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Major Article

Incidence and risk factors for infection in spine surgery: A prospective multicenter study of 1764 instrumented spinal procedures

Wenfei Gu MD, Laiyong Tu MD, Zhiquan Liang MD, Zhenbin Wang MD, Kahaer Aikenmu MD, Ge Chu MD, Enfeng Zhang MD, Jiang Zhao MD *

Department of Spine Surgery of Traditional Chinese Hospital Affiliated With Xinjiang Medical University, Urumqi, Xinjiang, China

Key Words:
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Background: Surgical site infection (SSI) is a common complication in spinal surgery, imposing a high burden on patients and society. However, information about its characteristics and related risk factors is limited. We designed this prospective, multicenter study to address this issue.

Methods: **:** From January 2015 through February 2016, a total of 1764 patients who had spinal trauma or degenerative spinal diseases were treated with instrumented surgeries and followed up for 1 year with complete data. Data on all patients were abstracted from electronic medical records, and SSIs were prospectively inspected and diagnosed by surgeons in our department. Any disagreement among them was settled by the leader of this study. SPSS 19.0 was used to perform the analyses.

Results: A total of 58 patients (3.3%, 58 of 1764) developed SSI; 1.1% had deep SSI, and 2.2% had superficial SSI. Of these, 60.6% (21 of 33) had a polymicrobial cause. Most of them (51 of 58) occurred during hospitalization. The median occurrence time was 3 days after operation (range: 1–123 days). SSI significantly prolonged hospital stays, by 9.3 days on average. The univariate analysis revealed reason for surgery as the only significant risk factor. The multivariate analysis, however, revealed 8 significant risk factors, including higher BMI, surgical site (cervical), surgical approach (posterior), surgery performed in summer, reasons for surgery (degenerative disease), autograft for fusion and fixation, and higher preoperative platelet level.

Conclusion: Identification of these risk factors aids in stratifying preoperative risk to reduce SSI incidence. In addition, the results could be used in counseling patients and their families during the consent process.

INTRODUCTION

With the rapid development of transportation and the aging of the population, the incidence of spinal trauma and degenerative spinal diseases is on the rise. Spinal surgery with instrument fixation is currently the predominant treatment choice for such diseases. However, postoperative complications are inevitable, and surgical site infection (SSI) is the most common type, with a reported incidence[1-4] of 1%–15%. The occurrence of SSI has a substantial impact on patients. Aside from its substantive effect on patient survival and quality of life, SSI markedly increases health care costs for patients undergoing spinal surgery, with prolonged hospital stay being a major contributor. In addition, readmission to the hospital for wound treatment and management is another costly intervention, required for approximately 25% of these patients.[5] Therefore, comprehensive preoperative evaluation of patients' medical conditions, identification of related risk factors for SSI, and introduction of cost-effective interventions for preventing SSI are certainly warranted.

Several risk factors have been found to be significantly associated with the occurrence of SSI in spine surgery: male gender, advanced age, higher body mass index (BMI; >30), smoking, diabetes, poor nutritional status (preoperative albumin level <3.5 mg/dL), history of infection in the surgical site, preoperative steroid therapy, spinal trauma, posterior spinal fusion, number of levels

* Address correspondence to Jiang Zhao, MD, Department of Spine Surgery of Traditonal Chinese Hospital Affiliated With Xinjiang Medical University, NO.116 HuangHe Rd, Urumqi City, Xinjiang Province 830000, China.
E-mail address: xjzhaojiang111@163.com (J. Zhao).

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fused, and prolonged surgical time (>3 hours).[6–13] However, most of these results come from single-center, retrospective studies that generally were limited by inaccuracy of collected data owing to patients'recall bias and incomplete medical records. Consequently, underestimation of the incidence of this complication, and imprecise estimation of risk for some variables, are inevitable. In addition, a tertiary referral center is generally the type of institution at which research of a certain sample of participants can be conducted; thus, participants' medical conditions are typically more severe and do not represent the overall incidence of spinal surgery. Given these issues, we designed the current research as a prospective, multicenter study with 2 aims: to describe the incidence and characteristics of SSI in instrumented spine surgeries during at least 1-year of follow up; and to investigate related risk factors for SSI.

