Background: Surgical site infection in the spine is a serious postoperative complication. Factors such as posterior surgical approach, arthrodesis, use of spinal instrumentation, age, obesity, diabetes, tobacco use, operating-room environment, and estimated blood loss are well established in the literature to affect the risk of infection. The goal of this study was to analyze and identify independent risk factors for surgical site infection among spine patients undergoing posterior lumbar instrumented arthrodesis.

Methods: The medical records of 3218 patients who underwent posterior lumbar instrumented arthrodesis from January 2000 to December 2006 were reviewed to identify those who developed a postoperative infection (eighty-four patients; 2.6%). The size of this single-institution patient group allowed construction of a multivariate logistic regression model to evaluate the independent associations of potential risk factors for surgical site infection in the spine.

Results: In the final regression model, obesity, estimated intraoperative blood loss, ten or more people in the operating room, a dural tear, history of diabetes, chronic obstructive pulmonary disease, coronary heart disease, and osteoporosis were critical risk factors for the onset of spinal surgical site infection. Obesity and a history of chronic obstructive pulmonary disease were the strongest risk factors for postoperative spinal infection after adjusting for all other variables. The most common pathogen was methicillin-resistant Staphylococcus aureus with a prevalence of 34.5%. This study established a single institution infection rate for posterior lumbar instrumented arthrodesis at 2.6%.

Conclusions: This analysis confirms previously demonstrated risk factors for postoperative infection while reporting on new potential independent risk factors of osteoporosis, chronic obstructive pulmonary disease, and dural tears in the setting of posterior lumbar instrumented arthrodesis. Areas of new research can focus on the roles these novel factors may play in the pathogenesis of surgical site infections in the spine.

Level of Evidence: Prognostic Level II. See Instructions to Authors for a complete description of levels of evidence.

Surgical site infection is one of the most serious complications that can occur in the early postoperative period following surgical procedures. Postoperative spine infections can negatively impact clinical outcomes, require operative debridement and subsequent revision procedures, may induce chronic pain or deformity, require additional hospitalization time, and incur additional treatment costs.

In the most recent National Nosocomial Infections Surveillance (NNIS) report, the infection rate following spinal arthrodesis was cited as 2.1% in 2004, a decrease from the rate of 2.4% cited in the previous report, published in 1993. Individual institutions have conducted various case-control and retrospective cohort studies in the past ten years, and the rate of infection following all spinal operations reported in those studies ranged from 1.9% to 4.4%.

Risk factors have been separated into two main categories: patient-related and procedure-related factors. Established patient-related risk factors associated with postoperative infections include advanced age, obesity, previous spinal operation, hyperglycemia, diabetes, malnutrition, tobacco use, and...
corticosteroid use. Additionally, various authors have documented risk factors for infection that relate to the operating-room environment, including the use of spinal instrumentation, posterior surgical approach, tumor resection, multilevel surgical arthrodesis involving the sacrum, and prolonged duration of the surgical procedure. Many of these studies have been limited by a small sample size, which has restricted their investigation to a few potential risk factors, and most lack the power to perform a multivariate analysis.

Our goal was to conduct a large retrospective case-control study and multivariate analysis to assess previously identified risk factors as well as to report novel risk factors for infection in patients undergoing posterior lumbar arthrodesis with instrumentation.

Materials and Methods

Study Design

Institutional review board approval was obtained for this study. The medical records of patients who underwent posterior instrumented lumbar or lumbosacral arthrodesis from January 2000 to December 2006 were reviewed to identify those who developed a postoperative surgical site infection. Records were located by International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure codes. The code most commonly used was 81.08 (spinal fusion – lumbar or lumbosacral fusion, posterior technique) from January 2000 to December 2006. All surgical procedures were performed by an orthopaedic spine surgeon on 3218 patients from eighteen to ninety-nine years of age. Exclusion criteria included patients who on admission had the ICD-9-CM diagnosis code for intraspinal abscess (324.1), surgical site infection (998.5, 998.51, and 998.59), or osteomyelitis (730.08, 730.18, and 730.28). Any patient with a revision spinal surgical procedure (<5% of the total number of lumbar spinal fusions) was excluded if suspicion of infection existed or if the primary procedure was performed at an outside institution. Any documentation by a physician suggestive of current infection at the time of initial admission was an exclusion criterion.

