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Risk Factors for Acute Surgical Site Infection after Spinal Instrumentation Procedures: A Case-Control Study

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ABSTRACT

Background: Surgical site infection (SSI) prevalence in spinal instrumentation varies, depending on patient and surgery factors. This study aims to identify patient- and procedure-related factors associated with SSI after spinal instrumentation in 3 patient-specific groups: those undergoing surgery for degenerative, trauma-related, and pediatric deformity conditions.

Methods: A case-control (1:2 ratio) analysis of SSI after spinal instrumentation, from 2009 to 2017, in a University Hospital and Spinal Trauma Centre was performed.

Results: From a total of 2582 surgeries, 33 cases (1.3%) were identified with SSI according to study inclusion criteria: 14 (out of 1326) in the degenerative group, 11 (out of 207) in the trauma group, and 8 (out of 850) in the pediatric deformity group. Cases were matched with controls ($n = 66$) of the same group. Univariate analysis identified procedure and anesthesia duration in the degenerative group ($P = .032$ and $.038$, respectively), age ($P = .014$) and need for intraoperative and postoperative blood transfusions (both $P = .039$) in the trauma group and American Society of Anesthesiologists score ($P = .022$) and neuromuscular scoliosis ($P = .002$) in the pediatric deformity group as associated with SSI. After multivariate analysis, procedure duration was independently associated with SSI in degenerative surgery (odds ratio [OR], 2.23; 95% confidence interval [CI], 1.03–4.82) and procedure duration (OR, 3.79; 95% CI, 1.27–11.32) and number of levels instrumented (OR, 11.77; 95% CI, 1.55–89.40) in the trauma group.

Conclusions: This study identified procedure duration as a risk factor for SSI after spinal instrumentation in degenerative and trauma spine surgery and the number of levels instrumented in trauma spine surgery. Awareness of these factors will help develop strategies to improve patient and health system overall outcomes.

Complications

Keywords: risk factors, spinal fusion, spinal instrumentation, surgical site infection

INTRODUCTION

Surgical site infection (SSI) is one of the most common and serious complications following spinal surgery. It results in increased rates of morbidity, mortality, and health care costs, often requiring surgical debridement, long-term antibiotics, and hardware removal.¹ Even after successful treatment of the infected area, a postoperative infection has a negative emotional impact on a patient's overall outcome.²

The prevalence of SSI reported in the literature ranges from 0.7% to 12.0%, depending on the indication for surgery and the type of surgery performed.^{3–5} Naturally, more complex procedures result in higher infection rates since the nature of the procedure accounts for the variability of the infection risk; for instance, the rate of infection

after simple discectomy or laminectomy is approximately 1%, whereas spinal fusion has rates of 2%–5%.^{4,6}

Given the ongoing substantial clinical and economic impact of SSIs, efforts to reduce their occurrence are critically needed. One of the most important first steps in reducing the incidence of SSIs is to identify risk factors for their occurrence. Improved understanding of potentially modifiable risk factors, and even those that are not modifiable, may lead to systematic changes that can influence the selection of patients for surgery or type of surgical procedure performed, decreasing SSI risk on a large scale and improving patients' overall outcome.

Among published studies of SSIs complicating spine surgery, there has been much variation in patient population.^{7,8} A relatively limited number of

studies were conducted specifically following spinal fusion surgery and even fewer on specific groups of patients such as those undergoing degenerative, trauma or pediatric spinal deformity surgery.

The goal of this study was to assess risk factors for SSI after different specific spinal fusion procedures performed for degenerative conditions, traumatic injury, or pediatric spinal deformity, in order to develop effective prevention strategies.

METHODS

A retrospective study was conducted with patients who underwent lumbar spinal instrumentation between January 2009 and August 2017 in a university hospital and tertiary spinal trauma center. The study protocol was approved by the institutional review board of the hospital. Patients were categorized in 3 groups: (1) fusion for lumbar spinal degenerative diseases, which includes fusion for spinal stenosis, disc herniation, spondylolisthesis or adult degenerative deformity; (2) spinal instrumentation/fusion for fractures; and (3) fusion for pediatric spinal deformity. Cases were identified by monitoring positive wound culture reports and readmissions with a minimum 1-year follow-up, according to the Centers for Disease Control and Prevention criteria.^{9,10} Patients who underwent fusion through an anterior approach were excluded from this study because anterior approach procedures have a significantly lower infection rate than procedures involving a posterior approach.^{8,11} Patients undergoing fusion surgery for tumors and cases with negative wound cultures were also excluded from analysis.