METHODS

This prospective, multicenter study involved 3 hospitals (1 level I and 2 level II hospitals) in the Xinjiang Province of China and was performed during a 14-month period from January 2015 through February 2016. All patients aged 18 years or older who had spinal diseases (traumatic fractures; degenerative spinal diseases such as spinal canal stenosis, spondylolisthesis, and lumbar disk herniation) treated by instrumented surgery (decompression or fusion) were included. The exclusion criteria were: age less than 18 years; history of spinal surgery; pathological fractures (metastasis, tuberculosis); old fractures (>21 days from initial injury); and reoperation for other specific reasons (deformity, revision, infection, malignancy).

To analyze the relationship between risk factors and SSI, as much information as possible was collected about the patient, the surgical procedure, and laboratory test results. Patient-related characteristics included the following: age; gender; BMI; place of residence (city or village); current smoking status; current alcohol use level; and comorbidities (diabetes mellitus, hypertension, coronary heart disease, pulmonary disease, chronic nephrosis, anemia, long-term steroid therapy, and any previous operation). Surgery-related variables included the following: reason for surgery (trauma, degenerative diseases); length of preoperative hospital stay; length of total hospital stay; surgical location (cervical, thoracic, lumbosacral); season in which surgery was performed; hospital level (I or II); surgeon level (visiting staff, vice archiater, and archiater); American Society of Anesthesiologists, anesthesia type (general, regional); intraoperative antibiotic use; postoperative antibiotic use; duration of surgery; incision cleanness grades; level of intraoperative blood loss; number of instrumented levels; and postoperative drainage use. Variables from laboratory tests were as follows: white blood cell count; red blood cell count; platelet (PLT) level; hemoglobin level; neutrophil count; lymphocyte count; monocyte count, eosinophil count; basophil count; total protein level; albumin level; globulin level; and albumin/globulin ratio.

Definition and identification of SSI and quality control

An SSI was diagnosed on the basis of the SSI definition criteria put forth by Mangram et al.[14] at the Centers for Disease Control and Prevention. We considered an SSI to be deep if it met any of the following criteria: infection beyond the deep fascia, persistent wound discharge or dehiscence, visible abscess or gangrene requiring surgical debridement and instrument exchange or removal. Wound swabs were collected and sent for causative agent culture and sensitivity analysis, if available. Any patient who commenced antibiotic treatment for wound problems (redness, swelling, heat, pain) and did not meet the criteria for diagnosis of deep SSI was deemed to have a superficial SSI, irrespective of any microbiology results. Based on the timing of SSIs, we created a line chart, with the x-axis indicating timing (day of occurrence), and the y-axis indicating the overall number of SSIs over the elapsed time.

Data on infection were collected by the 6 surgeons in the department of spinal surgery, who were trained by the infection control team of our hospital before the start of this study. These 6 surgeons visited the patients' wards every day and inspected suture sites for signs of infection, starting from the second postoperative day and continuing until patients were discharged from the hospital. Any disagreements on the identification of a specific SSI were settled by the leader of this study (Jiang Zhao, corresponding author). After patients were discharged, surgeons followed up with them via telephone to determine if SSI was present, at 2 weeks, and 1, 3, 6, and 12 months postoperatively. For patients suspected of having SSI were asked to provide detailed information on timing of occurrence, treatment course, and results. If any doubts arose regarding accuracy of patient reporting, the patient was excluded from the study, to ensure precision of the data.

