymal stem cells (MSCs) derived from whole bone marrow aspirate from vertebral bodies can provide an alternative source of MSCs for tissue engineering applications in spine surgery (Figure 1). These cells have shown optimal biological characteristics and specific expression levels of HOX and TALE genes (Figures 2 and 3). Given the increase in average life, it is relevant to investigate the clinical efficacy of this application in spine surgery even in the presence of osteoporosis.

Methods: Cell proliferation, gene expression of main surface markers, osteogenic, adipogenic and chondrogenic potential and gene expression of the main HOX and TALE genes were evaluated and compared in MSCs derived from vertebral whole bone marrow aspirate of osteoporotic and non-osteoporotic patients, cultured under hypoxic conditions to better stimulate the physiological microenvironment.

Results: Compared to MSCs derived from bone marrow aspirate from vertebral bodies of non-osteoporotic patients the MSCs from osteoporotic patients showed alterations related to the expression of alkaline phosphatase (osteogenic marker), significantly less expressed, and to the adiponectin expression (adipogenic marker), significantly more expressed. However, MSCs derived from bone marrow aspirate from vertebral bodies of osteoporotic patients did not show alterations in the expression of all the other osteogenic, adipogenic and chondrogenic markers and in the expression levels of HOX and TALE genes (Figures 4 and 5).

Discussion: MSCs derived from bone marrow aspirate from vertebral bodies of osteoporotic patients have shown to represent a valid cellular source even in the presence of some intrinsic functional alterations due to the osteoporotic microenvironment. However, preliminary data have shown that the use of the bone marrow aspirate clot can represent an alternative and more effective biological approach for cell isolation even in osteoporotic patients.

References: [1] Barbanti Brodano G, Mazzoni E, Tognon M, Griffoni C, Manfrini M. Human mesenchymal stem cells and biomaterials interaction: a promising synergy to improve spine fusion. *Eur Spine J.* 2012 May;21 Suppl 1:S3-9.

[2] Khashan M, Inoue S, Berven SH. Cell based therapies as compared to autologous bone grafts for spinal arthrodesis. *Spine (Phila Pa 1976).* 2013 Oct 1;38(21):1885-91.

[3] Barbanti Brodano G, Terzi S, Trombi L, Griffoni C, Valtieri M, Boriani S, Magli MC. Mesenchymal stem cells derived from vertebrae (vMSCs) show best biological properties. *Eur Spine J.* 2013 Nov;22 Suppl 6:S979-84.

[4] Salamanna F, Sartori M, Brodano GB, Griffoni C, Martini L, Boriani S, Fini M. Mesenchymal Stem Cells for the Treatment of Spinal Arthrodesis: From Preclinical Research to Clinical Scenario. *Stem Cells Int.* 2017;2017:3537094.

[5] Eltorai AE, Susai CJ, Daniels AH. Mesenchymal stromal cells in spinal fusion: Current and future applications. *J Orthop.* 2016 Oct 25;14(1):1-3. eCollection 2017 Mar. Review.

Figure 1

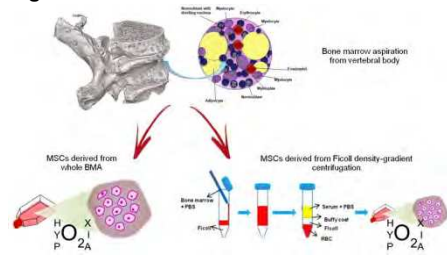


Figure 2

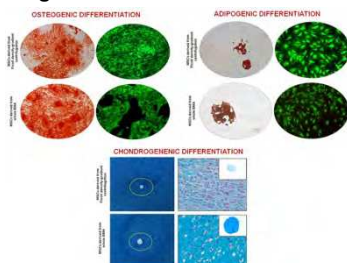


Figure 3

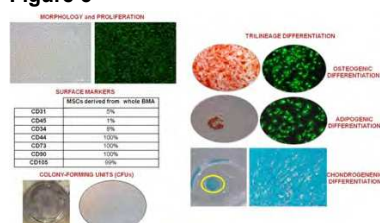


Figure 4

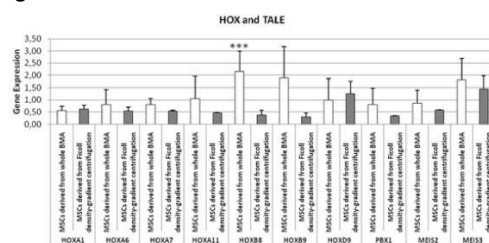
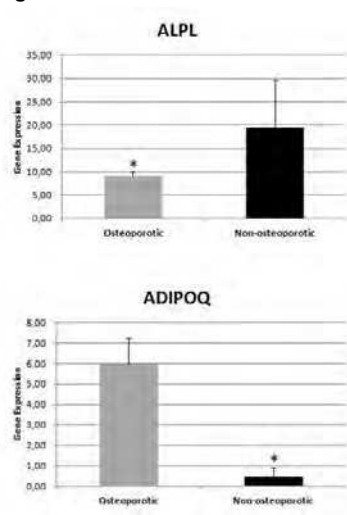


Figure 5



The greater the difference of global spino-plevic alignment between supine and standing positions, the worse the low back pain disability in the patients with adult spine deformity

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Introduction: Adult spinal deformity (ASD) is a major low back pain-related pathology. Several reports concluded that PT and PI-LL combined with SVA can predict patient disability.¹⁾ On the other hands, there is a report which suggests suggest the regional lumbar mal-alignment is not drivers of patient-perceived outcomes.²⁾ ASD patients are aware of the symptoms when standing and tend to stoop with back pain, whereas the symptoms usually disappear when lying on a bed. We thought that positional change of the spino-pelvic alignment can be a factor of deterioration of the symptom in the patients with ASD and hypothesized that the greater the difference of the alignment between supine and standing, the worse the low back pain-related symptom.

Purpose: To test the hypothesis.

Methods: Based on the inclusion criteria: ASD with age > 50y, and TK>50° or PI-LL>20° or PT>30° who were examined by a slot-scanning 3D X-ray imager (EOS) and computed tomography (CT); the exclusion criteria: previous spine surgery and central nervous system disorders, consecutive forty patients (mean age: 69.2 years, range 56-82 years; all women) were enrolled. The CT DICOM dataset of the whole spine in the supine position was transformed to two-dimensional digital reconstructed radiography images which were input for 3D measurement by the EOS software. The whole spine alignment parameters (TK, LL, PT, PI, TPA,³⁾ Cobb angle, rotation angle) were compared with those of standing by EOS measurement. The correlation between the positional difference of the alignment parameters and the symptom evaluated by ODI were examined by Spearman's rank correlation coefficient.

Results: The Cobb angle of the major curve was significantly greater in the standing position than in the supine position. LL during standing was significantly kyphotic. The pelvis significantly retroversed in the standing than in the supine. ODI deteriorated with greater ΔTPA, but did not with other regional positional changes. Based on the linear fit equation, when ODI is 40, ΔTPA is 16.9° (Table 1).

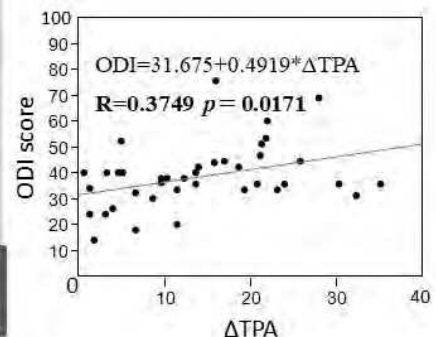
Discussion and Conclusions: Contrary to our hypothesis, the low back pain disability evaluated by ODI of the patients with ASD did not significantly correlate with the regional positional changes in regional spino-pelvic parameters, but did weakly correlate with the global change, ΔTPA (Table 1). The greater the difference of global spino-pelvic alignment between supine and standing, the worse the low back pain disability. The result is compatible with the symptom of ASD patients.

References:

1. Schwab F, Blondel B, Bess S, et al. (2013) Radiographical spinopelvic parameters and disability in the setting of adult spinal deformity. *Spine* 38, E803-812.
2. Chapman TM, Baldus CR, Lurie J, et al. (2016) Baseline patient-reported outcome measures correlate weakly with radiographic parameters. *Spine* 41, 1701-1708.
3. Protosaltis T, Schwab F, Bronsard N, et al. (2014) The T1 pelvic angle, a novel radiographic measure of global sagittal deformity, accounts for both spinal inclination and pelvic tilt and correlates with health-related quality of life. *J Bone Joint Surg Am* 96, 1631-1640.

Table 1. Comparison of the spino-pelvic alignment between supine and standing positions, and correlations between ODI score and the positional difference (Δ) of global sagittal alignment

Parameters (°)	position	Image modality	Mean	R: Δ and ODI	p
T1-T12 Kyphosis	supine	CT	23.2	0.1676	0.3011
	standing	EOS	22.9		
LL	supine	CT	27.4	0.1159	0.4762
	standing	EOS	9.8		
PT	supine	CT	22.0	0.1687	0.2981
	standing	EOS	36.1		
PI	supine	CT	52.4	0.1496	0.3568
	standing	EOS	57.1		
TPA	supine	CT	13.4	0.3749	0.0171
	standing	EOS	22.8		
Cobb angle*	supine	CT	28.6	0.1532	0.3452
	standing	EOS	35.4		
Rotation*	supine	CT	10.5	0.0145	0.9293
	standing	EOS	9.6		



ΔTPA: difference of T1 pelvic angle between supine and standing positions

*patients with kyphoscoliosis, ** p<0.05 by paired t-test

Establishment of a novel measurement technique for pedicle screw stability: Laser resonance frequency analysis: a cadaveric study

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Introduction: Insertion torque (Fig. 1a)¹ and pull-out strength (Fig. 1b)² are generally used for evaluating pedicle screw stability at the laboratory level. However, these techniques are bone-invasive, and it is therefore, impossible to perform them more than once after the pedicle screw has been inserted. As a result, these techniques are difficult for clinical use. A non-invasive and repeatable measurement technique termed resonance frequency analysis (RFA) has been widely used for evaluating implant stability in the dentistry field using a vibrating magnet attached to a dental implant with a magnetic pulse^{3,4}. We developed a novel pen type device to perform RFA using a laser that is non-invasive, non-contact, and repeatable technique for applications in the field of spinal surgery (Fig. 1c, d and e). Here, we examined the relationships among three test forces, namely, insertion torque, pull-out strength, and Laser-RFA using model bones and fresh human cadaveric vertebrae.

Methods: Six different types of model bones and 20 fresh non-frozen cadaveric human lumbar vertebrae were tested. We inserted the Associa® pedicle screw (Kyocera Medical Corporation, Osaka, Japan). Three kinds of test forces, namely, peak torque as a part of insertion torque (Nm), pull-out strength (N), and Laser-RFA (vibrating laser: Q-Switch Nd:YLF Laser, measurement laser of resonance frequency: laser Doppler vibrometer) (Hz), were performed (Fig. 1c, d and e). Pearson's correlation coefficients (R) were used to evaluate relationships among the three test forces in model bones and vertebrae.

RESULTS: Model bones: There was a strong correlation between insertion torque and pull-out strength ($R = 0.901$, $p < 0.01$) as previously reported³. Laser-RFA showed only moderate correlations with insertion torque ($R = 0.742$, $p < 0.01$) and pull-out strength ($R = 0.739$, $p < 0.01$) (Fig. 2a and b).

Vertebrae: There was a strong correlation between insertion torque and pull-out strength ($R = 0.823$, $p < 0.01$). Laser RFA showed moderate correlation with insertion torque ($R = 0.656$, $p < 0.01$) and pull-out strength ($R = 0.601$, $p < 0.01$). Overall, the results for vertebrae tended to have lower correlation coefficients than those for model bone (Fig. 2a and b).