We used ICD-9-CM codes to identify surgical site infections within the group of 3218 patients who fit the inclusion criteria for our study. The ICD-9-CM codes that were used were intraspinal abscess (324.1), surgical site infection (998.5, 998.51, and 998.59), or osteomyelitis (730.08, 730.18, and 730.28). Any patient with a revision spinal surgical procedure (<5%) of the total number of lumbar spinal fusions) was excluded if suspicion of infection existed or if the primary procedure was performed at an outside institution. Any documentation by a physician suggestive of current infection at the time of initial admission was an exclusion criterion.

Infection Control

Patients at our institution are treated according to published CDC/NNIS guidelines for preventing surgical site infections. With the dose based on the patient’s weight, 1 to 2 g of cefazolin, a first-generation cephalosporin, is administered within one hour prior to the skin incision. During the first twenty-four hours following wound closure, surgical patients are treated with a prophylactic antibiotic regimen per this protocol.

Data Collection

Investigators collected data including patient demographics, operating-room number, date of procedure, specific type of procedure, spinal levels fused, and symptoms due to surgical site infection from the patients’ medical records. These data were then confirmed by using the infection surveillance software system (AIICE Millennium; Austin, Texas) utilized at our institution and the database from the spinal surgeons at our institution to verify the type of operative procedure, number of spinal levels fused, and other confounding information. A standardized data collection sheet was then created for use in obtaining the following: patient’s sex, medical comorbidities, number of operating-room personnel present, spinal implant manufacturer, perioperative data with laboratory values, and microbiological information (for the infected group). These data underwent extensive logic checks by other coinvestigators to identify illogical or impossible data. All illogical data were repeatedly reviewed by comparing both the medical and electronic patient records.

Data Analysis

Biostatisticians at our institution completed statistical analysis of the collected data. Statistical analysis of the case-control data consisted of a descriptive evaluation with use of means and standard deviations for continuous variables and frequencies and percentages for discrete variables. All potential risk factors were evaluated for a univariate association with spine infection, with use of independent-samples t tests for continuous variables and chi-square or Fisher exact tests for categorical or discrete variables. Unadjusted odds ratios and 95% confidence intervals (CI) were calculated and presented for discrete variables. A multivariate logistic regression was then used to evaluate the independent associations of each potential explanatory variable. All variables that had been previously identified in the literature, those with clinical and/or biologic plausibility, and those with a univariate p value of ≤ 0.20 were considered eligible for inclusion in the model. With use of a forward, stepwise procedure, variables that achieved a p value of < 0.15 remained in the final model, with significant variables defined as those that achieved a p value of ≤ 0.05. Adjusted odds ratios and their respective 95% confidence intervals were reported in the final model.

Source of Funding

Medical Indemnity Assurance Company, the internal infection control committee at our institution, the Hospital for Special Surgery, provided funding for this study.

Results

Patient-Related Factors

The overall rate of infection following posterior lumbar arthrodesis with instrumentation during the five-year period of the study was 2.61% (eighty-four infections in 3218 operations). The patient-related factors that were investigated are shown in Table 1. According to the univariate analysis, advanced age was associated with postoperative spinal infection, and within the groups the mean age was 61.0 years for the patients with an infection and 56.9 years for the control group (p = 0.036). Also in the univariate analysis, female sex was a significant risk factor for developing a surgical site infection, as 66% of the infection group was female (p = 0.048). Investigation of obesity and other comorbidities, such as diabetes mellitus (either Type 1 or 2), hypertension, hypercholesterolemia, coronary heart disease, chronic obstructive pulmonary
disease, obstructive sleep apnea, congestive heart failure, history of tobacco use, rheumatoid arthritis, and osteoporosis, determined that obesity (defined as a body-mass index of \( \geq 30 \text{ kg/m}^2 \)) was most strongly associated with a surgical site infection (odds ratio, 9.75; 95% CI: 4.70 to 20.21; \( p < 0.001 \)). Coronary heart disease was also identified as a risk factor for surgical site infection (odds ratio, 5.35; 95% CI: 2.57 to 11.10; \( p < 0.001 \)). The presence of three or more of these comorbidities was a risk factor in our study population (odds ratio, 10.81; 95% CI: 4.63 to 25.27; \( p < 0.001 \)).

**Procedure-Related Factors**

The result of univariate analysis of procedure-related risk factors is displayed in Table II. Factors analyzed included the number of surgeons, number of scrub technicians, number of nurses, number of residents and/or fellows, total number of persons in the operating room, duration of surgery, number of drains used in the procedures, and estimated blood loss. Revision spinal surgery procedures were noted. The use of crystalloid, packed red-blood cells, and autologous blood transfusion were evaluated for association with postoperative infection.