Definition of variables of interest

Patients' BMI was calculated, as weight divided by the square of height, and was divided into 5 groups on the basis of Chinese reference criteria (underweight, <18.5; normal, 18.5–23.9; overweight, 24–27.9; obese, 28–31.9; morbidly obese, ≥32). Preoperative hospital stay, defined as the interval between admission to the hospital and day of surgery, was divided into 3 groups, by duration in days: <3, 3–6, and ≥7.

Patients' lifestyles and comorbidities were obtained directly from patients and their relatives or from electronic medical records, and were represented as being present or not. Specifically, smoking status is indicated as "present" only if a patient was a then-current smoker; those who had smoked previously or who smoked only very occasionally (<1 cigarette every 3 days) are defined as "not present." Corticosteroid use in a regular regime for at least 1 month before the hospitalization is indicated as "present"; any other use was classified as "not present." Cleanness of the operating room was classified into 1 of 4 levels, according to the bacterial quantity per square centimeter. Intraoperative blood loss level was divided into 5 groups (in ml): <200, 200–399, 400–599, 600–799, and ≥800.

For results of laboratory tests, we documented their values and divided them into 3 groups: normal (range), above upper limit, and below lower limit.

This study was approved by the institutional review board of each of the 3 centers; all participants provided written consent.

STATISTICAL ANALYSIS

The mean and standard deviation were calculated for continuous variables; number and percentage were calculated for categorical variables. First, a univariate logistic regression analysis was performed to evaluate the relationship between each categorical variable and SSI. The *t*-test or Mann-Whitney U test was used for continuous variables, depending on the data distribution (equal variance and normality or not). A P value <.05 was considered to be significant. Further, all the related variables were entered into the multivariate logistic regression model to determine the independent risk factors for SSI. The Hosmer-Lemeshow C test was used to evaluate the goodness of fit of the final model.

RESULTS

During the 14-month study interval, all 1764 patients with a diagnosis of spinal disease (spinal trauma and degenerative diseases) who were treated with surgical instrumentation in the selected institutions were included. Of these, 933 were men and 831 were

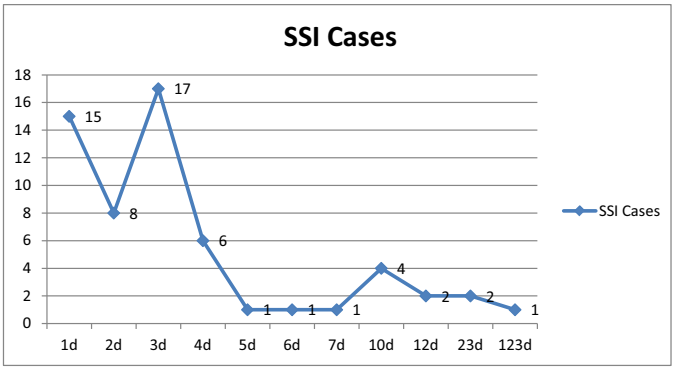

Fig 1. Distribution of SSI incidence per time elapsed.
SSI, surgical site infection.

women, and the SSI rate was, respectively, 2.9% (27 of 933) and 3.7% (31 of 831). The overall mean age was 51.9 years (range: 18–86 years), with a mean of 49.6 years (range: 18–86 years) for men and 54.5 years (range: 19–85 years) for women. Reasons for surgery were fractures only (461 cases), spinal cord injury (51 cases), fractures combined with spinal cord injury (16 cases), and degenerative disease (1172 cases).

Surgical sites were cervical spine (400 cases; 22.7%), thoracic spine (220 cases; 12.5%), and lumbar spine (1144 cases; 64.8%). Surgery was performed via a posterior approach, in most cases (79.3%; 1398 of 1764), an anterior approach (20.4%; 361 of 1764), or a combination of an anterior and posterior approach (0.3%; 5 of 1764). The number of surgeries did not vary greatly by time of year (370 in spring, 562 in summer, 426 in autumn, and 406 in winter). Patients generally waited for a mean of 4.3 days (range: 1–33 days) preoperatively for surgery, and stayed in the hospital a mean of 18.0 days overall (range: 5–133 days).