Discussion: In dentistry, unlike insertion torque and pull-out strength, which reflect axial force, RFA reflects stability when the implant is tilted sideways, which is more similar to the multidirectional stress applied to implants *in vivo*⁵. We previously indicated that the RFA tends to have a similar tendency even with the pedicle screw using the dental RFA device³. There is a possibility that results of Laser-RFA indicate the correct pedicle screw fixation strength than insertion torque and pull-out strength as the same as dental RFA system. For the continued development of pedicle screws, a quantitative, repeatable, and non-invasive method to measure implant stability is necessary (Fig. 2c). This is the first report assessing Laser-RFA. Our findings lend a strong support for the hypothesis that Laser-RFA is a suitable method for evaluating pedicle screw stability, and it could therefore, replace conventional methods.

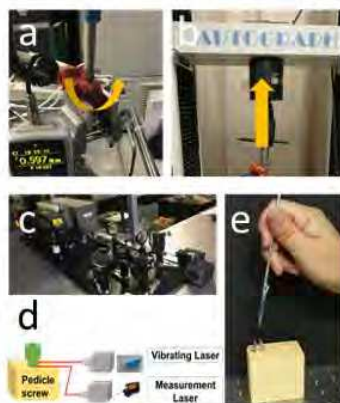
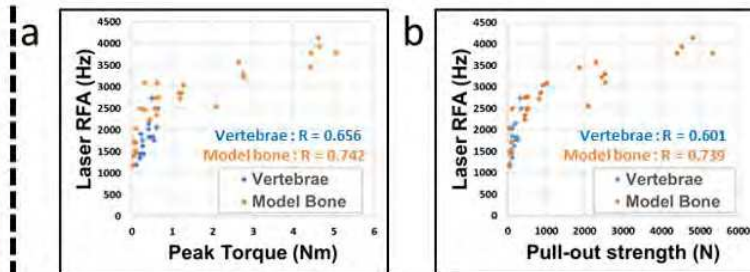


Figure 1: Test forces. a: peak torque, b: pull-out strength, c: Laser-RFA, d: schema of Laser-RFA system, e: pen type device of Laser-RFA



	Invasiveness	Repeatability	Reproducibility	Actual stress	Contactability
Pull-out torque	×	×	×	×	×
Dental RFA	○	○	○	○	×
Laser RFA	○	○	○	○	○

Figure 2: The relationship between conventional test forces (peak torque and pull-out strength) and Laser-RFA

a: peak torque vs. Laser-RFA, b: pull-out strength vs. Laser-RFA, c: schema of the characteristics of four test forces (pull-out strength, peak torque, dental RFA and Laser-RFA)

1. Ab-Lazid, R. et al. Journal of biomechanics (2014). 2: Siddiqui, A. et al. Injury (2005). 3: Nakashima, D. et al. PloS one (2018). 4: Aparicio, C. et al. Clinical oral implants research (2006). 5: Pagliani, L. et al. Journal of oral rehabilitation (2013).

Independent validation of a machine learning based spinal MRI grading system on the Finnish population cohort

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Introduction: Fully automated radiological grading of the intervertebral discs and the vertebral bodies in lumbar magnetic resonance imaging (MRI) using deep learning based SpineNet[1] system has been previously demonstrated with high accuracy. Such approaches offer the potential to reduce intra- and inter-reader variation in MRI grading and open up the possibility to compare subjects from the multiple symptomatic and asymptomatic cohorts collected within the research community. However, the grading conventions used the different cohorts can vary considerably, which then presents challenges for validation. In this study, we investigated the correlation between the gradings produced by SpineNet and the visual grading using the Northern Finland Birth Cohort 1966.

Methods: The Northern Finland Birth Cohort 1966[2] (NFBC1966) is a prospective longitudinal population-based cohort study with an unselected population (n=12058 live births) with expected date of birth between January 1st and December 31st 1966. A subset of these participants were invited to attend lumbar MRI. The final MRI study population consist of 1540 participants (77% participation rate) scanned at a mean age of 47 years (SD 0.4 years). Of them, ca. 56% were females. 101 T2 weighted spinal MR images were selected from the NFBC1966 cohort and automatically analysed using the web-based SpineNet software (<http://zeus.robots.ox.ac.uk/spinenet>). Of the eight gradings produced automatically, disc degeneration (DD) using Pfirrmann classification and Modic change (MC, general presence) were compared to the visual assessments using kappa coefficients. For historical reasons, visual assessment of Pfirrmann classification included scores from 2 to 5 (2=normal) whereas SpineNet assessment included scores from 1 to 5. Therefore, SpineNet Pfirrmann scores 1 and 2 were combined to score 2 in the analyses.

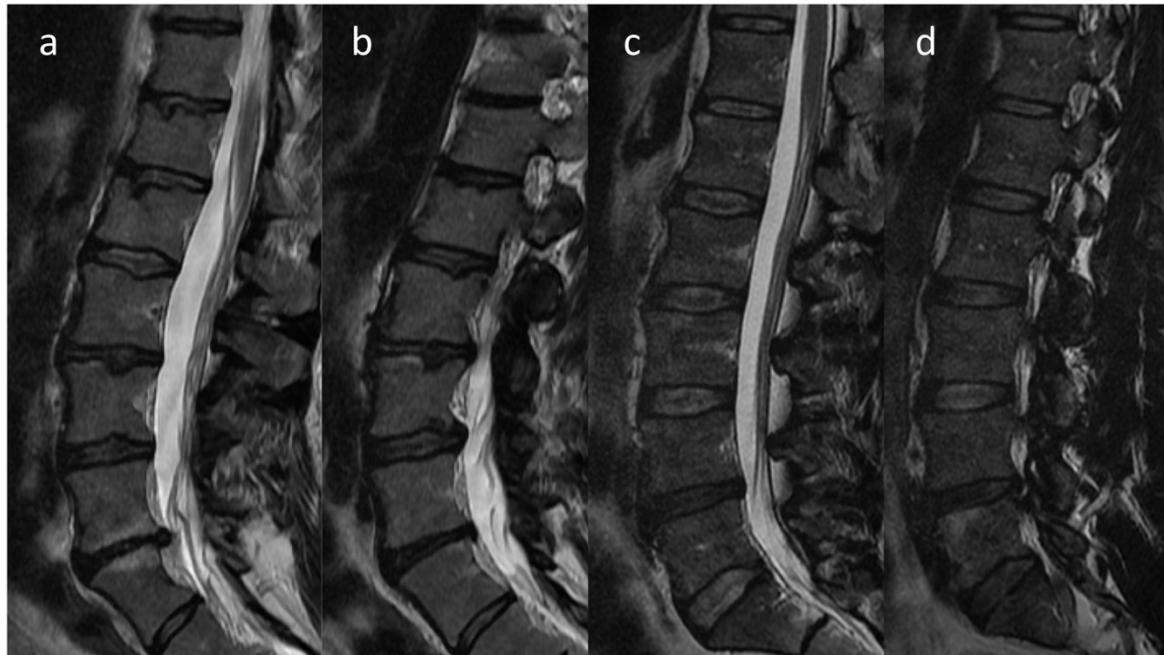
Results: Of 101 subjects, 50 (49.5%) were male. General prevalence of MC by subject was 74.3% in the visual assessment group compared to 72.3% in SpineNet assessment. MC prevalence by endplate was 25.9% in both assessment groups. Pfirrmann score 2 was the most frequent DD score in both groups (43.8% in visual and 38.4% in SpineNet group). Kappa value (95% confidence interval, CI) for MC assessment was 0.67 (0.62-0.72) and for Pfirrmann 0.65 (0.61-0.70).

Discussion: Previous kappa values of visual assessment of NFBC1966 cohort have been found to be 0.74 (intra-rater) and 0.80 (inter-rater). The kappa values between SpineNet and visual assessment are acceptable and indicate that the system may be useful in performing multi-cohort comparisons. We may calibrate SpineNet using training data from the NFBC1966 cohort to improve the kappa scores further.

Figure: MRI two different cases (midsagittal plane a&c, lateral plane b&d).

A/B: SpineNet Pfirrmann scores 2, 3, 3, 5 and 5 (from L1/2 to L5/S1) whereas visually assessed scores were 2, 2, 3, 3 and 4, respectively. SpineNet observed Modic change at caudal L4, and rostral and caudal L5 endplates compared to rostral L4, caudal L5 and rostral S1 endplates in the visual evaluation.

C/D: SpineNet and visual assessment evaluated Pfirrmann scores as 2, 2, 2, 3 and 2 (from L1/2 to L5/S1). SpineNet did not observe any MC, whereas visual assessment found MC at rostral L5 endplate.



1. Automation of Reading of Radiological Features from Magnetic Resonance Images (MRIs) of the Lumbar Spine Without Human Intervention Is Comparable with an Expert Radiologist A. Jamaludin, M Lootus, T. Kadir, A. Zisserman, J. Urban, M. C. Battié, J. Fairbank, I. McCall. European Spine Journal, 2017
2. Effects of leisure-time physical activity on vertebral dimensions in the Northern Finland Birth Cohort 1966 Oura P, Paananen M, Niinimäki J, Tammelin T, Herrala S, Auvinen J, Korpelainen R, Junno J-A, Karppinen J. Sci Rep-UK 2016; 6:27844.

Immediate changes in chest mobility and trunk muscle activity following different trunk muscle exercises

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Introduction: Trunk muscle exercises are core or conventional exercises prescribed based on individual requirement and condition. Excessive activity of the superficial trunk muscles across the chest and pelvis is believed to limit chest mobility and change the trunk muscle activity pattern during chest and pelvic movements. We examined the immediate effects of the trunk muscle exercise types on chest mobility and the trunk muscle activity pattern.

Methods: In total, 14 healthy males performed random trunk side flexion and draw-in exercises using a cross-over design. Trunk and neck muscle activities and kinematic data before and after each intervention were examined during maximum inspiration/expiration and maximum pelvic anterior/posterior tilt while standing.

Muscle activity during each intervention and task was recorded using surface electromyography. Surface electrodes were attached to the following: rectus abdominis (RA), external oblique (EO), internal oblique/transversus abdominis (IO/TrA), lumbar erector spinae, thoracic erector spinae, sternocleidomastoid, and scalene.

Body images of the maximum position in each task were captured using three cameras. Image J software was used to calculate the kinematic data of the upper and lower chest using reflective markers affixed on the body.

Two-way repeated measure analysis of variance was used to test muscle activity and kinematic data ($p < .05$).

Results: The muscle activity of EO during trunk side flexion and of IO/TrA during draw-in exercises was the highest among the recorded muscle activities.

According to the maximum pelvic anterior tilt results after side flexion, the muscle activities of RA (pre $2.9 \pm 2.1\%$ MVC, post $4.1 \pm 2.6\%$ MVC) and EO (pre $4.2 \pm 3.7\%$ MVC, post $5.6 \pm 4.1\%$ MVC) were significantly greater than those before intervention. The upper and lower chests of the elevation distance (upper chest: pre 36.4 ± 2.5 cm, post 35.5 ± 2.5 cm, lower chest: pre 16.7 ± 2.7 cm, post 16.3 ± 2.6 cm) were significantly less than those before the trunk side flexion. Furthermore, the upper and lower chests of the lateral diameter (upper chest: pre 31.4 ± 1.9 cm, post 30.8 ± 1.7 cm, lower chest: pre 28.4 ± 1.6 cm, post 27.8 ± 1.5 cm) during maximum inspiration were significantly less than those before the trunk side flexion.

After draw-in exercises, EO activity during maximum expiration was significantly greater than that before intervention. Additionally, the upper chest of the elevation distance and anteroposterior tilt angle during maximum anterior pelvic tilt were significantly greater than those before the draw-in exercises.

Discussion: Considering the origin and insertion of trunk superficial muscles, excessive contraction of the superficial muscles during side flexion may limit chest mobility during the maximum pelvic anterior tilt and maximum inspiration. Since, an increased in the abdominal pressure by abdominal muscle cause chest expansion (A De Troye, et al. 2015), the facilitated abdominal deep muscles during draw-in exercise might increase the upper chest mobility. Deep muscle exercise is similar to expiratory muscle exercise in improving expiratory functions (Suzuki et al., 1995); therefore, the muscle activity of EO may increase following draw-in exercises.

Briefly, chest mobility may be decreased by facilitated superficial trunk muscles and increased by facilitated deep trunk muscles.