A greater number of people in the operating room during the surgical procedure was identified as a risk factor for infection (\( p < 0.001 \)), and specifically the number of nurses was significantly higher in the infected group than the control group (\( p < 0.001 \)). A longer duration of surgery and higher estimated blood loss were associated with surgical site infection (\( p < 0.001 \) for both). Similarly, the administration of packed red-blood cells and crystalloid were risk factors for postoperative infection (\( p = 0.004 \) and \( p = 0.001 \), respectively). Strongly associated procedure-related factors in the univariate analysis also included the amount of time the patient was in the post-anesthesia care unit (\( p < 0.001 \)) and the length of the hospital stay (\( p < 0.001 \)).

**Perioperative Laboratory Data**

Perioperative laboratory values were collected during the study to determine association with postoperative infections and are presented in Table III. Serum glucose, hemoglobin, hematocrit, and lymphocyte counts were collected both preoperatively and postoperatively. Postoperative serum glucose levels were significantly higher in the infected group (\( p < 0.001 \)).

**Multivariate Analysis**

Table IV shows the results of a multivariate logistic regression analysis used to assess the association of risk factors when adjusting for all other potential risk factors. In the final model, obesity (\( p < 0.001 \)), estimated blood loss (\( p = 0.045 \)),
ten or more people in the operating room (p = 0.014), a dural tear (p = 0.024), coronary heart disease (p = 0.020), history of diabetes (p = 0.018), chronic obstructive pulmonary disease (p = 0.013), and osteoporosis (p = 0.010) were critical independent risk factors for the onset of surgical site infection. Obesity (odds ratio, 6.76; 95% CI: 2.91 to 15.71) and a history of chronic obstructive pulmonary disease (odds ratio, 5.61; 95% CI: 1.44 to 21.87) were the strongest risk factors for postoperative surgical site infection after adjusting for all other variables. Likewise, a dural tear (odds ratio, 3.95; 95% CI: 1.20 to 13.01), history of diabetes (odds ratio, 3.20; 95% CI: 1.22 to 8.40), and osteoporosis (odds ratio, 4.30; 95% CI: 1.41 to 13.10) were also important risk factors and were associated with a threefold increased risk for the development of a postoperative surgical site infection. Female sex was significant in the univariate analysis, but did not meet significance in the final logistic regression model.

### Nature of Infections

Culture results are displayed in a table in the Appendix. The most common pathogen was methicillin-resistant *Staphylococcus aureus* with over one-third (34.5%) of the cultures identified as this pathogen. The majority of the infections were monomicrobial.

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**TABLE II Distribution of Procedure-Related Risk Factors for Patients with Surgical Site Infection and Matched Controls**