Characteristics of SSI

During the follow-up period, 58 patients (3.3%) developed SSI; 20 (1.1%) were deep SSIs, and 38 (2.2%) were superficial SSIs. All of the deep SSIs, and 13 of the superficial SSIs, were cultured for bacterial species. Results were as follows: 21 cases (60.6%) were polymicrobial; 6 were caused by methicillin-resistant *Staphylococcus aureus*, 4 by methicillin-susceptible *Staphylococcus aureus*, 1 by *Bacillus cereus*, and 1 by *Enterococcus faecalis*. The earliest diagnosis of SSI was at the first day after surgery; the latest was at 123 days postoperatively, with a median time at 3 days. A total of 51 SSIs occurred during hospitalization (87.9%), and 7 (12.1%) occurred after discharge from the hospital. Figure 1 details the timing of SSI occurrence. From Table 1, we can see patients without SSI were 4.5 years older than patients with SSI (52.1 ± 12.9 vs 47.6 ± 13.5, $P = .009$). Patients with an SSI had to stay in the hospital significantly longer than did those without an SSI (26.5 ± 14.7 vs 17.2 ± 9.4, $P < .001$). No significant difference was observed between the SSI and non-SSI groups for the following continuous variables: BMI (25.3 ± 3.1 kg/m^2 vs 25.0 ± 3.7 kg/m^2, $P = .516$); length of preoperative stay (4.8 ± 3.4 days vs 4.3 ± 3.4 days, $P = .266$); incision length (12.2 ± 5.7 cm vs 12.1 ± 4.9 cm, $P = .864$); intra-operative blood loss (534.0 ± 457.3 ml vs 493.1 ± 511.2 ml, $P = .548$); and operation duration (158.5 ± 70.5 mins vs 149.9 ± 66.1 mins, $P = .333$); and C-reactive protein level (67.8 ± 33.4 mg/10L vs 72.2 ± 27.9 mg/10L, $P = .243$).

Table 1
Comparison of continuous variables in patients with vs without SSI

Variable	Patients without SSI (n = 1706) (mean±SD)	Patients with SSI (n = 58) (mean±SD)	*P* value
Age (y)	52.1 ± 12.9	47.6 ± 13.5	.01
Body mass index (kg/m^2)	25.0 ± 3.7	25.3 ± 3.1	.52
Preoperative stay (d)	4.3 ± 3.4	4.8 ± 3.4	.27
Hospital stay (d)	17.2 ± 9.4	26.5 ± 14.7	<.001
Incision length (cm)	12.1 ± 4.9	12.2 ± 5.7	.86
Intra-operative blood loss (ml)	493.1 ± 511.2	534.0 ± 457.3	.55
Surgery duration (min)	149.9 ± 66.1	158.5 ± 70.5	.33
C-reactive protein (mg/10L)	72.2 ± 27.9	67.8 ± 33.4	.24

SD, standard deviation; *SSI*, surgical site infection.

Univariate and multivariate analyses

In the univariate analysis, reason for surgery (spinal fracture only, spinal cord injury only, fracture combined with spinal cord injury and degenerative disease) was found to be the only significant risk factor for development of SSI after instrumented spinal surgeries ($P = .027$). Age, diabetes mellitus, current smoking status, allergy, and drainage use were not found to be significant risk factors ($P < .1$, but $P > .05$). Other factors, including demographics, underlying diseases, perioperative factors, and results from laboratory tests were not associated with SSI occurrence. Detailed information on these finding is presented in Table 2.

All the related variables were entered into the multivariate logistic regression model. After adjustment for confounding factors, higher BMI, surgery site, surgical approach (posterior), surgery performed in summer, reason for surgery (degenerative disease), autograft for fusion and fixation, and a higher preoperative PLT level were found to be significantly associated with SSI after instrumented spinal surgeries. Results are detailed in Table 3.