Biomechanical comparison of anterior column realignment and pedicle subtraction osteotomy for severe sagittal imbalance correction

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Introduction: Anterior column realignment (ACR) has been recently introduced as an advantageous surgical alternative to pedicle subtraction osteotomy (PSO) to correct sagittal imbalance due to lumbar disc degeneration. Although current clinical literature reported a lower complication rate compared to PSO, no retrospective data have reported yet on the incidence of mechanical-related failures (e.g. rod breakage, pseudarthrosis, subsidence). Moreover, very poor biomechanical data support the usage of a standalone hyperlordotic cage or rather suggest the need for posterior fixation. The aim of the study is to investigate the biomechanical effects of anterior column realignment (ACR) and pedicle subtraction osteotomy (PSO) on local lordosis correction, primary stability and rod strains.

Methods: Seven cadaveric spine segments (T12-S1) underwent ACR at L1-L2: following anterior longitudinal ligament release, a 30° hyperlordotic cage was inserted. A standalone hyperlordotic cage condition was initially tested, then it was supplemented with posterior bilateral fixation. The same specimens had already underwent PSO at L4 sequentially stabilized by alternative constructs [La Barbera et al. 2018, Eur Spine J 27(9): 2357-2366]: simple bilateral fixation (2 rods), with the addition of one satellite rod (3 rods) and with two accessory rods (4 rods), both before and after interbody cages implantation at L3-L4 and L4-L5. Following each preparation stage sagittal X-ray scans were obtained to determine any variation on lordosis. In vitro flexibility tests were performed under pure moments (± 7.5 Nm) in flexion/extension (FE), lateral bending (LB) and axial rotation (AR) to determine the range of motion (RoM), the neutral zone (NZ), while measuring the primary rod strains with strain gauge rosettes. A nonparametric Friedman test followed by post-hoc Bonferroni correction was used to highlight statistically significant differences in terms of RoM, NZ and rod strains across different constructs ($p = 0.05$).

Results: Local lordosis correction with ACR ($24.7 \pm 3.7^\circ$) and PSO ($25.1 \pm 3.9^\circ$) was similar. A standalone hyperlordotic cage demonstrated a relatively-highly increase of median RoM compared to the intact condition (FE: +418%, LB: +179%, AR: +351%). NZ data were found to be proportional to RoM. Bilateral fixation significantly reduced the RoM (FE: 31%, LB: 2%, AR: 18%), providing a stability consistent with PSO constructs ($p > 0.05$); however, it demonstrates significantly higher rod strains compared to PSO constructs with lateral accessory rods (4 rods) and interbody cages in FE and AR ($p < 0.05$), while being comparable in FE or slightly higher in AR compared to PSO constructs with 2 and 3 rods ($p > 0.05$).

Discussion: The usage of a standalone hyperlordotic cage should be avoided for safety reasons to prevent excessive instability. Bilateral posterior fixation is highly recommended following ACR to provide adequate primary stability; however, primary-rod strains are comparable or higher than weak PSO constructs often associated with frequent rod-failure in the literature [Hyun et al. 2014, Spine 39(22):1899–1904; Smith et al. 2017, J Neurosurg Spine 27(4):444–457; ISSG et al. 2015, Spine J 15:154S–155S], therefore caution is recommended.

Sarcopenia affecting low back pain in patients with lumbar spinal stenosis

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Introduction: Patients with LSS have a higher prevalence of sarcopenia than healthy older adults. However, the clinical features of sarcopenia in patients with LSS have been poorly studied. The purpose of this study was to identify factors associated with sarcopenia in patients with LSS using multimodal assessments.

Methods: This cross-sectional study, which was conducted at the Spine Care Center, Wakayama Medical University Kihoku Hospital, from September 2017 to August 2018, enrolled patients presenting with symptoms of neurogenic claudication caused by magnetic resonance imaging-confirmed LSS. Muscle mass was measured using bioelectrical impedance using the InBody S10 (BioSpace, Seoul, Korea). We collected data in regard to hand grip strength, 5-m gait speed, a numerical rating scale (NRS) of low back pain, leg pain and numbness, the 36-item Short-Form Survey (SF-36), the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), bone mineral density (BMD) and radiographic measurements (sagittal vertical axis, thoracic kyphosis, lumbar lordosis, pelvic tilt [PT], pelvic incidence [PI], sacral slope, % slip, and number of vertebral fractures). Sarcopenia was defined according to the guidelines of the Asian Working Group for Sarcopenia (hand grip strength < 26 kg for men and < 18 kg for women and/or gait speed < 0.8 m/s and skeletal muscle mass index [SMI] < 7.0 kg/m² for men and < 5.7 kg/m² for women). Patients were classified into sarcopenia and non-sarcopenia groups. P-values < 0.05 were considered significant.

Results: In total, 178 patients (average age: 75.8y; 77 men, 101 women) were enrolled, 35 of whom (average age: 78.9 y; 11 men, 24 women) were classified into the sarcopenia group and 143 (average age: 72.6 y; 66 men, 77 women) into the non-sarcopenia group. The prevalence of sarcopenia was 19.7%. The average age and % slip of patients in the sarcopenia group were significantly higher than those in the non-sarcopenia group ($P < 0.05$). Height, body mass index (BMI), BMD of the lumbar spine and the femoral neck, physical function as assessed by the SF-36 and gait disturbance as assessed by the JOABPEQ were significantly lower in the sarcopenia than those in the non-sarcopenia group ($P < 0.05$). A trend was observed toward differences between groups in back pain as assessed by the NRS, PI, PT and PI-LL ($P < 0.1$). Significant correlations were observed between sarcopenia and age ($r = 0.32$), height ($r = -0.32$), BMI ($r = -0.30$), lumbar spine BMD ($r = -0.27$), femoral neck BMD ($r = -0.34$), % slip ($r = 0.31$) ($p < 0.05$). A trend was observed toward correlations between sarcopenia and PT ($r = 0.21$) and PI-LL ($r = 0.22$) ($p < 0.1$). In the logistic-regression analysis, significant association were seen between sarcopenia and %slip (odds ratio 1.15, 95% CI 1.01-1.30).

Discussion: Patients with LSS and sarcopenia had higher age and degree of slippage, lower height, BMI, BMD, and physical function than those without sarcopenia and reported more severe low back pain. Sarcopenia in patients with LSS is not only associated physical function but also might exacerbate low back pain.

810 nm low level laser therapy down-regulate the activation and secretion of astrocyte by altering the polarization of macrophage

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Introduction: After spinal cord injury (SCI), macrophages infiltrate the injured area and polarize into M1 macrophages, which promote the activation and proliferation of astrocytes, which secrete extracellular matrix and form glial scar that inhibit regeneration of axon and repair of SCI. The previous study of the research group found that 810nm low level laser therapy (LLLT) can significantly improve the motor function of SCI rats, inhibit the secretion of inflammatory factors, reduce the number of M1 macrophages in the injured area, promote axonal regeneration. However, the effect of LLLT on activation and secretion of astrocytes in SCI is still unknown. Furthermore, whether this effect is related to macrophage phenotypic changes is also unclear. The purpose of this experiment was to investigate the effects of LLLT on astrocytes and the possible relationship with macrophages.

Methods: A standardized bilateral spinal cord compression model and an adoptive astrocyte culture model were used to study the effect of LLLT on astrocytes in vivo and in vitro, respectively. In vivo experiment, mice were randomly assigned to surgery group (SCI) group and surgery + laser therapy (LLLT) group. In vitro experiments, the cultured primary astrocyte were divided into 5 groups as the following: control group (ctrl, no specific management), M1 group (cultured with conditioned medium from M1 macrophage induced by LPS + IFN- γ), M1+L group (cultured with conditioned medium from M1 macrophage and irradiated with low level laser), L-M1 group (cultured with conditioned medium from irradiated M1 macrophage), L-M1+L group (cultured with conditioned medium from irradiated M1 macrophage and irradiated with low level laser). The expression of inflammatory factors and CSPGs core proteins (neurocan, NG2, brevican) was measured with immunofluorescence staining, RT-qPCR, Western blotting, CCK8.

Results: In vivo experiments showed that, compared with the SCI group, the expression of astrocyte markers GFAP and CSPGs of the LLLT group decreased in the spinal cord injury area, and the expression of M1 macrophage marker iNOS decreased. In vitro, LLLT significantly inhibited the expression of iNOS of M1 macrophage. In M1+L group, laser irradiation significantly inhibited the expression of astrocyte marker GFAP, decreased astrocytes proliferation, and reduced expression of neurocan, NG2, IL-1 β and TNF- α , compared with astrocytes which cultured with M1 macrophage conditioned media (M1 group). There was no significant statistical difference in the mRNA and protein expression of brevican. Moreover, the down regulation effect of astrocytes proliferation, inhibitory extracellular matrix CSPGs expression and inflammatory response was enlarged in L-M1 and L-M1+L group when compared with M1+L group.

Discussion: LLLT can significantly inhibit the activation of astrocytes after SCI and reduce the production of CSPGs, IL-1 β and TNF- α . However, compared with the direct irradiation of LLLT, the indirect inhibitory effect on astrocytes is more pronounced by changing the polarization phenotype of macrophages.

The Relationship between Degree of Scoliosis and Body Composition In Adolescent Idiopathic Scoliosis

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Introduction: Gene involvement is strongly suggested in adolescent idiopathic scoliosis (AIS). In terms of epigenetic factors, AIS is common in thin girls. Although low bone density has been reported, there are few reports on body composition, particularly muscle mass. The DEXA method is used for measuring bone and muscle mass, but there is radiation exposure. Body composition measurement using highly-versatile bioelectrical impedance analysis (BIA) can determine muscle mass and estimate bone mass. Muscle mass as measured by BIA has been reported to correlate strongly with results using the highly-invasive DEXA method. The purpose of this study is to measure body composition including muscle mass and estimated bone mass of AIS patients using the BIA method, and to clarify the relationship between degree of scoliosis and body composition.

Methods: Subjects were 157 girls (mean age 14.2 years, range 11-18 years) whose body composition was evaluated using BIA (Tanita MC-780). We abstracted the following variables: 1 - Body composition - including BMI, percent body fat, corrected lean muscle mass (muscle mass/height²), and estimated bone mass - was determined by age and compared with previous reports. 2 - We divided 114 subjects whose bone maturation we considered complete (Risser stage 5 or Risser stage 4 plus 2 years after menarche) into 3 groups for comparison of body composition metrics: those with Cobb angle between 10-20 degrees (mild scoliosis), those with Cobb angle between 20-40 degrees (moderate scoliosis), for whom brace therapy is considered, and those with Cobb angle 40 or more degrees (advanced scoliosis), for whom surgical correction is considered.

Results: 1 - Age-adjusted weight, BMI, percent body fat, and muscle mass were lower for all groups in all ages compared to means for the Japanese population. Additionally, increase with growth was poor for muscle mass and estimated bone mass. 2 - BMI, muscle mass, and estimated bone mass had significantly lower values in the advanced scoliosis group compared to the moderate scoliosis group ($p < 0.05$).

Discussion: Based on the results of this study, AIS patients are thinner, with lower BMI, percent body fat, and muscle mass compared to healthy girls the same age. Furthermore, growth of muscle mass and estimated bone mass was poor. It has been reported that 27 to 65 percent of AIS patients have osteopenia or osteoporosis. Estimated bone loss using the BIA method may be a useful method for screening for such bone loss in AIS patients. Furthermore, factors such as low BMI, low muscle mass, and low estimated bone mass are often considered when evaluating risk for surgery. There is a possibility that these factors may be involved in the degree of scoliosis. This study is a small cross-sectional study. Although we cannot establish the relationship between cause and effect here, there are currently no evidence-based options for treatment of AIS outside of brace therapy and surgery. Interventions based on new aims such as muscle training and improvement of nutritional status may be effective.

