Using the Spine Surgical Invasiveness Index to Identify Risk of Surgical Site Infection

A Multivariate Analysis

Amy M. Cizik, MPH, Michael J. Lee, MD, Brook I. Martin, PhD, MPH, Richard J. Bransford, MD, Carlo Bellabarba, MD, Jens R. Chapman, MD, and Sohail K. Mirza, MD, MPH

Investigation performed at the University of Washington Medical Center and Harborview Medical Center, Seattle, Washington

Background: Surgical site infection after spine surgery is a well-known complication that can result in poor outcomes, arthrodesis-site nonunion, and neurological injury. We hypothesized that a higher surgical invasiveness score will increase the risk for surgical site infection following spine surgery.

Methods: Data were examined from patients undergoing any type of spinal surgery from January 1, 2003, to December 31, 2004, at two academic hospitals. The surgical invasiveness index is a previously validated instrument that accounts for the number of vertebral levels decompressed, arthrodesed, or instrumented as well as the surgical approach. Relative risks and 95% confidence intervals were calculated for each of the categorical variables. Multivariate binomial stepwise logistic regression was used to examine the association between surgical invasiveness and surgical site infection requiring a return to the operating room for treatment, adjusting for confounding risk factors.

Results: The regression analysis of 1532 patients who were evaluated for surgical site infection identified the following significant risk factors for surgical site infection: a body mass index of >35 (relative risk, 2.24 [95% confidence interval, 1.21 to 3.86]; p = 0.01), hypertension (relative risk, 1.73 [95% confidence interval, 1.05 to 2.85]; p = 0.03), thoracic surgery versus cervical surgery (relative risk, 2.57 [95% confidence interval, 1.20 to 5.60]; p = 0.01), lumbosacral surgery versus cervical surgery (relative risk, 2.03 [95% confidence interval, 1.10 to 4.05]; p = 0.02), and a surgical invasiveness index of >21 (relative risk, 3.15 [95% confidence interval, 1.37 to 6.99]; p = 0.01).

Conclusions: Patients undergoing more invasive spine surgery as measured with the surgical invasiveness index had greater risk for having a surgical site infection that required a return to the operating room for treatment. Surgical invasiveness was the strongest risk factor for surgical site infection, even after adjusting for medical comorbidities, age, and other known risk factors. The magnitude of this association should be considered during surgical decision-making and intraoperative and postoperative care of the patient. These findings further validate the importance of the invasiveness index when performing safety and clinical outcome comparisons for spine surgery.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Surgical site infection after spine surgery is an uncommon but well-known complication that can result in a poor outcome, arthrodesis-site nonunion, and neurological injury[1-7]. In the setting of a surgical site infection, patients are likely to require intravenous (IV) antibiotics, a prolonged hospital stay[8], and operative debridement. The deleterious clinical effects of surgical site infection are associated with an increase in total costs[1]. Previous studies have shown that age, diabetes, obesity, and surgical approach and invasiveness are risk factors for surgical site infection[3-7]. The association of surgical invasiveness and increased risk for surgical site infection is fairly intuitive but has been poorly defined in the literature. Posterior surgical approaches have been found to increase the likelihood of surgical site infection threefold to eightfold when compared with

Disclosure: One or more of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of an aspect of this work. In addition, one or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

TABLE I Invasiveness Index Values and Component Scores in Sample Spinal Surgery Procedures ➤

Example	Description of Procedure	Anterior Decompression (ad)	Anterior Fusion (af)
1	L5-S1 posterior discectomy	No anterior decompression vertebrae (ad = 0)	No anterior arthrodesis vertebrae (af = 0)
2	L5-S1 anterior lumbar interbody fusion plating	L5–S1 disc (ad = 1)	L5 and S1 vertebrae (af = 2)
3	T5-T8 posterolateral arthrodesis with pedicle screws and no decompression	No anterior decompression vertebrae (ad = 0)	No anterior arthrodesis vertebrae (af = 0)
4	L4-L5 posterolateral arthrodesis with L4 and L5 laminectomy and structural graft or cages in the L4-L5 disc space	No anterior decompression vertebrae (ad = 0)	L4 and L5 vertebrae (af = 2)
5	T1-ilium posterior; pedicle screws bilaterally at T1, T4, T8, L1, L2, L3, L4, L5, S1, and ilium; laminectomy L1 to S1, and posterior interbody arthrodesis with cages at L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1	No anterior decompression vertebrae (ad = 0)	L1, L2, L3, L4, L5, and S1 vertebrae (af = 6)

