Lumbar fusion is a relatively common spine procedure, accounting for over 400,000 procedures annually. In addition, there was an approximate 15-fold increase in the number of lumbar instrumentation procedures performed from 2002 to 2007. As the number of spinal fusion procedures increases, the number of complications is also expected to rise. One of these complications is spinal infection. Postoperative spinal infection occurs in approximately 1%–5% of patients undergoing spine surgery. This risk is highest in patients undergoing posterior approaches, lumbar surgery, and of instrumentation-augmented procedures. Patients in whom infections develop typically have worse pain-related outcomes, increased deformity, higher medical costs, and longer hospital stays. The ability to identify patients with the greatest risk of developing postoperative spinal infections may therefore lead to more selective ways of minimizing infection.

Studies on postoperative spinal infections following instrumented lumbar fusion surgery are few and limited (Table 1). These previous studies confound the true incidence of infections for posterior lumbar instrumented fusion because they include patients with different pathological entities such as tumors and trauma, patients who underwent nonlumbar procedures, and patients who did not undergo instrumented fusion.
Therefore, it is difficult to interpret the risk of spinal infection for patients who are undergoing posterior lumbar fusion for degenerative spine disease, which is the most common type of fusion procedure.9,10 The goals of this study were therefore: 1) to ascertain the incidence of postoperative spinal infection among patients undergoing posterior lumbar fusion for degenerative spine disease, and 2) to identify the factors associated with an increased risk of spine infection in this patient population.

Methods

Patient Selection

All adult patients (age > 18 years) who underwent spinal surgery from 1993 to 2010 in the neurosurgery department at a single tertiary care institution were retrospectively identified and data were reviewed from a prospectively collected database by clinicians blinded to patient outcomes. Patients who underwent posterior lumbar instrumented fusion for degenerative spine disease were included. Patients who underwent surgery for trauma, tumor, infection, and/or vascular disorder were excluded. Additionally, patients who underwent cervical and/or thoracic fusions not involving the lumbar spine were not included. Likewise, patients who underwent anterior approaches and/or noninstrumented fusion, including in situ fusion, were excluded. These exclusions were done to create a more uniform population of patients with degenerative spine disease who underwent instrumented posterior lumbar fusion.

Recorded Variables

Eight hundred seventeen consecutive patients met the inclusion criteria. The neurosurgery clinical, operative, and postoperative notes for all patients who met the inclusion criteria were retrospectively reviewed by clini-
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cians. The information collected included patient demographics, comorbidities, previous surgeries, surgical levels, fused levels, decompressed levels, presence of a CSF leak, length of hospital stay, perioperative complications, wound infections, and antibiotic regimen. Severe obesity was defined as a body mass index greater than 35. Lesser degrees of obesity were not routinely recorded. The presence of a wound infection was identified based on postoperative clinical notes, using the CDC definition of infection.23 This was done, instead of using ICD-9 codes, to make sure all infections (both operative and nonoperative) were captured.

General Treatment Strategy

Instrumented fusion was generally pursued for patients with degenerative spine disease when they had clinical and/or radiographic signs of instability or were at risk for iatrogenic instability. Patients typically underwent medical evaluation prior to surgery, which allowed a more comprehensive inclusion of patient comorbidities. Prior to incision, the surgical area was typically cleaned with Betadine or chlorhexidine scrub followed by application of Betadine or chlorhexidine solution. Intravenous antibiotics were typically administered within 30 minutes of skin incision. Cefazolin (2 mg) was typically given, unless the patient had an allergy to penicillin-based drugs, and then clindamycin (500 mg) was given instead; it was then typically given again every 4 hours, and clindamycin every 8 hours. Surgical drains were typically placed and were removed when drainage was less than 50 ml/day. Antibiotics were either given for 24 hours after surgery or until drains were removed. The choice of hardware for instrumented fusion was based on the surgeon's preference. All hardware used after 2000 was titanium based.

Patients in whom an infection was suspected typically underwent MRI of the spine with and without Gd, as well as complete blood count, erythrocyte sedimentation rate, and C-reactive protein tests. An infectious disease team was involved in the care of these patients. The choice and duration of antibiotics was made by the infectious disease team and was determined by the culture sensitivities. The decision to preserve or remove the implanted hardware was made based on surgeon preference and the recommendations made by the infectious disease consultant. However, starting in 2002, an attempt to preserve the hardware was made in all cases.

Statistical Analysis

Summary data were presented as the mean ± SD and the median (interquartile range) for parametric and nonparametric data, respectively. Stepwise multivariate proportional hazards regression analysis was used to identify independent factors associated with developing a wound infection. In this analysis, univariate analyses were first performed to identify potential factors associated with infection. Factors with p < 0.10 were included in a stepwise multivariate proportional hazards regression analysis, and values with p < 0.05 were considered statistically significant. JMP v9 software (SAS) was used unless otherwise specified.