A Role for Toll-Like Receptors in Degenerating Scoliotic Facet Joints

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Introduction: Adolescent idiopathic scoliosis (AIS) is a poorly understood progressive curvature of the spine. The 3-dimensional spinal deformation brings abnormal biomechanical stresses on the load-bearing organs. We have recently reported for the first time the presence of facet joint cartilage degeneration comparable to age-related osteoarthritis in scoliotic adolescents. To better understand the degenerative mechanisms and explore new therapeutic possibilities, we focused on Toll-like receptors (TLRs) which are pattern recognition receptors that can recognize pathogens and endogenous proteins such as fragmented extracellular matrix components (alarmins) present in intervertebral discs (IVD) and articular cartilage. Once activated, they trigger a molecular cascade that produces pro-inflammatory cytokines, proteases and neurotrophins which can lead to matrix catabolism, inflammation and potentially pain. These mechanisms have however not been studied in the context of AIS or facet joints.

Methods: Facet joints of AIS patients undergoing corrective surgery and of cadaveric donors (non-scoliotic) were collected from consenting patients or organ donors with ethical approval. Cartilage biopsies and chondrocytes were isolated using 3mm biopsy punches and collagenase type 2 digestion respectively. qPCR was used to assess gene expression of the degenerative factors (MMP3, MMP13, IL-1 β , IL-6, IL-8). The biopsies were cut into two equal halves; one was treated for 4 days with a TLR2 agonist (Pam2CSK4, Invivogen) in serum-free chondrocyte media while the other one was cultured in media alone. MMP3, MMP13, IL-6 and IL-8 ELISAs and DMMB assays were performed on the biopsy cultured media. The *ex vivo* cartilage was then fixed, cryosectioned and also stained with SafraninO-Fast Green dyes.

Results: Baseline gene expression levels of TLR1,-2,-4,-6 were all upregulated in scoliotic chondrocytes compared to non-scoliotic. Pearson correlation analysis revealed that all TLR1,-2,-4,-6 gene expression correlated strongly and significantly with degenerative markers (MMP3, MMP13, IL-6, IL-8) in scoliotic chondrocytes but not in non-scoliotic. (Figure 1) When monolayer facet joint chondrocytes were activated with Pam2CSK4, there was a significant upregulation in previously described degenerative markers, TLR2 and NGF, a potent neurotrophin. These findings were strengthened by protein secretion analysis of select markers such as MMP-3, -13, IL-6 and IL-8 which were all upregulated after TLR2 activation. The scoliotic biopsies which were treated with Pam2CSK4 had a significant loss of proteoglycan content as shown by histology, was reflected in the proteoglycan content found in the media by DMMB.

Discussion: The fact that TLRs gene expression levels were upregulated and correlated with proteases and pro-inflammatory cytokines in degenerating scoliotic cartilage suggests that they are promoting cartilage degradation, especially considering the lack of correlations in non-scoliotic healthy cartilage. Furthermore, when TLRs are activated by Pam2CSK4 it triggers the release of the same proteases and pro-inflammatory cytokines in our *ex vivo* experiment. All this exacerbates the loss of proteoglycan in the cartilage *ex vivo* model after four days of insult with a TLR2 specific agonist. These results suggest that TLRs are an important pathway partaking in the cartilage degeneration of scoliotic facet joints and potentially all cartilage beyond our scope. Future studies aim at blocking TLRs to alleviate proteolysis and inflammation.

The pelvic incidence value is inversely correlated with the true acetabular anteversion angle value

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Mawatari¹

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Introduction: The importance of evaluating the sagittal spino-pelvic alignment (SSPA) has been recognized in treatment planning for total hip arthroplasty (THA). Acetabular anteversion angle (AAA) is measured on computed tomography (CT). Apparent AAA is a positional parameter influenced by pelvic tilt (PT) and true AAA is an anatomical parameter measured in PT=0°. Lazennec et al. advocated a concept of spine users and hip users: spine users have a high pelvic incidence (PI) and lumbar lordosis (LL) in order to mainly move their spine, which results in low true AAA; hip users have low PI and LL values in order to mainly move their hips, which results in high AAA. The purpose of the present study is to investigate relationship between PI and true AAA.

Methods: We performed a retrospective study of 110 HOA females who received pelvic CT and pelvic radiographs on anteroposterior view in the supine / standing position and lateral view in the standing position. Firstly, PI (anatomic), PT (standing), and apparent AAA (supine) were measured from CT and radiographs on lateral view. Generally speaking, SSPA (standing) and apparent AAA (supine) are measured in different posture. A positional change from the supine to standing position results in pelvic retroversion as well as a high apparent AAA. Secondly, PT (supine) was calculated from PT (standing). The pelvic inclination angle (PIA) in the supine and standing position were measured from anteroposterior pelvic radiographs in the supine and standing position. The change in the PIA from the supine to the standing position (Δ PIA) were measured. $PT(\text{supine}) = PT(\text{standing}) - \Delta$ PIA. Thirdly, true AAA (anatomic) was calculated from apparent AAA (supine) and PT (supine). Apparent AAA increases 1° for every 2° increase of PT according to Lazennec, et al., so true AAA (anatomic) = apparent AAA (supine) - PT (supine)/2. Fourthly, the relationship between true AAA (anatomic) and PI (anatomic) were investigated. The patients were classified into categories defined by Lazennec et al. according to the PI as follows: PI<40 (n=44), 40<PI<65 (n=56), and PI>65 (n=10) and we investigated the true AAA. A one-way analysis of variance with post hoc tests were performed. Pearson correlation coefficient is used to measure the strength of a linear association between PI and true AAA. P values of <0.05 were considered to indicate statistical significance.

Results: The true AAA was $16.8 \pm 12.6^\circ$ in PI<40, $5.7 \pm 12.5^\circ$ in 40<PI<65, and $4.4 \pm 15.8^\circ$ PI>65 (P<0.05). True AAA in PI<40 was larger than in 40<PI<65 (P<0.05). There were negative correlations between the PI and true AAA ($r = -0.411$, P<0.05).

Discussion The main finding of the present study was that patients who have a small PI value have a large true AAA value and vice versa, which is equal to the assumptions and hypotheses of Lazennec et al. Some reports confirm that PI is related to a pelvic compensation ability and AAA is related to a range of hip joint motion, so spine users have abilities of a large pelvic compensation and a small range of hip joint motion.

Estimation of a Density-Elastic Modulus Equation for Improved Vertebral Fracture Risk Prediction

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Introduction: Quantitative computed tomography-based finite element analysis (QCT/FEA) is a popular tool used for fracture risk prediction. Vertebral coupon experimental testing and linear regression analysis have been previously performed to relate compressive elastic modulus and density measured using computed tomography. However, this process does not include the whole vertebral body, endplates, cortical bone, and other important characteristics of vertebrae. The aim of this study was to develop an optimum density-elastic modulus equation, incorporating the whole vertebral body and accounting for all variables used during finite element modeling for fracture risk prediction.

Methods: Nine (9) human cadaveric torsos were obtained and 54 thoracic and lumbar single vertebral bodies were dissected. The vertebra were CT-scanned using a clinical protocol and a calibration phantom was used to convert Hounsfield units to equivalent bone mineral density (BMD; ρ_{ash}). The vertebrae were then experimentally compressed to obtain stiffness and failure loads. 3D finite element models were developed for each specimen by segmenting the bone, applying boundary conditions mimicking the experiment and assigning material properties.

Each model was imported into ANSYS and QCT/FEA predicted stiffness outcomes were determined. A widely used power law material model equation was used to relate density-elastic modulus with two unknown coefficients ($E = a \times \rho_{ash}^b$). All 54 vertebrae were used simultaneously to find optimized values for the two unknowns **a** and **b**. An objective function in the form of the root mean square (RMS) was defined between experimentally measured stiffness (K_i) and QCT/FEA-estimated stiffness (K_{ii}) values as $J = \sqrt{\sum_{i=1}^n (K_i - K_{ii})^2}$, where **n** is the number of vertebrae used in the optimization process. Iteratively, the constants (**a** and **b**) in the elastic modulus equation implemented in the QCT/FEA models were changed using the Nelder-Mead simplex optimization algorithm, leading to an optimal match between the QCT/FEA-estimated stiffness values and those measured experimentally. Post-optimization, vertebral failure loads were then evaluated using a pre-defined failure criterion equation ($\epsilon = 0.01 \times \rho_{ash}^{0.5}$). Coefficients of determination with respect to $Y=X$ were calculated for the optimized stiffness and fracture load predictions, and the experimental outcomes.

Results: The optimization processes was successfully developed and the coefficients **a** and **b** were determined ($E = 970 \times \rho_{ash}^{0.84}$). Linear regression analysis between experimental outcomes and QCT/FEA optimized stiffness and fracture loads were $R^2=0.5$ and $R^2=0.4$, respectively.

Discussion: Using an inverse QCT/FEA approach on 54 vertebrae an optimum density-elastic modulus equation was obtained based on the experimentally-measured stiffness. This optimum stiffness equation was based on a routinely used clinical CT protocol and the entire vertebral body. Using the optimized stiffness equation and the pre-defined failure criterion, 40% of the variance in the experimentally measured fracture loads could be explained. Future studies will optimize the failure criterion to improve the predictive power of the process.

Biomechanical stability of pedicle versus cortical screws in the lumbar spine

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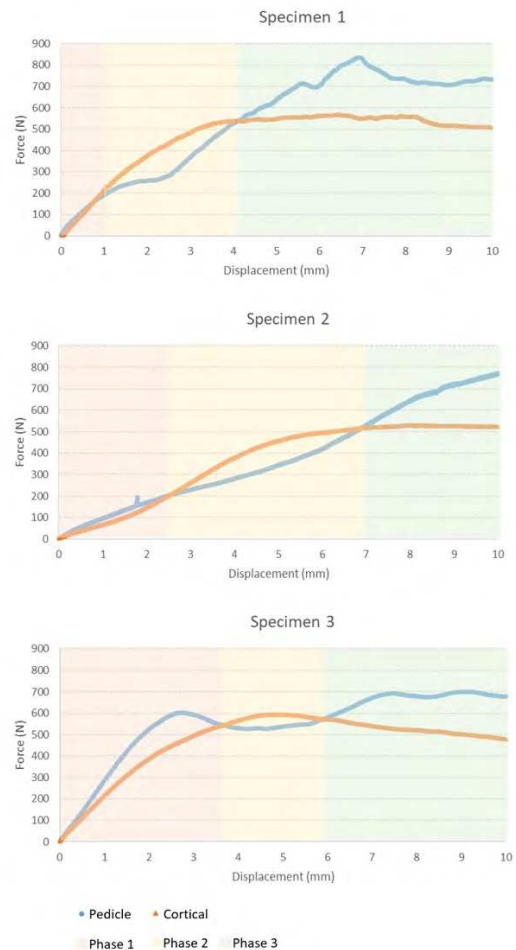
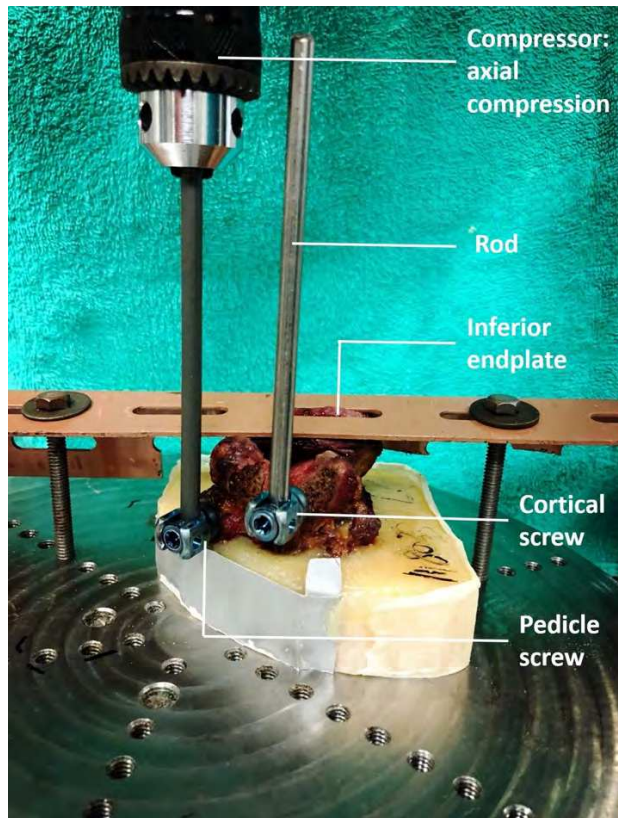
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Introduction: For posterior lumbar spine fusion, instrumentation is usually performed with pedicle screws (PS). However, there is a trend for minimally invasive techniques such as cortical screws (CS) to reduce the degree of muscle dissection needed. Previous cadaveric biomechanical cyclic testing of the stability of PS and CS has reported that CS required an increased force to cause the same amount of displacement as PS on the same specimen. However, implant failure complications in CS is not low (8.9%). Furthermore, the load failure mechanisms of PS and CS remain unclear. Thus, this study aims to investigate the load failure mechanisms of PS and CS and compare the stability of these two fixation methods.