an anterior approach[3,7,9,10], whereas surgical instrumentation has been shown to increase the likelihood of surgical site infection 2.5-fold[10]. A surgical invasiveness scoring index as described by Mirza et al.[11] quantifies invasiveness by assigning points per vertebral level of decompression, arthrodesis, and instrumentation from an anterior and/or posterior approach. Although the index has been correlated with blood loss and operative time[12], previous studies have not demonstrated its association with other measures such as surgical site infection. We hypothesized that a higher surgical invasiveness score increases the risk for surgical site infection following spine surgery.

Materials and Methods

Data Source

The Spine End Results Registry (SERR) is a prospective data registry of all patients undergoing spine surgery from January 1, 2003, to December 31, 2004, at two academic hospitals: a university-based medical center and a county hospital serving as the only level-I trauma center in a large, multistate area. Detailed demographic and comorbidity data were recorded prospectively with use of a combination of previously described surveillance methods that ranged from an active recording of data by a variety of health-care providers to a review of the medical records[11,12]. Institutional review board approval for the present study was given by the university human subjects committee. Consent was obtained for every patient who agreed to participate in the Spine End Results Registry. For those subjects who declined to participate in the registry, the human subjects committee stipulated that only data that were related to adverse events following spine surgery could be included and used for research purposes without consent.

Exclusion Criteria

Patients who had the index procedure for the treatment of spinal infection and those who had a history of spinal infection were excluded from the present analysis. We also excluded patients under the age of eighteen years and those for whom the surgical invasiveness index was either missing or equal to 0. The latter group included patients who had closed reduction of spinal fractures with application of a Risser cast, spinal instrumentation removal, or halo placement.

Surgical Site Infection and Risk Factor Definitions

The primary outcome measure was surgical site infection that required a return to the operating room for irrigation and debridement (see Appendix). Superficial infections that did not necessitate a return to the operating room were not classified as a surgical site infection in the present study. With use of univariate and multivariate analysis, we also examined the influence of other potential risk factors for surgical site infection. These risk factors included age, sex, smoking, any alcohol consumption, drug use, diabetes, body mass index (BMI), comorbidity, primary diagnosis (trauma, degenerative disease, neoplasm, other), vertebral level of diagnosis (cervical, thoracic, lumbar, sacral), previous surgery, and surgical approach (anterior, posterior, or combined). Patients were followed for at least two years after the procedure.

Surgical Invasiveness Index

The surgical invasiveness index is a previously validated instrument that accounts for the number of vertebral levels decompressed, arthrodesed, or instrumented as well as the surgical approach[11]. The index score ranges from 0 to 48 points, with a higher score indicating greater invasiveness. The index is the sum of six weighted surgical components: anterior decompression (ad), anterior fusion (af), anterior instrumentation (ai), posterior decompression (pd), posterior fusion (pf), and posterior instrumentation (pi) (see Appendix). The weights for each component represent the number of vertebral levels at which each is performed[12]. For example, for a C5 to C6 anterior discectomy with arthrodesis and plating, the score is 5 (ad = 1 [one disc] + af = 2 [two-vertebrae arthrodesis] + ai = 2 [plate at both levels]) (Table I). For our purposes, we categorized the score into six groups: 1 to 5, 6 to 10, 11 to 15, 16 to 20, 21 to 25, and >25.