The results of the Hosmer-Lemeshow test demonstrated the adequate fitness of the final model ($X^2 = 4.675$, $P = .792$; Nagelkerke $R^2 = .185$).

DISCUSSION

Most patients who need surgery for spinal degenerative diseases are elderly and have accompanying morbidities, which make them more likely to be predisposed to adverse complications postoperatively. Spinal trauma, including fracture, spinal cord injury, and spine instability, is also likely to be complicated by adverse events, mainly because of damage to circumambient soft tissues and blood supply. SSI has been found to be the most common complication in spinal surgeries, with a reported varied incidence of 0.7% to 12%,[7,15–19] depending on study design, type of surgery, and population studied. This study, with its prospective, multicenter design, had the dual aim of investigating both the incidence of and risk factors for SSI after instrumented spinal surgeries. Results revealed the overall SSI prevalence to be 3.3% within 1 year of follow-up—1.1% for deep SSI, and 2.2% for superficial SSI. Hospital stays were prolonged by SSI by up to 9.3 days, considering only the first hospital admission. Approximately 90% of the SSIs occurred during the hospitalization; in three-fifths of cases, the causative pathogenic microorganism was polymicrobial. The following factors were found to be significantly associated with SSI after instrumented spinal surgeries: a higher BMI, surgery site in the cervical spine, a posterior surgical approach, surgery performed during summer, degenerative disease requiring surgery, autografting for fusion and fixation, and a higher preoperative PLT level.

The incidence of SSI reported in this study was consistent with that reported previously in the literature.[7,20,21] In a prospective single study of 1030 patients who underwent elective, routine, degenerative lumbar surgeries, Klemencsics et al.[20] reported an SSI incidence

Table 2
Univariate analysis of factors associated with SSI after surgery

Variable	Patients without SSI (n = 1706)	Patients with SSI (n = 58)	*P* value
Hospital (level II)	744 (43.6)	28 (48.3)	.481
Surgeon level (archiater)	1131 (66.3)	31 (53.4)	.206
Season in which surgery was performed (summer)	562 (32.9)	23 (39.7)	.168
Level of operating room (class 10,000 and higher)	363 (21.3)	15 (25.9)	.924
Professional (peasant)	1400 (82.1)	52 (89.7)	.143
Gender (male)	800 (46.9)	31 (53.4)	.327
Preoperative stay (≥3 d)	1120 (65.7)	45 (77.6)	.247
Autograft for fusion and fixation	785 (46.0)	33 (56.9)	.105
Diabetes mellitus	103 (6.0)	7 (12.1)	.068
Hypertension	387 (22.7)	12 (20.7)	.721
Chronic heart disease	79 (4.6)	3 (5.2)	.847
Steroid use	200 (11.7)	10 (17.2)	.193
Previous suregery in any site	355 (20.8)	13 (22.4)	.767
Current smoking	127 (7.4)	8 (13.8)	.079
Surgery duration (≥ 180 min)	545 (31.9)	21 (36.2)	.369
Incision cleanness (II–IV)	26 (1.5)	1 (1.7)	.990
Intraoperative blood loss ≥400 ml	1253 (55.8)	37 (63.8)	.444
Surgical sites			.235
Cervical	383 (22.5)	17 (29.3)	
Thoracic	213 (12.5)	7 (12.1)	
Lumar	1110 (65.0)	34 (58.6)	
Age (>60 y)	477 (28.0)	10 (17.2)	.073
Surgical approach			
Anterior	3519 (20.6)	10 (17.2)	
Posterior	1350 (79.1)	48 (82.8)	
Anterior and posterior combination	5 (0.3)	0	
Anesthesia (general)	1420 (83.2)	52 (89.7)	.492
Preoperative antibiotic use	245 (14.4)	8 (13.8)	.903
Intraoperative antibiotic use	1434 (84.1)	10 (82.8)	.791
Postoperative antibiotic use	1387 (81.3)	52 (89.7)	.113
Drainage use	1438 (84.3)	54 (93.1)	.077
White blood cells (10^9/L)			.884
References (4–10)	1458 (85.5)	50 (86.2)	
<4	63 (3.7)	2 (3.4)	.628
>10	185 (10.8)	6 (10.3)	
Neutrophils (10^9/L)			.628
References (1.8–6.3)	1388 (81.4)	48 (82.8)	
<1.8	23 (1.3)	2 (3.4)	
>6.3	295 (17.3)	8 (13.8)	
Lymphocytes (10^9/L)			.993
References (1.1–3.2)	1446 (84.8)	8 (100)	
<1.8	194 (11.4)	0	
>3.2	66 (3.9)	0	
Monocytes (10^9/L)			.198
References (0.1–0.6)	1393 (81.7)	44 (75.9)	
<0.1	24 (1.4)	0	
>0.6	288 (16.9)	14 (24.1)	
Eosinophils (10^9/L)			.747
References (0.02–0.52)	1408 (82.5)	50 (86.2)	
<0.02	268 (15.7)	6 (10.3)	
>0.52	29 (1.7)	2 (3.5)	
Basophils (10^9/L)			.997
References (0–0.06)	1638 (96.1)	58 (100)	
>0.06	66 (3.9)	0	
Red blood cells (10^{12}/L)*			.141
References	1496 (87.7)	55 (94.8)	
< lower limit	143 (8.4)	2 (3.4)	
> upper limit	67 (3.9)	1 (1.7)	
Hemoglobin (g/L)*†			.346
References	1427 (83.6)	50 (86.2)	
< lower limit	136 (8.0)	6 (10.3)	
> upper limit	143 (8.4)	2 (3.5)	
Platelets			.102
References (100–300)	1518 (89.0)	48 (82.8)	
< lower limit	18 (1.1)	0	
> upper limit	170 (10.0)	10 (17.2)	