Method: Three vertebral cadaveric specimens (two L4 and one L5) from an aged group (>65yrs) were collected and prepared by removing all associated muscles and ligaments. For each specimen, a PS (diameter:5.5mm; length:40mm) and a CS (diameter:5.5mm; length:35mm) was inserted. Each screw underwent displacement controlled (10mm) vertical loading. The force-displacement curve features were compared between these two fixation methods.

Results: For all specimens, it was found that vertical loading of the screws induced no cut out of the screws. The comparative trend of the force-displacement curves between PS and CS generated from three specimens were consistent and for each of the specimen, three phases of force-displacement behavior featuring different PS and CS stabilities were discovered. During the initial phase (with the displacement of the screws on specimen 1: <1mm displacement; specimen 2: <2.5mm displacement; specimen 3: <3.5mm displacement), the forces required to migrate the PS were larger than the forces required to migrate the CS. However, a snap-through buckling effect was discovered at the second phase of the force-displacement curves (with the displacement of the screws on specimen 1: 1-4mm; specimen 2: 2.5-7mm displacement; specimen 3: 3.5-6 mm displacement) whereas CS demanded larger forces to cause the same amount of displacement as PS. Interestingly, at the third phase (with the displacement of the screws on specimen 1: >4mm; specimen 2: >7mm displacement; specimen 3: >6 mm displacement), while the CS did not require increased force to cause increased displacement, PS demanded increasing force.

Discussion: A three-phases-force-displacement behavior was discovered when comparing PS and CS, with PS being more stable at phase 1 and phase 3 and the CS performing superiorly at phase 2. Under loading, the overall performance of CS is predictable, but PS fails faster than CS until the stable point is reached. This phenomenon is possibly associated with the material complexity surrounding PS including both cortical and trabecular bone, whereas for CS the surrounding material is mainly cortical bone. In conclusion, under large displacement, PS can withstand increased force than CS.



Length of Fusion is a Significant Risk Factor In Development of Adjacent Disc Disease in a normal and osteoporotic Lumbar Spine : A Finite Element Study

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Introduction : Fusion in the form of posterior spinal instrumentation causes loss of motion at the fused segment requiring adjacent segments to compensate this loss of motion causing adjacent segment disease (ASD). In this study with a help of finite element model of a lumbar spine, we tested the hypothesis that a longer fusion, would increase the likelihood of ASD.

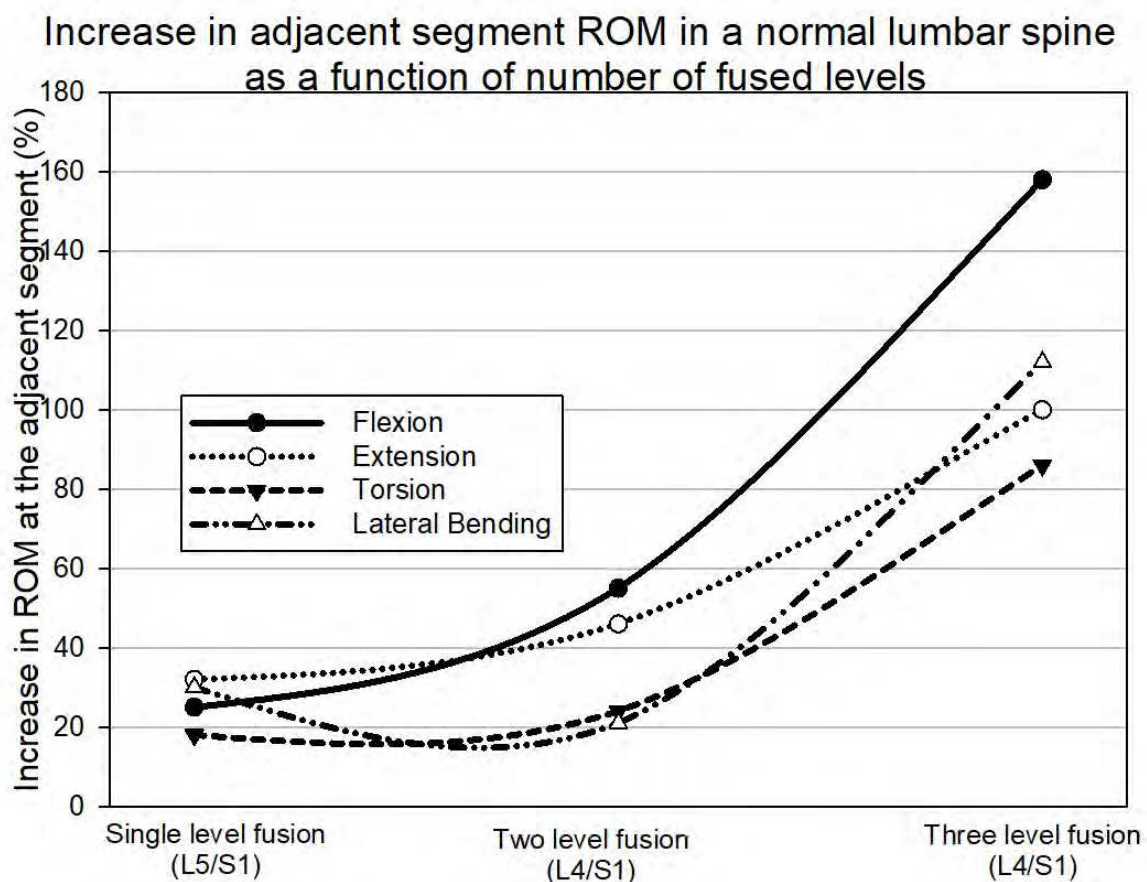
Materials and Methods: A non-linear 3D finite element model of a normal lumbar spine (L1-S1) was modified to simulate an osteoporotic spine. In both normal and osteoporotic spines three different posterior instrumented fixation systems were modeled: the Ti screw-rod system (5 mm) covered either L5-S1 or L4-S1 or L3-S1 levels. The moments applied along the three physiological directions to the un-instrumented spine were modified and applied to the instrumented spine such that L1-S1 motion is the same in both the instrumented and in the un-instrumented lumbar spine. Outcome measures were range of motion (RoM) and intradiscal stress.

Results: Range of motion: The current analyses showed a non-linear increase in adjacent segment motions in both normal and osteoporotic spine as the number of fused levels increased. For example, in a normal spine adjacent segment flexion motion increased by 25%, 55% and 158% as the length of fusion extended from L5/S1 to L4/S1 and to L3/S1 respectively. Increase in adjacent segment motions showed similar trend and magnitudes in the osteoporotic spine as well.

Intra-discal stress: Changes in intradiscal stresses due to fusion were observed both at the fused as well as at the level adjacent to the fused segment under all loading modes. For example, under flexion motion, fusion at L5/S1 increased nucleus stress at the adjacent segment nominally from 0.22 MPa to 0.23 MPa, while a much larger increase in nucleus stress was observed (0.22 MPa to 0.37 MPa) at the adjacent segment when the fusion extended up to level L3. At the fused segment, nucleus stresses reduced as much as 98% while at the segment adjacent to fused segment they increased by as much as 100% to 200%.

Similar trend and values were once again observed in the osteoporotic spine as well.

Conclusions: Lower lumbar level fusion produced about 20% increase in motion at the segment adjacent to the fused level and these results support Rohlmann et al., (1) who predicted about 10% to 20% increase at the adjacent level after single level spinal fusion. The conclusion reached by both Gillet (2) who showed that the number of patients with ASD nearly doubled when the length of segments fused increased from 1 to 3 or 4 and by Cheh et al., (3) who also observed fusion up to L3 increased the risk of ASD when compared with L4 and L5 agreed with our findings that extending the fusion up to level L3 did significantly increase the adjacent segment motions (about 100%) as well as increased nucleus stresses (about 150%). The hypothesis that a longer fusion would increase the likelihood of ASD in both normal and osteoporotic spine was validated.



1. References: (1) Rohlmann et al., E.Spine J, 16:2007; (2) Gillet et al., J.Spinal Disord Tech, 16:2003; (3) Cheh et al., SPINE, 32, 2007.

Associations between accumulated Advanced Glycation End-products, revealed by skin autofluorescence, and chronic low back pain

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Introduction: The aim of this study was to determine whether advanced glycation end products (AGEs) revealed by skin autofluorescence (SAF) can serve as a biomarker for chronic low back pain.

Methods: The participants were 111 patients who came to our hospital, dividing into chronic low back pain group (C group : 48 persons, average age 52.2) and without low back pain group (N group : 63 persons, average age 40.8).

SAF was measured as a parameter of AGEs with an autofluorescence reader. Measurements of low back pain visual analog scale (VAS), presence of diabetes, and SAF were recorded, and correlations between VAS, diabetes and SAF was investigated.

Results: C group had significantly higher SAF than N group ($P < 0.05$), and SAF of diabetes case were significantly higher than without diabetes ($P < 0.05$). SAF had no correlation with VAS ($P = 0.18$)

Discussion: This study shows that SAF as accumulation of AGEs correlates with chronic low back pain and diabetes, can serve as a biomarker for chronic low back pain.

On the other hand, because we found no correlation between SAF and low back pain VAS, the dynamics of SAF and AGEs appear to be unrelated with the severity of low back pain.

Paravertebral muscles metabolism changes with age in agreement with EMG particularly at L4-5, less at higher levels: a Near Infrared Spectroscopy (NIRS) evaluation

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Introduction: The metabolic changes that occur over time in paravertebral muscles are not yet well-characterized. The aim of this study was to test a non-invasive method for the evaluation of the paravertebral lumbar muscles since there is evidence of a correlation between highly fatigable back muscles and chronic low back pain.¹

Methods: We recruited a convenience sample of 37 healthy subjects (18-80 yrs) (20 males and 17 females), to have at least 5 participants per age group (15 below 30, 5 aged 30-49, 7 aged 50-59, and 5 aged 60-69 and 70-79). All patients reported no episodes of back pain in the last 5 years. The Biering Sorensen Muscle Test (BSME) was used to cause fatigue: it was repeated three times, to limit adaptation while allowing muscle warm-up. Muscular metabolism of paravertebral muscles was studied checking blood deoxygenation using Near Infrared Spectroscopy (NIRS)² at the L2-3, L3-4 and L4-5 levels. According to the literature, we used the only reliable phase of the hemoglobin deoxygenated curve (HHb) that is the rapid one, corresponding to the growth of oxygen consumption before reaching a fully aerobic steady state. We compared all parameters among groups and searched correlations with age, weight, height and BMI. Muscle contraction was studied with surface EMG, particularly Slope Coefficient of Mean Frequency (MNF) was used to analyze EMG Data.

Results: We did not find any difference in the results for the examined levels, even if L2-3 showed to be the most reliable (82% of evaluable curves versus L4=76% and L5=71%). We did not find any difference for sex or side neither for NIRS nor for EMG. While EMG slope decreased with age, at the L4-5 level the NIRS angle of slope decreased and in men the time to reach plateau increased. We found a direct correlation between EMG and NIRS slope only, but after averaging the two sides. EMG slope was also directly correlated with height, but only in males. We did not find correlations with weight and BMI.