Analysis

Categorical data were presented as the number of patients and percentages. For continuous variables, two-sample Student t tests were used to compare means. For categorical values, the Pearson chi-square test or the Fisher exact test (in cases in which cell counts were low) were used to assess the effect of various risk factors. Relative risk and 95% confidence intervals (CI) were calculated for each of the categorical variables. Multivariate binomial stepwise logistic regression was used

TABLE I (*continued*)

Anterior Instrumentation (ai)	Posterior Decompression (pd)	Posterior Fusion (pf)	Posterior Instrumentation (pi)	Invasiveness Index Value
No anterior instrumentation vertebrae (ai = 0)	L5 lamina and L5–S1 disc (pd = 1)	No posterior arthrodesis vertebrae (pf = 0)	No posterior instrumentation vertebrae (pi = 0)	1
L5 and S1 vertebrae (ai = 2)	No posterior decompression vertebrae (pd = 0)	No posterior arthrodesis vertebrae (pf = 0)	No posterior instrumentation vertebrae (pi = 0)	5
No anterior instrumentation vertebrae (ai = 0)	No posterior decompression vertebrae (pd = 0)	T5, T6, T7, T8 vertebrae (pf = 4)	T5, T6, T7, T8 vertebrae (pi = 4)	8
L4 and L5 vertebrae (ai = 2)	L4 and L5 laminae (pd = 2)	L4 and L5 vertebrae (pf = 2)	L4 and L5 vertebrae (pi = 2)	10
L1, L2, L3, L4, L5, and S1 vertebrae (ai = 6)	L1, L2, L3, L4, L5, and S1 laminae (pd = 6)	Twelve thoracic vertebrae (T1–T12), five lumbar vertebrae (L1–L5), S1, and ilium (pf = 19)	T1, T4, T8, L1, L2, L3, L4, L5, S1, ilium (pi = 10)	47

to examine the association between surgical invasiveness and surgical site infection, adjusting for confounding risk factors. In the model, we included risk factors that were of clinical importance based on previously reported risk factors for surgical site infection found in the literature, that were known confounders, or that had a univariate association with invasiveness ($p < 0.10$). Because surgical approach and the number of operatively treated vertebral levels are components of the invasiveness index, they were not included in the multivariate regression model. Statistical analysis was performed with hypothesis testing with use of a two-tailed test of significance and an alpha level of $p < 0.05$.

Source of Funding

The present study was supported by grants from the National Institutes of Health/National Institute of Arthritis, Musculoskeletal, and Skin Disorders 5K23AR48979 and 5P60-AR48093. The present study also was supported in part by the Spine End-Results Research Fund at the University of Washington through a gift from Synthes (West Chester, Pennsylvania).

Results

Patient Characteristics

We identified 1745 eligible patients from hospital admission logs, preoperative clinical visit records, and/or surgical patient logs (Fig. 1). Two hundred and thirteen patients (12%) were excluded. Of these, seventy-two (34%) were excluded because of a previous infection; 103 (48%), because the invasiveness score was missing or 0; and thirty-eight (18%), because of an age of less than eighteen years.