Each case patient was matched with a control (1:2 ratio) of the same preoperative diagnosis (degeneration, trauma, or pediatric deformity), with surgery performed immediately before and immediately after the index case, using a previously described methodology.¹²

Electronic and paper medical records were retrospectively reviewed for all cases and controls. Patient-related variables included demographic data (age and sex), body mass index, the American Society of Anesthesiologists (ASA) physical status classification system, presence of diabetes mellitus, current tobacco use, preoperative hemoglobin value, and previous spine intervention. The indication for each surgical procedure was categorized as degenerative spine disease, trauma, or pediatric spinal deformity.

Intraoperative parameters collected included number of instrumented levels, type of bone graft used (local autograft alone, iliac crest bone graft, allograft) and cage use, vertebral region involved, estimated intraoperative blood loss, procedure and anesthesia duration, blood transfusion requirements, appropriate antibiotic prophylaxis (intravenous cefazolin or clindamycin administered within 60 minutes of incision, and repeated for procedures exceeding 240 minutes). Postoperative risk factors assessed included blood transfusion requirements, total hospital length of stay, and placement and duration of drains.

Statistical Methods

Statistical analysis was performed using SPSS 25.0. Univariate analysis was conducted to identify the potential risk factors for SSI using Student *t* tests for continuous data and χ^2 tests for dichotomous data. Multivariate logistic regression analysis was performed to determine the independent risk factors by systematically pruning the least significant variables out of a multiple logistic regression model that initially included all variables. A significant difference was set as $P < .05$.

RESULTS

During the study period, from a total of 2582 surgeries, 33 cases (1.3%) were identified with SSI according to study inclusion criteria: 14 (out of 1326) in the degenerative group, 11 (out of 207) in the trauma group, and 8 (out of 850) in the pediatric spinal deformity group. Each case was paired with 2 controls with a total of 66 patients. Infections were diagnosed a mean of 76 days postprocedure (range: 15–330 days). Twenty-seven patients (82%) underwent at least 1 reoperation to treat the infection with debridement of the infected tissue.

The most common microorganism isolated from the cultures obtained from the surgical wounds was *Staphylococcus aureus*, which was found in 22 cases, 12 of which were methicillin resistant. Most of the cases were monomicrobial, but in 10 cases (30%) a polymicrobial infection was found. Table 1 provides a summary of the microorganisms identified in the reported infections.

Univariate analysis of patient- and surgery-related risk factors associated with spinal fusion surgical site infection is presented on Table 2. In the degenerative group, statistically significant differ-

Table 1. Clinical features of cases of surgical site infection following spinal fusion procedures.

| Pathogens | Value, n = 33 |
|--|---------------|
| Gram-positive, n (%) | |
| <i>Staphylococcus aureus</i> , methicillin susceptible | 12 (36) |
| <i>Staphylococcus aureus</i> , methicillin resistant | 10 (30) |
| Coagulase-negative staphylococci | 5 (15) |
| Others | |
| <i>Enterococcus faecalis</i> | 2 (6) |
| <i>Streptococcus mitis</i> | 1 (3) |
| <i>Streptococcus salivarius</i> | 1 (3) |
| Gram-negative, n (%) | |
| Enterobacteriaceae | |
| <i>Escherichia coli</i> | 3 (9) |
| <i>Proteus mirabilis</i> | 1 (9) |
| <i>Klebsiella pneumoniae</i> | 4 (12) |
| <i>Enterobacter aerogenes</i> | 1 (9) |
| <i>Morganella morganii</i> | 1 (9) |
| <i>Pseudomonas aeruginosa</i> | 2 (6) |
| Others, n (%) | |
| <i>Acinetobacter baumannii</i> | 2 (6) |
| Polymicrobial | 10 (30) |
| Time to SSI diagnosis, d | 76 |
| Surgical treatment, yes, n (%) | 27 (82) |