(*continued on next column*)

Table 2
Continued

Variable	Patients without SSI (n = 1706)	Patients with SSI (n = 58)	*P* value
Total protein			.350
References (65–85 g/L)	1201 (70.4)	44 (75.9)	
< lower limit	499 (29.2)	14 (24.1)	
> upper limit	6 (0.4)	0	
Incision length (>16 cm)	216 (12.7)	7 (12.1)	.453
ASA (≥3)	311 (18.2)	11 (19.0)	.459
Intraoperative transfusion	416 (24.4)	17 (29.3)	.455
History of allergy	127 (7.4)	8 (13.8)	.079
Causes for surgery			.027
Spinal fracture only	461(27.0)	8 (13.8)	
Spinal cord injury only	57 (3.3)	2 (3.4)	
Fracture combined with spinal cord injury	16 (0.9)	0	
Degenerative disease	1172 (68.7)	48 (82.8)	
Albumin (<40 g/L)	332 (19.5)	12 (20.7)	.845
Globulin (<20 g/L)	154 (9.0)	6 (10.3)	.799
Blood glucose (abnormal)	147 (8.7)	2 (3.4)	.188
Body mass index			
Reference (18.5–23.9)	693 (40.6)	18 (31.0)	.162
Underweight (<18.5)	26 (1.5)	0	
Overweight (24–27.9)	655 (38.4)	22 (37.9)	
Obesity (28–31.9)	272 (15.9)	13 (22.4)	
Morbid obesity (>32)	60 (3.5)	5 (8.6)	

NOTE. Values are n (%), unless otherwise indicated.
#Significant variable.
†Reference range: females, 110-150 g/L; males, 120-160 g/L.
‡Reference range: females, 3.5-5.0/10^{12}; males, 4.0-5.5/10^{12}.
ASA, American Society of Anesthesia; *SSI,* surgical site infection.