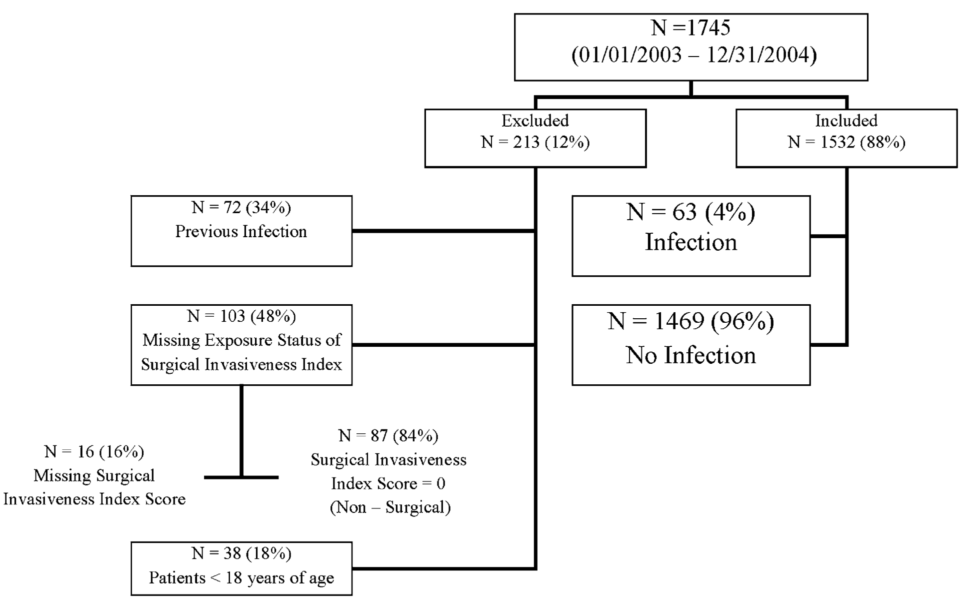

Fig. 1

Patient flow diagram illustrating the inclusion and exclusion criteria for the present study.

TABLE II Univariate Analysis of Relative Risk for Surgical Site Infection

Risk Factors	Surgical Site Infection (N = 63 [4%])	No Surgical Site Infection (N = 1469 [96%])	Relative Risk of Surgical Site Infection	95% CI	P Value
Age* *(yr)*	53.5 ± 16.1	49.4 ± 16.0			0.05
Age group†					
18 to 39	14 (3%)	409 (97%)	1.00	—	—
40 to 64	33 (4%)	783 (96%)	1.22	0.66 to 2.26	0.52
≥65	16 (5%)	277 (95%)	1.65	0.82 to 3.33	0.16
Sex†					0.60
Male	34 (4%)	842 (96%)	1.00	—	
Female	29 (4%)	627 (96%)	1.14	0.70 to 1.85	
BMI* *(kg/m²)*	28.8 ± 8.0	27.6 ± 6.4			0.28
BMI category†					
Underweight (<18.5)	8 (6%)	119 (94%)	1.83	0.81 to 4.14	0.15
Normal (18.5 to <25)	17 (3%)	476 (97%)	1.00	—	—
Overweight (25 to <30)	16 (3%)	475 (97%)	0.95	0.48 to 1.85	0.87
Obese (30 to <35)	8 (3%)	252 (97%)	0.89	0.39 to 2.04	0.79
Morbidly obese (≥35)	14 (9%)	147 (91%)	2.52	1.27 to 5.00	0.007‡
Smoking†					0.83
No	45 (4%)	1031 (96%)	1.00	—	
Yes	18 (4%)	438 (96%)	0.94	0.55 to 1.61	
Any alcohol consumption†					0.08
No	43 (5%)	841 (95%)	1.00	—	
Yes	20 (3%)	628 (97%)	0.63	0.38 to 1.07	
Any drug use†					0.79
No	58 (4%)	1338 (96%)	1.00	—	
Yes	5 (4%)	131 (96%)	0.88	0.36 to 2.17	
Diabetes†					0.003‡
No	49 (4%)	1316 (96%)	1.00	—	
Yes	14 (8%)	153 (92%)	2.34	1.32 to 4.14	
Previous cardiac incident (valve disease, mitral valve prolapse, and/or abnormal electrocardiogram)†					0.05
No	53 (4%)	1343 (96%)	1.00	—	
Yes	10 (7%)	126 (93%)	1.94	1.01 to 3.72	
Myocardial infarction†					0.19
No	57 (4%)	1387 (96%)	1.00	—	
Yes	6 (7%)	82 (93%)	1.73	0.77 to 3.90	
Congestive heart failure†					<0.001‡
No	55 (4%)	1420 (96%)	1.00	—	
Yes	8 (14%)	49 (86%)	3.76	1.88 to 7.53	
Cerebrovascular disease†					0.37
No	58 (4%)	1391 (96%)	1.00	—	
Yes	5 (6%)	78 (94%)	1.51	0.62 to 3.65	
Chronic obstructive pulmonary disease†					0.004‡
No	53 (4%)	1373 (96%)	1.00	—	
Yes	10 (9%)	96 (91%)	2.54	1.33 to 4.84	
Asthma†					0.95
No	54 (4%)	1263 (96%)	1.00	—	
Yes	9 (4%)	206 (96%)	1.02	0.51 to 2.04	
Peripheral vascular disease†					0.17
No	62 (4%)	1463 (96%)	1.00	—	
Yes	1 (14%)	6 (86%)	3.51	0.56 to 21.9	
Hypertension†					0.002‡
No	33 (3%)	1035 (97%)	1.00	—	
Yes	30 (6%)	434 (94%)	2.09	1.29 to 3.39	