Abbreviation: SSI, surgical site infection.

ences were found in surgery duration (175 ± 53 [mean \pm SD] minutes in cases and 136 ± 54 minutes in controls, $P = .032$) and anesthesia duration (233 ± 65 minutes in cases and 190 ± 60 minutes in controls, $P = .038$). In the trauma group, among patient-related risk factors, cases were significantly older (67 ± 16 versus 48 ± 20 years old, $P = .014$) when compared with controls. Cases

Table 3. Multivariate logistic regression model for surgical site infection after spine instrumentation.

| Multivariate Analysis | P | OR | 95% CI |
|---------------------------------|------|-------|------------|
| Denegenerative | | | |
| Procedure duration, h | .041 | 2.23 | 1.03–4.82 |
| Trauma | | | |
| Procedure duration, h | .017 | 3.79 | 1.27–11.32 |
| Length of instrumentation (lvl) | .017 | 11.77 | 1.55–89.40 |

Abbreviations: CI, confidence interval; lvl, number of levels; OR, odds ratio.

had higher blood transfusion requirements during and after surgery compared with controls (both $P = .039$). In the pediatric deformity group, cases presented a higher ASA score when compared with controls ($P = .022$) and SSI occurred more frequently in neuromuscular scoliosis in comparison with idiopathic scoliosis ($P = .002$).

After multivariate analysis (Table 3), procedure duration was the only statistically significant independent risk factor for SSI in degenerative surgery, so that each additional hour of surgery doubled the risk for SSI (odds ratio [OR], 2.23; 95% confidence interval [CI], 1.03–4.82). In the trauma group, this difference was even more pronounced, with an almost fourfold higher SSI risk for each additional hour of surgery (OR, 3.79; 95% CI, 1.27–11.32). Also, in trauma spine surgery, a supplemental level of instrumentation represented a 12-fold increased

Table 2. Univariate analysis of patient-related and surgery-related risk factors associated with spinal fusion surgical site infection.