Table 3
Multivariate analysis of factors associated with SSI after instrumented spine surgery

Variable	Exp (B)	95% CI (lower limit)	95% CI (upper limit)	*P* value
Body mass index (kg/m^2)	1.27	1.02	1.59	.035
Surgical locations (cervical)	3.17	1.95	5.13	<.001
Surgical approach	5.59	2.08	15.04	.001
Surgeon level (others vs archiater)	1.83	1.19	2.81	0006
Season in which surgery was performed (summer)	2.16	1.17	4.00	.014
Reasons for surgery	1.46	1.08	1.96	.013
Autograft for fusion and fixation	2.12	1.11	4.04	.022
Preoperative platelet level	1.46	1.01	2.12	.049

rate of 3.5% in the test cohort, and 3.9% in the validation cohorts. That percentage was nearly the same as the percentage we found, which was 3.93% (48 of 1220) for degenerative spinal diseases in this study. The only difference was that their study included any type of surgery and we included only instrumented surgery. Cooper et al.[21] investigated the incidence of and risk factors for SSI in trauma patients treated by instrumented surgery in a single, level I center, and they observed an SSI incidence of 3.7%. The incidence they reported was higher than that found in our study, which was 1.7% (8 of 469) for spinal fracture only, and 3.4% (2 of 59) for spinal cord injury only. In addition, for deep SSI, we found an incidence of 1.1%, which was slightly higher than that (0.9%) reported by Ogihara et al.[13] in their prospective, multicenter study of deep SSI; surgery was performed via a posterior approach, which differed slightly from ours (anterior, posterior, and combination). With data from only those surgeries conducted via a posterior approach, the difference between the 2 studies in incidence of deep SSI was extremely small, because the posterior approach was itself a significant risk factor for SSI, relative to other approaches (odds ratio [OR], 5.59; 95% CI, 2.08–15.04). Direct comparison of this study and prior studies of SSI incidence is very difficult, if not impossible, due to the heterogeneity among studies in study design, participants, surgery type,

hospital level of treatment, and patients' medical conditions. However, using a prospective design and a large sample size, we were able to determine more- precisely the SSI incidence. In addition, this figure might be more useful for patients, especially those ready to undergo surgery.

In this study, we performed univariate and multivariate analyses to investigate the impact of related risk factors for development of SSI. In the univariate analysis, only reason for surgery (degenerative disease) was identified as a significant risk factor ($P = .027$). In the multivariate analysis, after adjustment for the multiple risk factors within individual patients, a total of 8 significant risk factors were identified, including reason for surgery (degenerative disease). The level of difference between the 2 statistical models was greater than anticipated, and we attribute this to 2 reasons. First, a total of 44 potential risk factors were included in this study, introducing high potential for confounding effects and interactions within individual patients, collectively resulting in SSI. This problem cannot be addressed with univariate analysis. Second, in the multivariate logistic regression model, we entered all 44 variables, except for those identified in the univariate analysis as having nearly significant ($P < .1$ or $P < .2$) or significant ($P < .05$) effects. The greatest advantage of conducting this analysis was to ensure that the significant risk factors were not omitted. For example, surgical site ($P = .235$) and surgeon level ($P = .206$) were not identified as risk factors, even with $P > .2$, in the univariate analysis, but were identified as such in the multivariate analysis (OR, 1.83; OR, 3.17). Therefore, we recommend the method of entering all the variables into the multivariate logistic regression model as a means to assess the multiple risk factors.