TABLE II (*continued*)

Risk Factors	Surgical Site Infection (N = 63 [4%])	No Surgical Site Infection (N = 1469 [96%])	Relative Risk of Surgical Site Infection	95% CI	P Value
Rheumatoid arthritis†					0.002‡
No	56 (4%)	1417 (96%)	1.00	—	
Yes	7 (12%)	52 (88%)	3.12	1.49 to 6.55	
Renal disease†					0.004‡
No	53 (4%)	1373 (96%)	1.00	—	
Yes	10 (9%)	96 (91%)	2.54	1.33 to 4.84	
Liver disease†					0.16
No	62 (4%)	1384 (96%)	1.00	—	
Yes	1 (1%)	85 (99%)	0.27	0.04 to 1.93	
Cancer †					0.62
No	54 (4%)	1290 (96%)	1.00	—	
Yes	9 (5%)	179 (95%)	1.19	0.60 to 2.37	
Bowel obstruction†					0.001‡
No	60 (4%)	1458 (96%)	1.00	—	
Yes	3 (21%)	11 (79%)	5.42	1.93 to 15.2	
Dementia†					0.77
No	63 (4%)	1467 (96%)	1.00	—	
Yes	0	2 (100%)	—	—	
Syncope or seizure†					0.44
No	61 (4%)	1390 (96%)	1.00	—	
Yes	2 (2%)	79 (98%)	0.59	0.15 to 2.36	
Anemia†					0.20
No	56 (4%)	1368 (96%)	1.00	—	
Yes	7 (6%)	101 (94%)	1.65	0.77 to 3.53	
Bleeding disorder or blood clots†					0.06
No	55 (4%)	1371 (96%)	1.00	—	
Yes	8 (8%)	98 (92%)	1.96	0.96 to 4.00	
Primary diagnosis†					
Degenerative	39 (4%)	952 (96%)	1.00	—	—
Trauma	17 (5%)	355 (95%)	1.16	0.67 to 2.03	0.60
Neoplasm	5 (4%)	112 (96%)	1.09	0.44 to 2.70	0.86
Other	2 (4%)	50 (96%)	0.98	0.24 to 3.94	0.97
Vertebral level of diagnosis†					
Cervical	12 (2%)	551 (98%)	1.00	—	—
Thoracic	15 (7%)	208 (93%)	3.16	1.50 to 6.63	0.001‡
Lumbosacral	36 (5%)	710 (95%)	2.26	1.19 to 4.31	0.01‡
Revision†					0.12
No	47 (4%)	1208 (96%)	1.00	—	
Yes	16 (6%)	261 (94%)	1.54	0.89 to 2.68	
Surgical approach†					
Posterior	36 (4%)	863 (96%)	1.00	—	—
Anterior	5 (2%)	279 (98%)	0.44	0.17 to 1.11	0.07
Combined	22 (6%)	327 (94%)	1.57	0.94 to 2.64	0.08
Invasiveness index*	12.7 ± 9.0	8.3 ± 7.4			<0.001‡
Invasiveness index category†					
1 to 5	14 (2%)	691 (98%)	1.00	—	—
6 to 10	19 (5%)	377 (95%)	2.42	1.22 to 4.77	0.009‡
11 to 15	14 (6%)	216 (94%)	3.07	1.48 to 6.33	0.002‡
16 to 20	6 (7%)	84 (93%)	3.36	1.32 to 8.52	0.008‡
21 to 25	3 (7%)	42 (93%)	3.36	1.00 to 11.3	0.04‡
>25	7 (11%)	59 (89%)	5.34	2.23 to 12.8	<0.001‡

*The values are given as the mean and the standard deviation. †The values are given as the number of patients, with the percentage of the number of patients in each category in parentheses. ‡Significant compared with the referent group.