| Univariate Analysis | Degenerative | | | Trauma | | | Pediatric Spinal Deformity | | |
|----------------------------------|-----------------------|--------------------------|------|-----------------------|--------------------------|------|----------------------------|--------------------------|------|
| | Cases (n = 14), n (%) | Controls (n = 28), n (%) | P | Cases (n = 11), n (%) | Controls (n = 22), n (%) | P | Cases (n = 8), n (%) | Controls (n = 16), n (%) | P |
| Sex (male) | 5 (36) | 7 (25) | ns | 8 (73) | 12 (55) | ns | 3 (38) | 4 (25) | ns |
| Age (years) | 60 (13) | 62 (17) | ns | 67 (16) | 48 (20) | .014 | 16 (3) | 16 (2) | ns |
| BMI (kg/m ²) | 28 (3) | 28 (5) | ns | 25 (2) | 26 (4) | ns | 20 (3) | 23 (6) | ns |
| Diabetes mellitus | 0 (0) | 3 (11) | ns | 1 (9) | 1 (4.5) | ns | 0 (0) | 0 (0) | ns |
| Tobacco use | 1 (7.2) | 1 (3.6) | ns | 3 (27) | 4 (18) | ns | 0 (0) | 1 (6) | ns |
| ASA ≥ 3 | 3 (21) | 5 (20) | ns | 5 (46) | 5 (23) | ns | 4 (50) | 0 (0) | .002 |
| Previous surgery | 4 (29) | 2 (7) | ns | 1 (9) | 1 (4.5) | ns | 0 (0) | 0 (0) | ns |
| Preoperative hemoglobin (g/dL) | 13.6 (2.2) | 13.3 (1.7) | ns | 13.6 (1.6) | 13.7 (1.6) | ns | 13.7 (1.1) | 13.9 (0.9) | ns |
| Length of instrumentation (lvl) | 1.5 | 2.2 | ns | 3 | 2 | ns | 13 | 11 | ns |
| Materials | | | | | | | | | |
| Autograft alone | 9 (64) | 17 (61) | ns | 1 (9) | 1 (4.5) | ns | 6 (75) | 15 (94) | ns |
| Iliac crest bone graft | 1 (7.2) | 1 (3.6) | ns | 0 (0) | 0 (0) | ns | 0 (0) | 0 (0) | ns |
| Cage | 0 (0) | 5 (18) | ns | 0 (0) | 0 (0) | ns | 0 (0) | 0 (0) | ns |
| Others | 0 (0) | 0 (0) | ns | 0 (0) | 0 (0) | ns | 2 (25) | 0 (0) | ns |
| EBL (mL) | 380 | 323 | ns | 145 | 111 | ns | 1010 | 1048 | ns |
| Intraoperative transfusion (yes) | 2 (15) | 2 (8) | ns | 2 (18) | 0 (0) | .039 | 2 (25) | 2 (13) | ns |
| Postoperative transfusion (yes) | 3 (21) | 3 (11) | ns | 2 (18) | 0 (0) | .039 | 4 (50) | 8 (50) | ns |
| Antibiotics | 11 (79) | 24 (86) | ns | 10 (91) | 18 (82) | ns | 8 (100) | 15 (94) | ns |
| Procedure duration (min) | 175 (53) | 136 (54) | .032 | 193 (45) | 107 (38) | ns | 183 (27) | 183 (44) | ns |
| Anesthesia duration (min) | 234 (65) | 191 (60) | .038 | 264 (48) | 168 (51) | ns | 282 (44) | 244 (48) | ns |
| Drainage placement (yes) | 2 (15) | 12 (43) | ns | 1 (9) | 0 (0) | ns | 1 (13) | 3 (19) | ns |
| Drainage duration, d | 1 | 1 | ns | 1 | - | ns | 1 | 1 | ns |
| Length of hospital stay, d | 20 | 6 | ns | 52 | 6 | ns | 10 | 5 | ns |
| Neuromuscular scoliosis | na | na | | na | na | | 4 (50) | 0 (0) | .002 |

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; EBL, estimated blood loss; lvl, number of levels; ns, not significant.

risk for SSI (OR, 11.77; 95% CI, 1.55–89.40). In the pediatric deformity group, no statistically significant results were found in multivariate analysis.

DISCUSSION

SSI is one of the most frequent and feared complications after spinal instrumentation surgery, representing an increase in morbidity and mortality for patients, considering the necessity for reoperation and long-term antibiotic therapy, as well as the potential need for hardware removal and potential risk of nonunion. Furthermore, SSI is a major driver of increased health-care costs, since it leads to prolonged care and therapy, unplanned hospital readmission, and delayed return to work. Because of its relevance, numerous studies have been carried out to identify risk factors associated with SSI after spinal surgery and several have been detected.^{7,12,13} However, most of these studies included mixed populations with and without spinal instrumentation, and are mainly focused on patients with degenerative disorders. It has been previously shown that the risk of SSI is greater in patients undergoing instrumentation compared to patients in whom only decompression is performed.^{14,15}

In addition, previous studies include cases of infection of patients with different spine pathologies, making an overall analysis of these patients difficult and biased. This is because degenerative pathology, spinal trauma, and pediatric spine deformity have their own characteristics related to patients and procedures, which require an independent analysis of these risk factors.

Taking these aspects into consideration, the objective of the present study was to identify risk factors for patient-dependent SSI in groups of patients with degenerative disease, traumatic injury, and pediatric spinal deformities undergoing spinal instrumentation surgery.

In this study, the duration of the procedure in the degenerative and trauma surgery groups presented as an independent risk factor for SSI with an increased risk of 2- and 4-fold, respectively, as previously demonstrated.⁸ A greater extension of instrumentation is also a previously identified risk factor for SSI.^{3,16,17} Since increasing the number of spinal levels fused will tend to require increased operative time, these procedure-related factors are likely linked, which may complicate the ability to assess them independently. Despite the statistically significant differences in univariate analysis in age

(trauma surgery) and ASA score (pediatric spine deformities), these results were not confirmed in the multivariate analysis model. On the other hand, potentially modifiable factors such as obesity,^{18,19} diabetes mellitus,^{16,20} and smoking status²¹ all of which are frequently associated with SSI and confirmed in multiple studies of spine surgery, were also not observed, so definitive conclusions could not be drawn based on the current data. Nevertheless, they should be considered.