<table>
<thead>
<tr>
<th>Operative characteristics*</th>
<th>No Surgical Site Infection (N = 168)</th>
<th>Surgical Site Infection Acquired (N = 84)</th>
<th>Odds Ratio (95% Confidence Interval)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of surgeons</td>
<td>1.20 ± 0.47</td>
<td>1.43 ± 0.65</td>
<td>–</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>No. of scrub technicians</td>
<td>2.71 ± 1.26</td>
<td>3.01 ± 1.40</td>
<td>–</td>
<td>0.090</td>
</tr>
<tr>
<td>No. of nurses</td>
<td>3.52 ± 1.73</td>
<td>4.32 ± 1.88</td>
<td>–</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>No. of residents and/or fellows</td>
<td>1.40 ± 0.67</td>
<td>1.54 ± 0.67</td>
<td>–</td>
<td>0.143</td>
</tr>
<tr>
<td>Duration of surgery (min)</td>
<td>291.6 ± 130.7</td>
<td>373.1 ± 167.1</td>
<td>–</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>No. of drains</td>
<td>1.44 ± 0.69</td>
<td>1.48 ± 0.72</td>
<td>–</td>
<td>0.703</td>
</tr>
<tr>
<td>Estimated blood loss (mL)</td>
<td>1104.6 ± 940.0</td>
<td>1894.0 ± 1333.6</td>
<td>–</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Postanesthesia care unit time (hr)</td>
<td>20.16 ± 17.63</td>
<td>36.20 ± 27.57</td>
<td>–</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Duration of antibiotics (hr)</td>
<td>40.60 ± 17.83</td>
<td>51.69 ± 24.73</td>
<td>–</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>6.86 ± 4.33</td>
<td>13.05 ± 7.55</td>
<td>–</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Personnel in operating room</td>
<td>8.84 ± 2.96</td>
<td>10.30 ± 3.26</td>
<td>–</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Total no. of persons*</td>
<td>13 (7.7)</td>
<td>1 (1.2)</td>
<td>(Reference)</td>
<td>0.002†</td>
</tr>
<tr>
<td>1 to 5 persons</td>
<td>118 (70.2)</td>
<td>47 (56.0)</td>
<td>5.18 (0.66, 40.70)</td>
<td></td>
</tr>
<tr>
<td>6 to 10 persons</td>
<td>31 (18.5)</td>
<td>30 (35.7)</td>
<td>12.58 (1.55, 102.2)</td>
<td></td>
</tr>
<tr>
<td>≥16 persons</td>
<td>6 (3.6)</td>
<td>6 (7.1)</td>
<td>13.00 (1.27, 133.3)</td>
<td></td>
</tr>
<tr>
<td>Duration of surgery‡</td>
<td>291.7 ± 130.7</td>
<td>373.1 ± 167.1</td>
<td>–</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>&lt;240 min</td>
<td>78 (46.4)</td>
<td>23 (27.4)</td>
<td>(Reference)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>241 to 360 min</td>
<td>64 (38.1)</td>
<td>27 (32.1)</td>
<td>1.43 (0.75, 2.73)</td>
<td></td>
</tr>
<tr>
<td>361 to 480 min</td>
<td>6 (3.6)</td>
<td>13 (15.5)</td>
<td>7.35 (2.51, 21.5)</td>
<td></td>
</tr>
<tr>
<td>481 to 600 min</td>
<td>14 (8.3)</td>
<td>10 (11.9)</td>
<td>2.42 (0.95, 6.17)</td>
<td></td>
</tr>
<tr>
<td>601 to 720 min</td>
<td>3 (1.8)</td>
<td>8 (9.5)</td>
<td>9.04 (2.22, 36.89)</td>
<td></td>
</tr>
<tr>
<td>≥721 min</td>
<td>3 (1.8)</td>
<td>3 (3.6)</td>
<td>3.39 (0.64, 17.95)</td>
<td></td>
</tr>
<tr>
<td>Ringer lactate‡</td>
<td>139 (82.7)</td>
<td>45 (53.6)</td>
<td>0.24 (0.13, 0.43)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Crystalloid‡</td>
<td>27 (16.1)</td>
<td>30 (35.7)</td>
<td>2.90 (1.58, 5.33)</td>
<td>0.001†</td>
</tr>
<tr>
<td>Packed red-blood cells‡</td>
<td>15 (8.9)</td>
<td>19 (22.6)</td>
<td>2.98 (1.43, 6.23)</td>
<td>0.004‡</td>
</tr>
<tr>
<td>Autologous blood‡</td>
<td>22 (13.1)</td>
<td>18 (21.4)</td>
<td>1.81 (0.91, 3.60)</td>
<td>0.091</td>
</tr>
<tr>
<td>Albumin‡</td>
<td>33 (19.8)</td>
<td>25 (29.8)</td>
<td>1.72 (0.94, 3.15)</td>
<td>0.078</td>
</tr>
<tr>
<td>Cell saver‡</td>
<td>163 (97.6)</td>
<td>81 (96.4)</td>
<td>0.66 (0.15, 3.03)</td>
<td>0.690</td>
</tr>
<tr>
<td>Dural tear‡</td>
<td>9 (5.4)</td>
<td>11 (13.1)</td>
<td>2.66 (1.06, 6.70)</td>
<td>0.038‡</td>
</tr>
<tr>
<td>Revision surgery‡</td>
<td>8 (4.8)</td>
<td>7 (8.3)</td>
<td>1.82 (0.64, 5.20)</td>
<td>0.265</td>
</tr>
</tbody>
</table>

*The values are given as the mean and the standard deviation. †Significant at α = 0.05. ‡The values are given as the number of patients or controls, with the percentage in parentheses.
Postoperative infection is a relatively uncommon complication of spinal procedures, but the surgical site infection rate is greater for longer surgical procedures that involve arthrodesis, posterior surgical approach, and spinal instrumentation. The focus of our study was to further define significant patient-related and procedure-related risk factors that contributed to a higher rate of infection postoperatively and that may be unique to posterior lumbar instrumented arthrodesis.