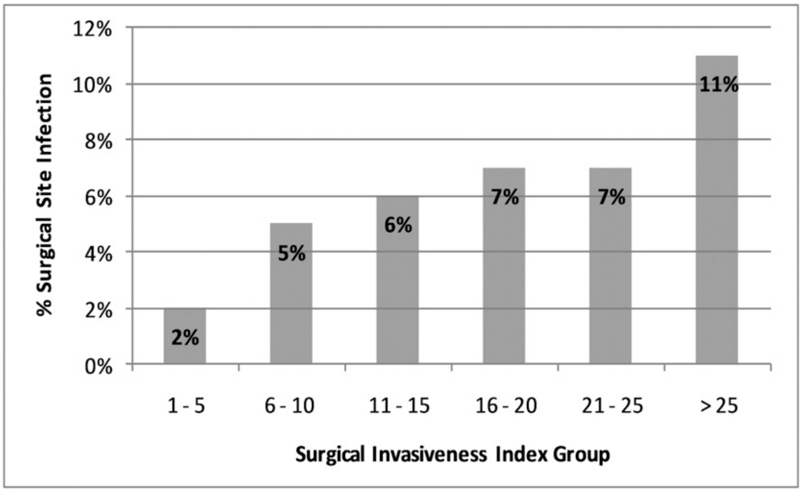

Fig. 2
Bar graph showing the rate of surgical site infection according to the spinal surgical invasiveness index.

Of the 1745 eligible patients, 1532 (88%) met the inclusion criteria for the present study and were followed with regard to surgical site infection. Sixty-three patients (4%) had a surgical site infection necessitating a return to the operating room for debridement. The mean surgical invasiveness score was 8.3 points (range, 1 to 48 points). None of the surgical procedures involved the use of minimally invasive tubular retractors. Most of the patients were male (57%; 876 of 1532). The mean age was 49.5 years, and the mean BMI was 27.6. Nearly two-thirds of the patients had a degenerative condition (65%; 991 of 1532), with patients who had spinal trauma comprising the next-largest group (24%; 372 of 1532). Most of the operations were performed with use of a posterior approach (59%; 899 of 1532), followed by a combined approach (23%; 349 of 1532). There were ninety-seven surgical site infections in sixty-three patients (4%), for an incidence of 1.98 per 100 person-years. The mean interval from surgery to infection was 2.7 months (range, zero to twenty-seven months).

TABLE III Multivariate Analysis of Relative Risk for Surgical Site Infection

Risk Factors	Relative Risk	95% CI Lower Limit	95% CI Upper Limit	P Value
BMI >35	2.24	1.21	3.86	0.01
Hypertension	1.73	1.05	2.85	0.03
Renal disease	1.89	0.93	3.44	0.05
Diagnosis level*				
Thoracic	2.57	1.20	5.60	0.01
Lumbosacral	2.03	1.10	4.05	0.02
Invasiveness index†				
6 to 10	2.34	1.20	4.70	0.01
11 to 15	2.47	1.18	5.16	0.01
16 to 20	2.51	0.90	6.17	0.06
≥21	3.15	1.37	6.99	0.01

*The referent group comprised patients who were diagnosed with cervical-level disease. †The referent group comprised patients who had an invasiveness index of 1 to 5.

Surgical Invasiveness

Surgical invasiveness had a strong dose response with surgical site infection; the greater the surgical invasiveness, the greater the proportion of patients who had a surgical site infection (Tables I and II). For example, the rate of surgical site infection was 2% (fourteen of 705) among patients with an invasiveness index score of 1 to 5, compared with 11% (seven of sixty-six) among those with a score >25 (Fig. 2).