The same applies to the etiology of scoliosis, which is a known strong determinant of infection rate. As reported by previous studies, the rate of wound infection after surgery for neuromuscular scoliosis ranges from 4% to 14%.²² However, the corresponding infection rate ranges from 1% to 3% in idiopathic scoliosis.²³ Patients with neuromuscular scoliosis stay in the intensive care unit during the postoperative period, are often nonambulatory, and may have difficulty in performing personal hygiene and poor preoperative nutrition, which may directly contribute to the higher risk of postoperative infection.²⁴

Although the risk factors that we were able to highlight are generally well recognized, strategies to address these risk factors are not consistently applied. In the setting of elective spinal fusion, preoperative management of modifiable risk factors may help to reduce the risk of SSI. According to our study, when feasible, modification of surgical strategies may offer additional opportunities to reduce the risk of SSI, including: minimizing the number of spinal levels to be fused and employing strategies to minimize operative time (eg, use of 2 attending surgeons for more complex cases).⁸ Even after controlling for all the previously described factors, adjuvant strategies can be implemented in high-risk populations with neuromuscular scoliosis or advanced age, or during long spine instrumentations, which proved to greatly decrease the incidence of postsurgical wound SSI following spinal surgeries.

The application of local vancomycin in powder form within the surgical wound as an adjunct to parenteral antibiotics to decrease the risk of SSI has gained widespread popularity among spine surgeons. Intrawound vancomycin powder appears to be a promising option for additional antibiotic prophylaxis due to its low cost, extensive availability, ease of application, good safety profile, and perception of effectiveness against most commonly

isolated pathogens in SSI such as gram-positive including methicillin-resistant *Staphylococcus aureus* and multidrug-resistant *Staphylococcus epidermidis*.^{25,26} Although development of vancomycin-resistant pathogens is a reasonable concern, evidence to date does not show an increase in SSI caused by such pathogens in patients who received intrawound vancomycin.²⁷

Regarding antibiotic perioperative prophylaxis, in addition to the usual cefazolin within 1 hour before skin incision,²⁸ intraoperative redosing also appears to reduce SSI risk in operations lasting longer than 4 hours.²⁹ There is a strong recommendation to limit the use of perioperative antibiotic prophylaxis to 24 hours and avoiding the use of broader-spectrum antimicrobials, even in the presence of long instrumentations or using of closed suction drains for more than 24 hours.²⁶

Closed suction drains have been used to decrease the rate of postoperative hematoma formation and thus SSIs. However contrary to previous beliefs, there is no difference in the incidence of hematoma, superficial wound infection, or deep infection in patients with versus patients without closed suction drains after lumbar surgery.^{30,31} Therefore, spine surgeons should not routinely rely on closed suction drains and the decision regarding its use should be individualized.

Closed-incision negative-pressure wound therapy and silver-impregnated dressings have been adapted by many spine surgeons as a safe and effective means of wound management in patients with increased risk of SSIs after spinal procedures; however, current evidence does not include sufficient high-level evidence defining the specific indications for its use in spine patients.²⁶

Whenever possible, a minimally invasive approach should be considered, as it presents a lower risk of SSI than open approaches.³²

The major limitation of this study was its retrospective design, so the accuracy of the data was dependent on the documentation inserted into electronic and paper medical records. Additionally, this is a single-institution study, with a limited dataset, and the lack of significance of some of the parameters of potential interest may reflect insufficient statistical power.

CONCLUSION

This study identified procedure duration as a risk factor for SSI after spinal instrumentation in

degenerative and trauma spine surgery; the number of levels instrumented was an additional risk factor in trauma spine surgery. Awareness of these factors will help to develop strategies to improve patient and health system overall outcomes.

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