**Patient-Related Risk Factors**

We identified associations between various previously identified risk factors, including diabetes, obesity, and coronary heart disease, and postoperative wound infection. Diabets and...
obesity were significant independent risk factors identified by our multivariate analysis, a finding consistent with other multivariate analyses performed on general populations of spine surgery patients. It has been demonstrated that diabetes can impede wound-healing and predispose patients to infection through ischemia secondary to microvascular abnormality. Obesity has consistently been reported as a risk factor for postoperative infection following surgery. Thicker layers of adipose tissue can introduce dead space on surgical closure of the wound. These areas may become necrotic with poor vascular perfusion, which can lead to superficial wound infections. An association between obesity and decreased perioperative tissue oxygenation has been suggested, which may be another link between obesity and postoperative infection.

In addition to diabetes and obesity, a history of chronic obstructive pulmonary disease and a history of osteoporosis were significantly associated with postoperative infection in our multivariate analysis (p = 0.013 and p = 0.010, respectively). The pathophysiology of osteoporosis may involve an extensive loss of collagen, including collagen levels in the skin as well as bone. A decrease in skin collagen and its regenerative capacity may explain why a patient with osteoporosis is at increased risk for abnormal wound-healing and, therefore, postoperative infection. A history of chronic obstructive pulmonary disease was an independent risk factor for surgical site infection. This association has been reported after general surgery but has not been noted in spine surgery studies to date, as far as we know. Patients with chronic obstructive pulmonary disease have chronic impairment in tissue oxygenation; therefore, the cellular defenses against microbes that use oxygen to generate radicals could potentially be impaired.

Procedure-Related Risk Factors
Intraoperative risk factors associated with postoperative infection through univariate analysis include the duration of the surgical procedure, number of people in the operating room, occurrence of a dural tear, estimated blood loss, and use of packed red-blood cells for volume replacement. Consistent with previous studies, estimated blood loss remained significantly associated with postoperative infection in the multivariate analysis (odds ratio, 2.58; 95% CI: 1.02 to 6.53; p = 0.045). A dural tear remained significant in the multivariate analysis as an independent risk factor, contrary to previous studies performed at this institution. A dural tear introduces communication between the epidural space and the cerebrospinal fluid, two separate compartments with different consistencies, glucose concentrations, and pressures. In addition to alteration in the surgical site milieu, a dural tear lengthens the operation time and prolongs the length of time for postoperative bed rest. In some cases, a dural tear with a cerebrospinal fluid leak delays epithelialization of the skin wound. This discrepancy could lie in the relatively underpowered nature of the multivariate analysis relative to revision surgeries. There is a higher incidental durotomy rate in revision spine surgery, and three of the eleven durotomy rates in this analysis occurred during revision surgery. While the connection of a dural tear and increased postoperative infection risk makes intuitive sense, this is an area that warrants additional dedicated study. As in previous studies, a high number of people in the operating room was associated with an increased risk of infection. This may be an indirect marker for complex cases in medically fragile patients rather than an intuitive increased opportunity for contamination.

A retrospective case-control study is the most practical way to study the relatively rare occurrence of postoperative infection; however, its use implies certain inherent limitations, such as the ability to assess associated rather than absolute risk. Similarly, the retrospective nature of the study implies the possibility of underestimating infection rates. Additionally, the study did not include an analysis of the spinal levels fused as a risk factor for surgical site infection, but an increased number of fusion levels can be inferred to contribute to increased operative time and therefore associated increased infection risk.

The strengths of the study include the large volume of surgical procedures performed at a single institution, allowing for a large sample and thereby increasing the power of analysis. This study is one of the first with enough power to conduct a multivariate analysis of risk factors to isolate independent variables to better assess their contribution to postoperative infection. This analysis confirms traditionally demonstrated risk factors for infection while identifying new potential independent risk factors in the setting of posterior lumbar instrumented arthrodesis including osteoporosis, chronic obstructive pulmonary disease, and dural tears. Areas for continued study include the role of osteoporosis and wound-healing; chronic obstructive pulmonary disease, tissue oxygenation, and posterior wound-healing in spine surgery; and the role of incidental durotomy, wound-healing, and infection in posterior lumbar spine surgery.

Appendix
A table showing the frequency of bacteria cultures identified in patients with a surgical site infection is available with the online version of this article as a data supplement at jbjs.org.
References