Table II presents the results of the univariate analysis for multiple risk factors. Table III presents the results of the multivariate analysis demonstrating the increased relative risk of surgical site infection with increased invasiveness. Patients with an invasiveness score of ≥21 had a 3.15 times higher risk of having a surgical site infection than those with an invasiveness score of <6, even after adjusting for age; sex; diabetes; smoking; cardiac, pulmonary, and renal disease; revision surgery; BMI; and diagnosis. Morbid obesity and diagnosis levels remained important factors associated with surgical site infection in the final model. Controlling for other factors in the model, patients undergoing lumbosacral and thoracic procedures had 2.03 and 2.57 times higher risks, respectively, for surgical site infection, compared with patients undergoing cervical spine surgery.

Discussion

We found that greater surgical invasiveness at the time of spinal surgery was associated with a significantly greater risk of a surgical site infection necessitating a return to the operating room for irrigation and debridement. Contrary to the findings reported by Fang et al.[5], Friedman et al.[4], and Olsen et al.[13], surgical invasiveness was by far the strongest risk factor for surgical site infection in the present study. The magnitude of this association should be taken into consideration during surgical decision-making, counseling, and intraoperative and postoperative care of the patient. For example, based on our findings, a two-level lumbar laminectomy with posterior lateral instrumented arthrodesis and interbody graft or device (invasiveness index, 11 to 15) is almost 2.5 times more likely to result in a surgical site infection as compared with a two-level laminectomy (invasiveness index, 1 to 5). These findings further validate the importance of the invasiveness index when performing safety and clinical outcome comparisons for spine surgery. Future studies examining adverse events associated with spine surgery may benefit from utilizing this index to adjust for operative complexity and to allow for more accurate patient safety comparisons.

Estimates of the rate of surgical site infection following spine surgery have ranged from 1.9% to 13.8%[2-8,14], depending on study design. Most studies on surgical site infection have included a retrospective analysis with matched control groups and have not adjusted for confounding factors[3-7]. In general, diabetes, obesity, medical comorbidity, age, and surgical invasiveness have been shown to be associated with surgical site infection, although inconsistently from study to study. Overall, we found that 4% of patients in the present study had a surgical site infection that required a return to the operating room. We did not observe a significant difference between our two institutions. One of the major strengths of the present analysis is that the extensive demographic, comorbidity, and complication data were recorded prospectively. Second, because of the large number of patients in the present study population, we were able to perform a multivariate analysis controlling for other potential risk factors.

It is important to note that in our definition of surgical site infection, we included only patients who returned to the operating room for formal irrigation and debridement. We did not differentiate between superficial and deep infections in the present analysis, and this distinction is important for future study. The sequelae from a deep wound infection are far more extensive than those of a superficial infection and may entail prolonged IV antibiotic treatment, possible removal of spinal instrumentation, and additional reconstructive surgery at a later time. A superficial infection may be treated adequately with short-term IV antibiotics followed by oral antibiotics.

There were weaknesses in the present study, the majority of which were inherent to the creation and maintenance of a detailed surgical registry. First, although these data were recorded prospectively, the present study design was not defined prospectively, making the present study a retrospective analysis of prospective data. Second, because our referral base included a five-state region, it is possible that some of the patients who returned to the operating room because of infection may have been missed as patients who could have undergone management outside our medical system. However, the present study was part of a larger quality assurance/quality improvement study, and all methods (passive and active surveillance) were specifically designed and used to capture adverse occurrences in the study population. Third, despite the level of prospective detailed data recording, all potential confounders may not have been recorded. Although many confounders were controlled in the analysis, not all were. For example, variation in antibiotic duration and surgical site preparation may influence the prevalence of surgical site infection; however, these data points were not recorded in the present study registry. It is our practice to administer preoperative antibiotics and at least twenty-four hours of postoperative antibiotics for inpatients, but many of these patients may have received antibiotics beyond twenty-four hours. Fourth, some risk factor data were recorded as categorical and not as continuous variables. Although we did record diabetes status and smoking status, the present study data did not reflect the severity of these risk factors (hemoglobin A1c, number of cigarettes per day, or pack-year history). The recording of these variables as categorical rather than continuous data points may account for some differences in the risk of surgical site infection across invasiveness groups. More detailed information such as perioperative laboratory values and pack-year smoking history may provide further insight and accuracy for analysis. Fifth, although a substantial number of operations were performed on trauma patients, the majority were elective procedures. Elective surgery is inherently less likely to be recommended for patients with severe medical or surgical comorbidity, and this may have attenuated the effect of these risk factors for certain covariates in the present study. Finally, the present study did not evaluate the influence of more contemporary minimally invasive surgical techniques on surgical site infections. Although it might seem intuitive that minimally invasive surgical techniques may be less likely to result in surgical site infection, future studies specifically examining this question are needed to sufficiently substantiate this hypothesis. As minimally invasive surgical approaches become more common, modifications to the invasiveness index may be needed to appropriately reflect minimally invasive surgical techniques.