Discussion: With age the growth of EMG signals decreases, and consensually the time to reach an aerobic steady state increases, while the angle of the growth phase consequently decreases. A correlation between metabolic and electromyographic activity has already been demonstrated in low back pain patients, but using a dynamic test and with older, less reliable instruments³. Even if the phenomena are clearly physiologically linked, there are other factors to be understood that could play a role (like vascularization, oxygen consumption capacity, etc.)⁴. While L3 is the most used level for NIRS studies, we found correlations only with L4-5 level, where the analysis of rapid phase of the hemoglobin deoxygenated (HHb) was correlated with age, but not to anthropometric parameters.

1. Russo, M. et al. Muscle Control and Non-specific Chronic Low Back Pain. *Neuromodulation J. Int. Neuromodulation Soc.* 21, 1–9(2018)
2. Ferrari, M. et al. The use of near-infrared spectroscopy in understanding skeletal muscle physiology: recent developments. *Philos. Transact. A Math. Phys. Eng. Sci.* 369, 4577–4590(2011)
3. Kovacs, KM. et al. Localized oxygen use of healthy and low back pain individuals during controlled trunk movements. *J Spinal Disord.* Apr;14(2):150-8 (2001)
4. Kalichman, L. et al. The Association between Imaging Parameters of the Paraspinal Muscles, Spinal Degeneration, and Low Back Pain. *BioMed Res. Int.* 2017, (2017)

Thoracic kyphosis and pelvic anteversion increases during walking in patients with adult spinal deformity: analyses of dynamic alignment change with three-dimensional gait motion analysis system

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Introduction: Global spinal alignment (GSA) measured by standing whole-spine radiograph is widely used as the evaluation of adult spinal deformity (ASD). However, we often encounter patients with symptoms and posture deteriorate while walking, suggesting that pathology of ASD includes a dynamic factor as a result of deformity. The purpose of this study was to elucidate dynamic alignment change while walking in patients with adult spinal deformity using a three-dimensional gait analysis system.

Methods: We analyzed dynamic spinal alignment change of 20 patients (3 men, 17 women) during walking with ASD by using a three-dimensional (3D) motion analysis system (VICON). The mean values of radiologic characteristics were as follows: C7SVA 142 mm, TK22°, LL 1.8°, PT 38°, PI 48°. We calculated dynamic spinal alignment parameters defined as follows: SVA and CVA were the sagittal and coronal distance between two reflective markers, SA and CA were the sagittal and coronal angle between the line connecting two reflective markers and the vertical line. PSA was the sagittal angle between the line from ASIS to PSIS and the horizontal line. Spinal levels were defined as follows: thoracic spine (T) was defined as the level between the two reflective markers on the C7 and T12 spinous processes, similarly, lumbar spine (L): between markers on the T12 and L1 spinous processes. Additionally, we evaluated the dynamic sagittal parameters of trunk tilt considering pelvic angle (T-P SA, L-P SA), which was defined as the sagittal angle between the line connecting the reflective markers on each spinal process and the line connecting ASIS and PSIS. The patients were asked to continue walking on an oval course on flat floor as long as possible, 15 minutes maximum. The dynamic parameters were evaluated using data from the initial and the final straight walking. A Wilcoxon signed-rank was used to evaluate differences between the initial and final walking. Statistical differences with $P < 0.05$ were considered significant.

Results: The mean of dynamic spinal alignment changes (initial walking/final walking) were as follows: T-SVA 154/173 mm, L-SVA 24/30 mm, T-CVA 11/12 mm, L-CVA 8.3/7.9 mm, T-SA 34/39°, L-SA 9.7/12°, T-CA 3.3/3.5°, L-CA 3.8/3.9°, PSA 3.2/5.2°, T-P SA 31/36°, L-P SA 6.4/6.8°. As a result, T-SVA, T-SA, L-SVA, L-SA, PSA, T-P SA significantly increased while walking ($P < 0.05$).

Discussion: The present analysis found only the sagittal dynamic parameters significantly increased while walking. However, coronal dynamic parameters did not significant change. Previous studies have reported the importance of sagittal spino-pelvic parameters. Sagittal balance is also important from the results of this dynamic evaluation using 3D gait analysis. As a result of dynamic change of trunk tilt considering pelvic tilt, anteversion of only thoracic segment significantly increased ($p < 0.05$), while anteversion of lumbar segment did not significant change. Accordingly, thoracic kyphosis and pelvic anteversion deteriorated while walking, suggesting the breakdown of compensation. Our three-dimensional gait motion analysis shows potential utility for quantitatively detecting the dynamic deterioration of ASD.

Sagittal spinal malalignment is a risk factor of positional pelvic retroversion

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Introduction: Pelvic tilt (PT) is important to decide the cup orientation in total hip arthroplasty (THA). Some reports confirm that acetabular cup anteversion and cup inclination in THA increase 7° and 3° because of 10° increasing of PT. Large pelvic retroversion from supine position to standing position is a risk factor of dislocation after THA and sagittal pelvic kinematics is often evaluated before THA. However, in hip osteoarthritis (HOA) patients, the risk factors of large pelvic retroversion are controversial. The purpose of the present study is to clarify the sagittal spinopelvic alignment (SSPA) of patients who have large pelvic retroversion from supine position to standing position.

Methods: We performed a retrospective comparative cohort study of 365 primary HOA females who received pelvic radiographs; anteroposterior view in the supine position, anteroposterior view in the standing position, and lateral view in the standing position. The average age of the patients was 69.1 ± 6.7 years old. The pelvic inclination angle (PIA) in the supine position and standing position were measured from anteroposterior pelvic radiographs in the supine position and standing position. The change in the PIA from the supine to the standing position (Δ PIA) were measured using anteroposterior pelvic radiographs in the supine position and standing position. The patients were classified into Δ PIA $\leq 10^\circ$ group (n=337) and Δ PIA $>10^\circ$ group (n=28). We investigated age, body mass index (BMI), pelvic incidence (PI), lumbar lordosis (LL : L1-S1), PT, The Japanese Orthopaedic Association (JOA) hip pain score, and vertebral compression fracture. JOA hip pain score ≥ 20 and JOP hip pain score ≤ 10 were regarded as without pain and with pain. The levels of the SRS-Schwab classification modifiers were used to investigate the degree of sagittal malalignment; PI-LL $> 20^\circ$ or PT $> 30^\circ$. The statistical analyses used as the univariate analysis were the unpaired T test or the Mann-Whitney U test after the normality test for continuous variables and the Chi-squared test for categorical variables. The statistical analysis used as the multivariate analysis was Logistic regression by using Δ PIA $>10^\circ$ as the dependent variable and the variables with a significant difference in the univariate analysis as the independent variables. P values < 0.05 were considered to indicate significance.

Results: The univariate analysis showed age, PI-LL $>20^\circ$, PT $> 30^\circ$, and vertebral compression fracture had significant effect on Δ PIA $>10^\circ$. The independent factors predicting Δ PIA $>10^\circ$ were PI-LL $> 20^\circ$ (odds ratio [OR]=4.0, P=0.009) and PT $> 30^\circ$ (OR = 5.5, P=0.001).

Discussion Patients with over 10° pelvic retroversion from the supine position to standing position had PI-LL $>20^\circ$ or PT $> 30^\circ$. It was clarified that the patients with sagittal malalignment keep standing positional balance by pelvic retroversion in standing position. Pelvic radiographs in the supine position and standing position are important in the patients with sagittal malalignment before THA.

Exploring the anthropometric parameters for improving reliability of estimation model of pelvic incidence

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Introduction: Increasing attention has been focused on the correlation between pelvic incidence (PI) and predisposition to low back pain (LBP) (Figure 1). Estimation of the angle of individual's PI without using X-rays would provide tailor - made preventive measures for LBP. Our previous research revealed a surrogate appearance angle (x_1) on the body correlating with PI (Figure 2). As for the estimation of PI, a multiple regression model accounting for the surrogate angle (x_1) and BMI indicated moderate reliability with 0.62 of adjusted R-square value indicating goodness-of-fit of the model. However little has been investigated about other surrogate anthropometric parameters improving the reliability of the estimation model. The current study aimed to explore possible covariates on anthropometric parameters for improving the reliability of the estimation model.

Methods: Fifty patients (26 males, 24 females, age: 63.5 ± 14.0 yrs., height: 158.9 ± 9.8 cm, weight: 58.5 ± 12.5 kg, and BMI: 22.9 ± 3.1 kg/m²) with cervical spondylotic myelopathy and lumbar spinal stenosis at Nagoya City West Medical Center were evaluated. A marker was attached (Figure 3) onto the right side of the participants and they were photographed from the side at a distance of 3 m using a digital camera. Image J software was used to assess the obtained image. Anthropometric parameters taken as covariates included x_2 : BMI, x_3 : slope of the anterior and posterior superior iliac spines (ASIS and PSIS), x_4 : the angle formed by the line connecting the malleolus and acromion to the vertical line, the thickness of the body, x_5 : height of the umbilicus, x_6 : height of the upper margin of the greater trochanter, x_7 : distance between the ASIS and PSIS, and x_8 : x_5/x_6 ratio (waist/hip). Multiple regression analysis with stepwise entering all covariates into equation was performed.

Results: Table 1 showed the standardized partial regression coefficients and R-square values of each model. All of the crude R square values had a tendency to slightly increase with the number of covariates, while the adjusted R squared values reached peak in Model 4 (Adj R²=0.653) before the decline of following models. Most of standardized β on each covariate indicated relatively low compared to that on the surrogate angle (x_1).

Discussion: One of the main findings was that possible covariates on anthropometric parameters except the surrogate angle (x_1) and BMI did not contribute to the improving of the reliability of the estimation model. These results suggest that even if PI does not change with posture, even if the subject is a patient, the positional relationship between the silhouette of the body and other body landmarks are affected by compensatory postural changes due to spinal diseases. On the other hand, it should be remarkable for the stable characteristics of surrogate appearance angle (x_1) in light of coefficient beta in each model. In future, we aim to devise a tool that can more easily analyze the PI angle using the surrogate appearance angle measurements, and apply it in public health and clinical practices.

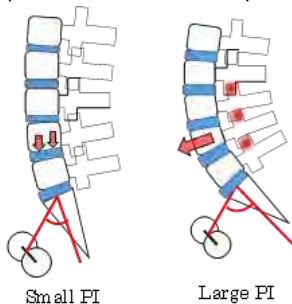


Figure 1: Difference in mechanical stress to lumbar vertebrae depending on the value of PI (Jentzsch T, et al., 2013)

Small PI : Stress to the facetjoint < Stress to the Disk (↓ ↓)
 Large PI : Increase stress to the facetjoint (↑) and involved in spondylolisthesis (↓)

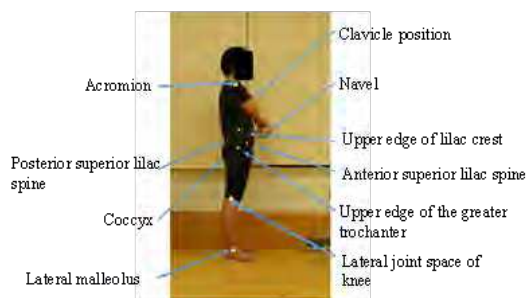


Figure 3: Marker placement and standing posture



x_1 : Angle between the line connecting the upper edge of the greater trochanter and upper edge of the iliac crest (Line A) and the line connecting the upper edge of the iliac crest and the buttock at the same height as the greater trochanter (Line B)

Figure 2 : Three types of measures for surrogate appearance angles correlating with PI

	Crude R-square	Adjusted R-square	Standardized partial regression coefficient (beta) of covariates entering into equation									
			x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8		
Model11(Crude)	0.614	0.606	0.78									
Model12	0.645	0.629	0.78	-0.17								
Model13	0.654	0.631	0.75	-0.17	-0.10							
Model14	0.681	0.653	0.75	-0.15	-0.04	-0.17						
Model15	0.681	0.645	0.73	-0.19	-0.04	-0.18	0.04					
Model16	0.684	0.640	0.74	-0.15	-0.04	-0.18	0.06	-0.08				
Model17	0.685	0.632	0.75	-0.13	-0.04	-0.19	0.06	-0.06	-0.04			
Model18	0.69	0.630	0.74	-0.12	-0.04	-0.18	-0.78	0.7	-0.06	0.65		

x_2 : BMI, x_3 : slope of the anterior and posterior superior iliac spines (ASIS and PSIS), x_4 : the angle formed by the line connecting the malleolus and acromion to the vertical line, the thickness of the body, x_5 : height of the umbilicus, x_6 : height of the upper margin of the greater trochanter, x_7 : distance between the ASIS and PSIS, x_8 : x_5/x_6 ratio (waist/hip), VIF: Variance Inflation Factor

Biomechanical advantages of multi-rods and interbody cages for the stabilization of pedicle subtraction osteotomy: an in vitro study

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Introduction: Pedicle subtraction osteotomy (PSO) is a challenging surgical technique with high potential for sagittal correction and long-term fusion. Although being effective for a variety of clinical indications, frequent post-operative complications have been reported in the literature due to rod breakage (16–39%) and pseudarthrosis (rate 12–31%). Several strategies based on multi-rods constructs and interbody spacers have been proposed in the clinical practice, but a clear understanding of the basic biomechanics behind PSO fixation is still missing. The aim of the study is, therefore, to investigate the effect of accessory, satellite rods and interbody cages on the primary stability and rod strains for PSO fixation in sagittal spinal deformities correction.