Of the 8 independent risk factors for SSI after spinal surgery, most (6 of 8) were surgery related (degenerative spinal disease, surgical site, surgical approach, surgeon level, surgery in summer, use of autografting). The surgeon's skills and experience did play an important role in reducing the incidence of SSI and other complications, especially for complex spinal diseases such as those with multilevel involvement, instable spinal fracture, and spinal cord injuries. The surgical site, and a posterior surgical approach, increased the OR of SSI occurrence by 3.17 and 5.59 times, respectively, in the current study; these were the most significant risk factors and have been reported widely.[7,8,22] Having an autograft for fusion and fixation was an important risk factor for SSI identified in the current study. However, the mechanism was unclear, and this variable has not been reported as a significant risk factor in the literature.[8,13] Poorer bone quality may have led to the need for an autograft for fixation or fusion, and thus was more likely a contributing factor than the autograft itself; this possibility needs verification in future research. Patients who underwent surgery in the summer were more likely to develop an SSI, compared with those who underwent surgery in other seasons, with an OR greater than 2 (2.16, range: 1.17–4.00). This result is consistent with that in our retrospective, multicenter study, and we attributed this effect to higher air temperature and humidity, which facilitated bacterial reproduction.[23]

The OR value of SSI increased 1.27 times per 4 units (kg/m^2) of BMI increase, and morbid obesity resulted in an SSI incidence as high as 7.7%. Fei et al.[8], in a meta-analysis, pooled the results in the literature and found that morbid obesity created a 2.33 times greater risk for SSI, similar to our results. Preoperative PLT level was identified as a significant risk factor for SSI ($P = .049$; OR, 1.46, 95% CI, 1.01–2.12). A higher PLT level ($>300*10^9/L$) indicated an existing pyogenic infection or an inflammatory response caused by specific inflammatory factors. Therefore, PLT level could have important predictive value in screening patients at high risk of SSI and thereby targeting preventive measures, including preoperative use of antibiotics.

In prior studies, diabetes mellitus was identified as a significant risk factor for SSI after spinal surgery.[8,9,23,24] However, in this study, diabetes mellitus was not found to be significantly associated with SSI, although it approached marginal significance in the univariate analysis ($P = .068$). The smaller number of patients with diabetes mellitus (6.3%), and the inclusion of dozens of potential risk factors in the final multivariate logistic model, may be responsible for these results. Similarly, steroid use, current smoking, and prolonged preoperative stay were not identified as risk factors in this study, although they have been found to be significant risk factors for SSI in previous studies.[9–11,25]

The risk of developing SSI cannot be completely avoided, because most risk factors are convertible, such as surgical site, BMI, and reason for surgery. However, given the high economic burden and morbidity rates, using all available instruments to reduce the occurrence of risk factors is very important in treating these patients. Therefore, preoperative, comprehensive evaluation of patients' medical conditions, lifestyle, and laboratory test results, and appropriately targeted and optimal precautionary and treatment protocols, are crucial in reducing the incidence of SSI. In addition, given that a considerable proportion of SSIs (12.1%) occur after patients are discharged from the hospital, patients and their relatives should be instructed to take care of the surgical site, especially during the first week at home.

This study has several limitations, despite its prospective, multicenter design and large sample size. First, some cases, such as those involving hematencephalon, presence of a tumor, liver disease, and anemia, had too small a sample size to allow investigation of their effects on SSI occurrence. Second, some variables that have potential to influence the development of SSI were not included because they were not considered prior to the start of the study, such as instrument materials (e.g., stainless steel, titanium, other) and types of intraoperative blood transfusion.

SUMMARY

During the postoperative 12-month follow-up period, a total of 58 SSIs (3.3%) occurred in 1764 cases of instrumented spinal surgeries, with 12.1% (7 of 58) occurring after patients' discharge from the hospital. Incidence of SSI significantly prolonged hospitalization (26.5 vs 17.2 days). Higher BMI (especially morbid obesity), surgical site, surgical approach (posterior), surgery performed in summer, reasons for surgery (degenerative disease), autograft for fusion and fixation, and higher preoperative PLT level were found to be significantly associated with SSI after instrumented spinal surgeries. Identification of these risk factors for SSI could be of great value in risk–benefit analysis of prophylaxis after spinal surgery, and aid in stratifying preoperative risk to reduce SSI incidence. In addition, the results could be used in counseling patients and their families during the consent process.

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