Although the surgical invasiveness index (Table I and Appendix) has been validated in prior studies, there are limitations with this scoring system, and it is not well designed to differentiate invasiveness between similar procedures. For example, if one were to compare an anterior cervical discectomy and fusion with and without anterior plating, both of these procedures would yield the same score. Clearly, the addition of a cervical plate increases the operative time and dissection and therefore adds to the invasiveness of the procedure, but this is not reflected in the invasiveness index. Similarly, a two-level anterior cervical discectomy and fusion from C4 to C6 with instrumentation yields the same score as an anterior C5 corpectomy and fusion from C4 to C6 with instrumentation. The addition of the C5 corpectomy clearly adds invasiveness to the procedure, but this is not reflected by the surgical invasiveness index.

Although subtle differences between similar procedures may not be accurately represented by the invasiveness index, broader differences among a larger spectrum of spine surgery are well represented. The present study population underwent surgery ranging from a single-level microdiscectomy to a T4-to-ilium arthrodesis with multiple interbody graft placements. Because of the large spectrum of surgery in the present study population, we categorized invasiveness with ranges of scores (1 to 5, 6 to 10, 11 to 15, 16 to 20, 21 to 25, and >25). Although limited in subtle differentiation between similar procedures, the invasiveness index has been validated[11] to well represent surgical invasiveness differences on a broader scale.

Diabetes and other medical comorbidities (except for hypertension), age, and revision surgery were not statistically associated with surgical site infection in the present multivariate analysis. However, we still clinically regard these as potential risk factors for surgical site infection.

The present analysis demonstrates that morbid obesity, hypertension, renal disease, thoracic and lumbosacral surgery, and elevated surgical invasiveness are significant risk factors for surgical site infection requiring operative debridement after spine surgery. Of these, surgical invasiveness was the greatest risk factor for the extent of surgical invasiveness. When considering patient safety and outcomes, surgical invasiveness should be included as a potential risk factor. We believe these data can aid providers and patients alike in the improvement of patient safety and informed decision-making related to surgical procedures involving the spine.

Appendix

eA Tables showing wound-healing and infection-adverse occurrence definitions and the surgical invasiveness index score component description are available with the online version of this article as a data supplement at jbjs.org. ■

NOTE: The authors would like to express appreciation to Mark Konodi, Jan Bower, Michaela Galapon, Salwa Mohamed, Todd Jarosz, Andrew Dailey, and all the spine surgeons at the University of Washington for assistance in protocol development and data collection.

Amy M. Cizik, MPH
Michael J. Lee, MD
Jens R. Chapman, MD
Department of Orthopaedics and Sports Medicine,
University of Washington Medical Center,
1959 N.E. Pacific Street, Box 356500, Seattle, WA 98195-6500.
E-mail address for A.M. Cizik: amorgan2@uw.edu

Brook I. Martin, PhD, MPH
Sohail K. Mirza, MD, MPH
Department of Orthopaedics,
Dartmouth-Hitchcock Medical Center, Spine Center,
One Medical Center Drive, Lebanon, NH 03756

Richard J. Bransford, MD
Carlo Bellabarba, MD
Department of Orthopaedic Surgery,
Harborview Medical Center,
325 9th Avenue, Box 359798, Seattle, WA 98104

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