Results

Preoperative and Perioperative Characteristics

Eight hundred seventeen consecutive patients underwent instrumented lumbar fusion during the period under review (Table 2). The average age of the patients was 56 ± 14 years, and 373 (46%) were male. Prior to surgery, 90 patients (11%) had diabetes, 102 (12%) had coronary artery disease, 82 (10%) were severely obese, 15 (2%) had chronic obstructive pulmonary disease, 11 (1%) had sleep apnea, 16 (2%) had atrial fibrillation, and 164 (20%) were smokers. Previous spine surgery had been performed in 329 patients (40%).

The perioperative characteristics are summarized in Table 2. The median numbers of surgical levels, fused levels, and decompressed levels were 3 (IQR 2–4), 3 (IQR 2–3), and 2 (IQR 1–3), respectively. A CSF leak occurred in 10 patients (1%). The median hospital stay was 5 days (IQR 3–6 days). Perioperatively, 16 patients (2%) had a urinary tract infection, 4 (0.5%) developed pneumonia, 1 (0.1%) had sepsis, and 9 (1%) suffered a deep vein thrombosis or pulmonary embolism. Thirty-five patients (4%) were lost to follow-up, but none of the patients with infections were lost to follow-up.

Postoperative Infection

At a median follow-up of 12 months (IQR 3–24 months), 37 patients (4.5%) developed a wound infection. Of these 37 patients, 18 (49%) developed an infection limited to the suprafascial compartment, while 19 (51%) had an infection below the fascia. The postoperative infection was diagnosed at a median of 0.6 months (IQR 0.3–0.9 months). Twenty-one patients (57%) returned to the operating room for incision, drainage, and/or debridement of the infection, and 3 (8%) had their hardware removed as part of the infection management. Of these 3 cases of hardware removal, 1 was due to presumed infected hardware and 2 were due to hardware loosening in the presence of infection. Surgery was more commonly pursued when infections were subfascial compared to suprafascial (84% vs 28%, p = 0.0008). Of the patients who returned to the operating room, only 1 (5%) required 2 washouts to eradicate the infection, while the remaining patients (95%) only required 1 washout. Primary closure of the wound infection was pursued in 17 patients (81%), and negative–pressure wound therapy (that is, wound VAC [vacuum-assisted closure]) was used in 3 patients (14%).

Twenty-two patients (59%) had Staphylococcus infection, 7 (19%) Enterococcus, 4 (11%) Klebsiella, 2 (5%) Pseudomonas, 2 (5%) Corynebacterium, 1 (3%) Escherichia coli, 1 (3%) Proteus, and 8 (22%) polymicrobial, and in 8 (22%) no organism was found (18 [49%] patients had more than 1 organism that was cultured from their wound). Twenty-seven patients (73%) received intravenous antibiotics for a median duration of 1.5 months (IQR 0.7–1.5 months), while 15 (41%) received oral antibiotics for a median duration of 0.7 months (IQR 0.5–1.3 months). Of these patients who received antibiotic therapy, 7 (19%) underwent oral and intravenous concomitant therapy and 2 (5%) received oral antibiotics after intravenous antibiot-
Factors Associated With Spinal Infection

In univariate proportional hazards regression analysis, the factors associated with postoperative infection were age, duration of hospital stay, diabetes mellitus, obesity, atrial fibrillation, prior surgery, number of surgically treated levels, number of fused levels, perioperative urinary tract infection, and CSF leak. No other clinical factors were associated with postoperative infection including smoking and number of decompressed levels.

In stepwise multivariate proportional hazards regression analysis (Table 3), the factors that remained significantly associated with an increased risk of infection were increasing age (RR 1.004 [95% CI 1.001–1.009], p = 0.049), diabetes mellitus (RR 5.583 [95% CI 1.322–19.737], p = 0.02), obesity (RR 6.216 [95% CI 1.832–9.338], p = 0.005), previous spine surgery (RR 2.994 [95% CI 1.263–9.346], p = 0.009), and increasing duration of hospital stay (RR 1.155 [95% CI 1.076–1.230], p = 0.003). In separate analyses, the age, number of previous spinal levels operated on, and duration of hospital stay most significantly associated with an increased risk of postoperative infection were age greater than 70 years (RR 5.954 [95% CI 1.622–10.141], p = 0.009), more than 2 previous spinal surgery levels (RR 9.0821 [95% CI 1.688–19.033], p = 0.007), and hospital stay greater than 7 days (RR 4.620 [95% CI 1.435–15.121], p = 0.01).