Methods: Seven human cadaveric spine segments (T12-S1) underwent PSO at L4 with posterior fixation from L2 to S1 (target lordosis of 70°). Six alternative fixation constructs, often used in the literature [Luca 2014, *Eur Spine J* 23(6):610–615; Hyun 2015, *Spine (Phila Pa 1976)* 40(7):E428–E432; Watanabe 2008, *Spine (Phila Pa 1976)* 33(10):1149–1155], were considered. Simple bilateral fixation (2 rods), addition of a central rod with laminar hooks (3 rods) and supplementation with lateral accessory rods (4 rods) were tested before and after the implantation of titanium interbody cages adjacent to the PSO level. Pure moments (± 7.5 Nm) in vitro flexibility tests were performed in flexion-extension (FE), lateral bending (LB) and axial rotation (AR) to determine the range of motion (RoM) and the neutral zone (NZ), while measuring the maximum strains acting on the primary rods with strain transducers. A nonparametric Friedman test followed by post-hoc Bonferroni correction was used to highlight statistically significant differences in terms of RoM, NZ and rod strains across the constructs ($p = 0.05$).

Results: All constructs had comparable effects in reducing spine kinematics (RoM) compared to the intact condition (-94% in FE and LB; -80% in AR). The NZ resulted to be proportional to RoM values. The multi-rod construct with lateral accessory rods (4 rods) coupled to cages was the most effective strategy in minimizing primary rod strains ($p \leq 0.005$; -50% in FE, -42% in AR, and -11% in LB), being effective even without cages ($p \leq 0.009$; -26%, -37%, -9%). The addition of a central satellite rod independently anchored with laminar hooks (3 rods) effectively reduced rod strains only in FE and in combination with cages ($p \leq 0.005$; -30%).

Discussion: The results support the usage of a 4-rods construct based on accessory rods combined with cages adjacent to the PSO site. Although less effective, the usage of accessory rods (4 rods) without cages and of a central satellite rod with hooks (3 rods) in combination with interbody spacers may offer some relative advantages over a simple bilateral fixation. The study provides a strong biomechanical rationale to interpret the failures met in the recent literature [Smith 2017, *J Neurosurg Spine* 27(4):444–457; ISSG 2015, *Spine J* 15:154S–155S; Hyun 2014, *Spine* 39(22):1899–1904]. Moreover, it contributes towards the optimization of the best fixation technique in the setting of PSO for sagittal deformity corrections.

The classification of lumbopelvic sagittal alignment based on the difference between standing and sitting position

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Introduction: Spinal sagittal alignment was mainly analyzed in the standing position and few studies analyzed subjects in the sitting position. The evaluation of lumbopelvic sagittal alignment at sitting and standing position is helpful to consider the lumbopelvic movement. Lumbopelvic sagittal alignment was affected by pelvic incidence (PI), and the PI affected the compensatory capacity of lumbopelvic sagittal alignment. The purpose of this study was to classify the changes in lumbopelvic sagittal alignment between the standing and sitting positions, and to study its association with PI.

Materials and Methods: This study included 361 subjects (221 men and 140 women; age 55.4 ± 7.4 years). The subjects were divided into three groups (younger age group (YG), from 20 to 49 years old; middle age group (MG), from 50 to 69 years old, and older age group (OG), of 70-years old and above). The following radiographic parameters were obtained by computer assisted measurement: lumbar lordotic angle (LL), sacral slope (SS), pelvic tilt (PT), and pelvic incidence (PI). Then, the associations between the changes in LL (ΔLL), SS (ΔSS), PT (ΔPT), and PI were analyzed.

Results: In all three groups, LL and SS in the sitting position was smaller and PT in the sitting position was larger than those in the standing position. The median value of ΔPT was 10° . In the YG, the amount of change in LL, SS and PT was larger than OG. These parameters correlated with age in the standing position but not in the sitting position. On the other hand, in all groups, there were positive correlations between PI and changes between the standing and sitting positions. Multiple logistic regression analysis demonstrated that $\Delta LL = 3.81 - 0.72 \times PT + 0.52 \times PI$, $\Delta SS = -4.50 - 5.3 \times PT + 0.34 \times PI$, and $\Delta PT = -9.1 + 3.5 \times PT - 0.21 \times PI$. The cut off value of $\Delta PT 10^\circ$ regarding PI and PT were 40° and 20° respectively.

Discussion: Change in lumbopelvic parameters between the sitting and standing positions correlated with PI and PT, but not directly with age. The type of change was classified into three types; type 1; increased PT, type 2a no changed PT with large PT, type 2b; no changed PT with small PI. Type 1 should be cared about lumbopelvic movement after lumbopelvic operation.

Gait features for discriminating between mobility-limiting musculoskeletal disorders: lumbar spinal stenosis and knee osteoarthritis

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Introduction: Functional limitations with ambulation are the hallmark of two prevalent musculoskeletal disorders: lumbar spinal stenosis and knee osteoarthritis. New technology is bestowing clinicians and researchers with the ability to better differentiate between such disease pathologies using gait parameters. In particular, the evaluation of gait parameters in a patient's natural environment as opposed to a clinical setting allows increased insight into authentic barriers to function, thus lending to more disease-specific and personalized therapies. These measurements can be captured in real time with a smartphone accelerometer, allowing for broad and inexpensive distribution and accessibility of clinical measurements outside of the clinic. Currently there are a number of clinical tests used to evaluate gait, including 40 meter Fast-Paced Walk Test (40mFPWT), 6-minute Walk Test (6MWT) and Self-Paced Walk Test (SPWT). Due to the innovative nature of this technology and its applications, it is not known which gait parameters best distinguish between disease populations, nor which of the clinical tests provides greater insight into the gait patterns and functional limitations of people with mobility limitations. The goal of this study was to 1) determine which gait features are most sensitive to distinguish between disease groups and 2) determine which functional test resulted in the identification of the greatest number of significant gait features that distinguish between disease groups.

Methods: We collected multi-site inertial measurement (IMU) data during three walking tests for subjects with lumbar spinal stenosis, knee osteoarthritis and matched controls. Walking tests included 40mFPWT, 6MWT, and SPWT. Analyses performed include: Feature selection, test with Loess regression and non-parametric ANOVA.

Results: There were a number of gait parameters that clearly differentiated between disease populations and controls, as well as between different disease populations. The strongest feature for differentiating between groups was median stance time. Other features that were able to differentiate between conditions across all three walking tests included: mean cycle duration, cadence, double support %, gait speed, and toe clearance (min/max). In terms of the walking test, the greatest number of differentiating parameters were uncovered from the SPWT.

Discussion: This data clearly demonstrates that gait parameters, measured using a simple IMU (equivalent to the hardware in a smartphone) can clearly differentiate between knee osteoarthritis, lumbar spinal stenosis and control subjects. The SPWT produced the greatest number of differentiating features, indicating that a longer walking test (beyond 40 meters or 6 minutes) may be necessary to discern the true functional barriers in diseased populations. Smartphone applications that collect gait parameters could be utilized to collect real-time functional information about patients that improves diagnostic and treatment precision.

AVERAGE GAIT SPATIO-TEMPORAL SIGNATURES			
Features	6MWT	40mTest	SPWT
Test Time		+	+++
Gait Time		+	+++
Number of Cycles Total	+	+	+++
Number of Straight Cycles	+	+	+++
Number of Turn Cycles	+		+++
Cycle Duration (mean)	+++	+++	+++
Cycle Duration (iqr)	+++	+	+
Cadence (median)	+++	+++	+++
Stance (median)	+++	+++	+++
Swing (median)		+++	+++
% Loading (iqr)		+++	+++
% Foot Flat (mean)		+++	+++
% Foot Flat (median)	+++		
% Pushing (median)	+++		+++
% Double Support (median)	+++	+++	+++
Strike Length (mean)		+++	+++
Strike Length (median)	+++	+	+
Gait Speed (median)	+++	+++	+++
Angular Velocity (mean)			+++
Angular Velocity (median)	+++	+++	
Heel Strike Angle (median)	+++	+	+
Lift off Angle (mean)	+	+++	+++
Lift off Angle (median)	+++	+	+
Min Toe Clearance (iqr)	+++	+++	+++
Max Toe Clearance (iqr)	+++	+++	+++

A pilot study of forward bending, lateral flexion and axial rotation of the spine in healthy subjects

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Introduction: The actual Gold Standard for spine assessment are X-rays, even if they just give a static view of the spine. Currently there are no accurate methods to thoroughly assess spine mobility in clinical practice: this is normally evaluated by physicians and therapists only observationally, and sometimes with a total Range of Motion (ROM) measurement. Through optoelectronic systems it's possible to have an objective dynamic analysis of the spine during movement. The data collected would allow a measure for an objective and standard assessment of the spine^{1,2}. The aim of this study was to explore the forward bending (FB), lateral bending (LB) and axial rotation (AR) of the spine using a complete protocol only focused on the spine, in order to understand the movement patterns in healthy subjects.

Methods: The research was conducted on a sample of 37 subjects (28 males and 9 female), aged 23 ± 2.12 after the approval by the local ethical committee, subjects have participated following acceptance of informed consent. The experimental protocol required eight optoelectronic cameras and the positioning of 32 markers on PSIS, ASIS and on selected vertebrae: C7, T3, T7, T12, L1, L2, L3, L4, L5 and S2 (Figure 1). Three markers were applied on each vertebra: one on the spinous process and the other two over the right and left transverse processes (except for S2)³. The subjects performed FB, LB and AR both sides at least three times at a non-imposed speed from standing to the maximum joint excursion, and back.

Results: The series of graphs (Figure 2) of each subject have been examined and provides us qualitative and quantitative information (symmetry, slope and mobility) about the movement patterns. FB graphs are symmetrical and have fluid curves. Increased ROM during the functional tests was observed. It is highlighted the motor's learning and muscular fatigue phenomenon, through the analysis of the anticipatory postural adjustments (APAs). The series of graphs of LB and AR show asymmetry between the right and left movements, in which there is a dominant side with a greater ROM. From the graphs of AR, it is also possible to recognize the vertebral alignment on the sagittal plan, discern the position of the vertebrae in space, differentiating the most from the less prominent.

Discussion: The optoelectronic system was able to provide information not only on the amplitude but also on the quality of the spine movements. Through the results of this study, we can trace a motion profile of each subject, and group the strategies adopted by participants to carry out the required movements.

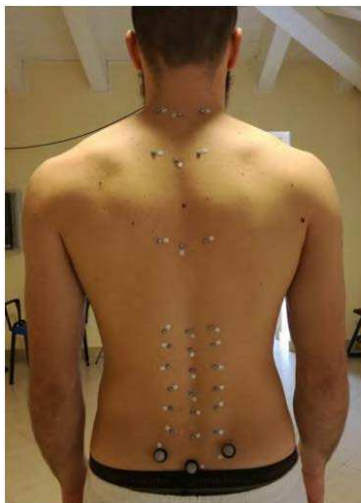


Figure 1 : Markers setting

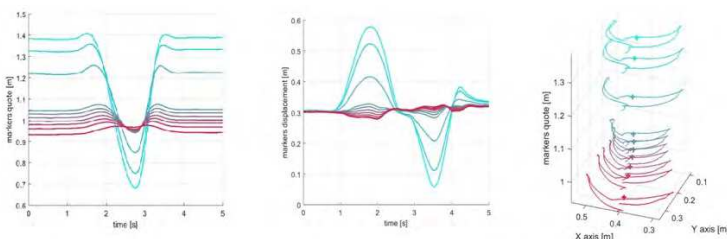


Figure 2: Graphical representation of Forward bending, Lateral bending, Axial rotation of spine.

1. Don, R. et al, Instrumental measures of spinal function: is it worth? A state-of-the art from a clinical perspective. Eur. J. Phys. Rehabil. Med. 2012 April;48(2):255-73
2. Negrini, S. et al, Trunk motion analysis: a systematic review from a clinical and methodological perspective. Eur. J. Phys. Rehabil. Med. 2016 Aug;52(4):583-92.
3. Barbara, P. et al. Functional assessment of the spine through an optoelectronic system. Gait & Posture. Volume 57, Supplement 1, September 2017, Pages 347-348

Three-dimensional assessment of the lumbar spine motion in vivo using the EOS stereography system : intra- and inter- observer reproducibility study

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Introduction: The EOS biplanar stereoradiography is an innovative imaging technology which allows simultaneous acquisition of two orthogonal images in order to be able to build a 3D virtual reconstruction of the whole skeleton in functional posture. The purpose of this study was to investigate the reproducibility of the mobilities angles for the lumbar spine using EOS.

Methods: 15 healthy volunteers were asked to perform maximal motion of the lumbar spine in flexion extension, axial torsion and lateral bending using a specific protocol on an ergonomic chair. Two independent observers did the image analysis twice (60 reconstructions, 240 registrations, 1500 vertebrae). Segmental and global angular mobilities of the lumbar spine have been measured. The inter-observer reproducibility were evaluated by the calculation of the variance of reproducibility.

Results: The segmental motilities in flexion ranged from 3.7° to 9.2° with a maximum of 2.2° for inter-observer reproducibility. The segmental motilities in extension ranged from 4.0° to 9.4° with a maximum of 1.8° for inter-observer reproducibility. The segmental motilities in axial torsion ranged from 2.9° to 6.0° with a maximum of 2.4° for inter-observer reproducibility. The segmental motilities in lateral bending ranged from 1.3° to 2.8° with a maximum of 3.6° for inter-observer reproducibility.

Conclusions: For each of the segmental mobility, the inter-observer reproducibility was close to the physiological values. However, this reproducibility is accurate to analyze the global mobility of the lumbar spine (L1S1) for the pure posture.

Biomechanical comparison of degenerative spondylolisthesis models between L4-L5 and L5-S1 segments

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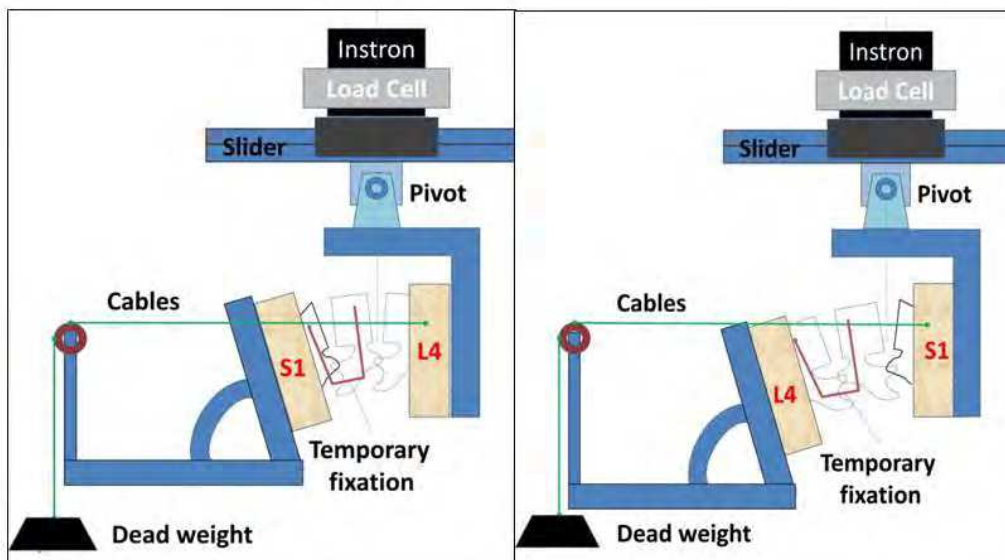
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Introduction: The biomechanical model of lumbar segmental degenerative spondylolisthesis has been established. Currently, there are no reports on the establishment of L5-S1 segmental and multi-segmental shearing models. The objective of the present study was to compare segmental shear characteristics at status of intact and simulated progressive spondylolisthesis between L4-L5 and L5-S1.

Methods: Eight fresh human lumbosacral vertebra specimens (L4-S1) were selected and placed on a self-made 3-DOF spinal shearing fixture after being embedded with the dental stone. The material testing machine applied the pure shear force of -50N ~250N to the disc of L4-L5 and L5-S1 respectively. At the same time, 300N follower compressive force was applied to the L4-S1 segment through cable and dead weight system to simulate the lumbosacral vertebral axial weight bearing. One segment bears the shear force while the other segment is temporarily fixed by a posterior pedicle screw-rod fixation. The measurements included status of intact and following bilateral facet joint resection and discectomy. The NDI motion measurement system was used to measure the movement of the infrared markers attached to each vertebra. the shear model was evaluated with the forward shear displacement of the segment and the shear stiffness.

Results: The shear displacement of the L4-L5 and L5-S1 segments was 0.5 ± 0.3 mm and 0.2 ± 0.1 mm in the condition of intact, respectively, and 1.4 ± 0.4 mm and 1.2 ± 0.5 mm in the condition of discectomy, respectively ($P < 0.05$). The shear stiffness of L4-L5 and L5-S1 segments was 633 ± 381 N/mm and 1092 ± 264 N/mm in the condition of intact, respectively, and there were significant differences between the two segments ($P=0.045$). The bilateral facetectomy decreased the shear stiffness of L4-L5 and L5-S1 segments to 255 ± 99 N/mm and 767 ± 573 N/mm, respectively, and there was no significant difference between the two segments ($P=0.084$). The discectomy further reduced the shear stiffness of the two segments to 193 ± 57 N/mm and 266 ± 191 N/mm, and there was no significant difference between the two segments ($P=0.316$).

Discussion: The present study suggests that the ability of L5-S1 segment to resist spondylolisthesis is stronger than that of L4-L5 segment, and the bilateral facet joints bear more shear loads in L5-S1 segment than L4-L5 segment. The first-degree degenerative spondylolisthesis biomechanical model can be established following facetectomy and discectomy either in the L4-L5 or the L5-S1 segment.



Sestrins inhibits stress-induced intervertebral disc degradation by enhancing autophagy

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Introduction: Intervertebral disc degeneration (IDD) is the primary cause of low back pain, and compromised stress defense may mediate this pathological process. The Sestrins (Sesn) promote cell survival under stress conditions and regulate AMP-activated protein kinase (AMPK) and mammalian target of rapamycin (mTOR) signaling. The aims of present study were to investigate the expression of Sesn in normal and degraded NP cells and its potential roles during IDD pathogenesis.

Method: By using PCR, western blot, and immunohistochemistry, we detected the Sesn expression in human normal and degraded NP cells respectively. To assess the function, Sesn expression in NP cells was downregulated by siRNA and overexpression by plasmid transfection. The cell apoptosis, extracellular matrix degeneration (ECM) degradation, autophagy, and AMPK and mTOR activation were next analyzed.

Results: The expression of Sesn were significantly reduced in degraded NP cells in DNA level, western blot and immunohistochemistry of human degraded NP cells also showed a corresponding reduction in protein levels. In human cultured NP cells, the expression of Sesn1, 2 and 3 increased after stimulated by 2-DG, a ER stress inducer. We also testified that 2-DG can increase cell apoptosis, promote ECM degradation and positively regulate autophagy. Sesn knockdown by siRNA increased NP cells apoptosis and ECM degradation under basal culture conditions and in the presence of 2DG. Sesn overexpression repressed IDD by enhancing autophagy, and this was related to changes in mTOR but not AMPK activation.

Discussion: These findings are the first to show that Sesn expression is suppressed in degraded NP cells. Sesn were first discovered as p53 targets. During the past decade, Sestrins have gradually been identified as modulators of peroxide signaling and antioxidant defense, and thought to be potential therapeutic targets for variety of diseases. Our data demonstrated that Sesn expression in NP cells is induced by stress inducer, which can induce cell apoptosis and ECM degradation. Knockdown of Sesn in stress-induced NP cells significantly increases cell apoptosis and ECM degradation. These results show that Sesn undertake an essential cellular protective function in NP cells. We also clarify the mechanism of Sesn protecting stress-induced NP cells. Our present data shows that Sesn repress stress-induced IDD by enhancing autophagy activation, which is modulated by mTOR activity. This process, unlike traditional way, is not relayed on AMPK phosphorylation. Sesn can function as guanine nucleotide dissociation inhibitors for Rag GTPases or interaction with GATOR2 to control mTORC1 signaling. The present study has the following limitations. In our study, the transfection efficiency in human NP cells is too low to achieve sufficient overexpression of proteins using plasmids. And there still needs relevant animal experiments for mimicking the actual IDD process and further in vitro and in vivo studies on the potential effect of Sesn on IDD are warranted.

Significance ER stress can induce IDD by promoting cell apoptosis and ECM degradation. Sesn can modulate mTOR activity and repress stress-induced IDD by enhancing autophagy activation. Suppression of Sesn might be an important cellular dysfunction mechanism in the process of IDD.

Simvastatin Inhibits IL-1 β -Induced Apoptosis and Extracellular Matrix Degradation by Suppressing the NF- κ B and MAPK Pathways in Nucleus Pulposus Cells.

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Statins are widely used hypocholesterolemic drugs that block the mevalonate pathway. Some studies have shown that statins may have the potential to inhibit intervertebral disk (IVD) degeneration (IDD). Interleukin (IL)-1 β , a catabolic cytokine, is a key regulator of IDD. This study aimed to investigate the mechanism underlying the effect of simvastatin on IDD. The viability of nucleus pulposus (NP) cells was determined by the methyl-thiazolyl-tetrazolium (MTT) assay. The apoptosis of NP cells was measured by flow cytometric analysis, terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL), and western blotting of relevant apoptotic proteins. The protein levels of catabolic factors and anabolic factors were determined by western blotting. The cells were stimulated with IL-1 β in the absence or presence of simvastatin to investigate the effects on matrix metalloproteinase (MMP)-3, MMP-13, a disintegrin and metalloproteinase with thrombospondin motifs (ADAMTS)-4, ADAMTS-5, type II collagen, and aggrecan expression. Our findings indicate that simvastatin considerably inhibited IL-1 β -induced apoptosis in NP cells. We also found that simvastatin attenuated IL-1 β -induced expression and MMP-3, MMP-13, ADAMTS-4, and ADAMTS-5 activities and also reduced the decrease in type II collagen and aggrecan expression. In addition, simvastatin considerably suppressed the nuclear translocation and activation of nuclear factor-kappa B (NF- κ B) by inhibiting p65 phosphorylation and translocation and blocking inhibitor κ B- α degradation. It also inhibited MAPK pathway activation by blocking c-Jun N-terminal kinase (JNK), p38, and ERK phosphorylation. The results of our study revealed that simvastatin is a potential agent for IDD prevention and treatment.