Discussion

In this study of 817 consecutive patients who underwent posterior lumbar instrumented fusion for degenerative spine disease, postoperative spine infection developed in 37 patients (4.5%), of whom 18 (49%) had a suprafascial infection and 19 (51%) had an infection below the fascia. The factors independently associated with an increased risk of infection in this patient population were age greater than 70 years, diabetes, obesity, previous spinal surgery, and staying more than 7 days in the hospital. Ninety-two percent of the patients were treated without hardware removal.

Previous Postoperative Spinal Infection Studies

The overwhelming majority of previous studies on postoperative spinal infections have included disparate patient populations (Table 1). Several of these studies include patients who did not undergo instrumented fusion.1,6,11,12,22,29–31,34,45,46 Pull ter Gunne et al. evaluated 3174 patients who underwent various types of spine surgery and found that 132 patients developed postoperative spine infection.34 The number of total patients who underwent fusion without instrumentation was not reported, but 27 (20%) of the 132 patients with infection did not have instrumentation.34 Among this disparate group of patients, they found that deep infections could typically be treated with debridement, while superficial infections could be treated medically.34 Olsen and colleagues studied 2316 patients who underwent orthopedic spine surgery, and 635 of these patients did not undergo instrumented fusion.9 The factors associated with an increased risk of infection included diabetes, serum glucose levels, obesity, number of residents involved in the surgery, and noncervical spine cases.30 More recently, Kurtz et al. evaluated, in the Medicare population database, the incidence of infection in patients older than 65 years.18 They found that the incidence of infection in this older population was 8.5% for primary surgeries, and the risk of infection was most influenced by increased Charlson comorbidity index, greater than or equal to 9 levels of surgery, and revision surgery, as well as obesity, surgical approach, and year of index procedure.18

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In addition to studies including patients who did not undergo instrumented fusion, several studies have included a significant number of patients with different pathologies and spinal levels. Patients with different pathologies are known to have different risks of infections. Weinstein et al. reviewed 2391 consecutive patients who underwent spine surgery and found 46 patients who developed postoperative infection. They reported that infection was highest in patients with metastatic spine disease. Olsen and colleagues compared 41 patients who developed infections following spine surgery over a 4-year period with 178 randomly selected controls. They found that procedures for tumor resection were associated with an increased risk of infection. Similarly, Fang and colleagues studied 1095 patients who underwent any type of spine surgery and reported found that infection occurred in 48 patients. They compared these 48 patients to 95 randomly selected patients and found that older age, positive smoking status, diabetes, previous infection, increased body mass index, and alcohol abuse were all higher in the group that developed. In addition to case-control studies, several studies have attempted to identify risk factors for infections by using administrative databases. While these databases are larger, they are prone to errors in coding, capturing all cases, and errors in diagnosis, among others.

Factors Associated With Postoperative Spinal Infection

Patients with an increased age in this study had an increased risk of postoperative spinal infection, and patients greater than 70 years of age had the highest risk. This finding has been seen in previous studies of patients undergoing any type of spine surgery. Similarly, Fang and colleagues studied 1095 patients who underwent any type of spine surgery and reported found that infection occurred in 48 patients. They compared these 48 patients to 95 randomly selected patients and found that older age, positive smoking status, diabetes, previous infection, increased body mass index, and alcohol abuse were all higher in the group that developed. In addition to case-control studies, several studies have attempted to identify risk factors for infections by using administrative databases. While these databases are larger, they are prone to errors in coding, capturing all cases, and errors in diagnosis, among others.

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mass index was greater than 35. Longer operative times and more wound healing issues are typically present in patients who are obese, and these factors have been documented in studies not limited to patients with posterior lumbar fusion. Diabetic patients, on the other hand, not only have an increased propensity for infections, but several clinical studies have shown that hyperglycemia increases morbidity and mortality rates, length of hospital stay, and long-term functional deficits in critically ill patients. Hyperglycemia is also associated with perioperative morbidity and mortality in terms of several processes involving the CNS, including aneurysms and brain tumors. Thus, potential preoperative weight loss, strict glucose control, maintenance of sterile techniques, and use of infection control measures are especially critical in obese and/or diabetic patients.

Patients with a history of lumbar spinal surgery and/or with a longer duration of hospitalization were also at an increased risk of infection. As with obesity, patients who have previously undergone lumbar surgery typically have longer surgery times, increased procedural complexity, and propensity for durotomies. The present study found that this was most significant for patients in whom 3 or more spinal levels were previously operated on. In addition, patients with longer periods of hospitalization also had an increased risk of infection, and patients who stayed for greater than 7 days had the greatest risk. It has been shown in the literature that increased hospital stay is associated with an increased risk of nosocomial infections, including urinary tract infections, pneumonia, and bloodstream infections. Moreover, these infections occur with more virulent and antibiotic-resistant organisms. Every attempt therefore should be made to discharge patients from the hospital as soon as possible to minimize nosocomial infections including wound-site infections.

**Treatment of Postoperative Spinal Infection**

It is well known that the use of instrumentation is associated with an increased risk of infection. There is a concern that the only way to eradicate infections in these cases is to remove the previously implanted hardware. In present series, only 3 patients (8%) had their hardware removed as part of the infection workup. The overwhelming majority of patients were treated with some combination of incision and drainage and/or antibiotics. None of the patients had signs of recurrent infection at last follow-up. This is similar to the findings of Palavigna et al., who treated 13 patients with deep wound infections that did not involve hardware removal. Therefore, this study shows that infections may be eradicated without hardware removal in the majority of cases. This study also supports the notion of attempting less aggressive means of eradicating infection before considering hardware removal, as explantation in many cases will not required this to control infection.

**Strength and Limitations**

We believe this study provides several useful insights. First, the risk of infection is unclear for patients who are undergoing instrumented posterior lumbar fusion to treat degenerative spine disease. Because previous studies have included disparate patient populations, the findings are not necessarily applicable to patients undergoing instrumented fusion for lumbar degenerative spine disease. Second, our study identifies factors independently associated with infection for this patient population. Older age, diabetes, obesity, previous lumbar surgery, and longer hospital stay were all independently associated with infection. Patients in whom these factors are present should be considered for stricter implementation of infection control measures including sterile technique, longer duration of perioperative antibiotics, and potentially closer surveillance. Third, we found that hardware removal is typically not necessary for infection control. Surgical debridement and/or antibiotic administration are usually sufficient at eradicating infections. This study may therefore provide useful information for helping to minimize infection in patients undergoing lumbar fusion for degenerative spine disease.

This study, however, has some limitations. One is that it was not designed to evaluate the efficacy of sterilization techniques or peri- and postoperative antibiotic regimens. The sterilization techniques and perioperative antibiotic regimen and duration were not consistently recorded, and therefore, their effect on outcome could not be assessed. Additionally, a small minority of patients was lost to follow-up. As a result, some patients who developed late infections that were treated elsewhere may have been missed in our study. Moreover, the type of hardware was not routinely recorded. Therefore, associations between hardware type and the development of postoperative infections were not analyzed. Additionally, this study was underpowered to evaluate if hardware removal was necessary for infection treatment. Of the 37 patients in whom postoperative wound infection developed, only 3 (8%) required hardware removal. Larger studies with longer follow-up times are needed. Finally, this study is inherently limited by its retrospective design. As a result, there may be an inherent bias associated with patient selection and treatment, as well as missing patient information. However, we tried to create a uniform patient population by utilizing strict inclusion criteria, thus providing more relevant information for patients undergoing posterior lumbar fusion for degenerative spine disease. Given these criteria and relatively precise outcome measures, we believe our findings are useful for the care of patients with degenerative spine disease. However, prospective studies are needed to provide better data to guide clinical decision making.

**Conclusions**

Posterior lumbar fusion for degenerative spine disease is a relatively common procedure, with an increasing number of procedures performed each year. A feared complication of these procedures is postoperative spinal infection. This study found that approximately 4% of patients developed an infection. The factors independently associated with an increased risk of infection were older age, diabetes, obesity, prior surgery, and prolonged hospital stay. Ninety-two percent of the patients who developed a postoperative infection were treated successfully with surgery and/or antibiotics, without necessity for hardware removal.
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Disclosure

Dr. Sciubba is a consultant for DePuy, Medtronic, NuVasive, and Globus. Dr. A. Bydon has received non–study related support from DePuy Spine. Dr. Gokaslan is a stockholder in US Spine and Spinal Kinetics; he received research support for the current study from AOSpine, NREF, and DePuy; and he is on the editorial boards of the following: Journal of Neurosurgery: Spine, Journal of Spinal Disorders, European Spine Journal, Nature Review, World Neurosurgery, and Journal of Surgical Oncology. Dr. Witham has received non–study related support from Eli Lilly.

Author contributions to the study and manuscript preparation include the following. Conception and design: Chaichana, McLaughlin, Sciubba, Gokaslan, Witham. Acquisition of data: M Bydon, Santiago-Dieppa, Hwang, McLaughlin, Wolinsky, A Bydon, Gokaslan, Witham. Drafting the article: Chaichana, M Bydon, Gokaslan, Witham. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Chaichana. Statistical analysis: Chaichana, M Bydon. Administrative/technical/material support: Witham. Study supervision: Gokaslan.

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