Risk Factors for Surgical Site Infection in Spinal Surgery and Interventions: A Retrospective Study

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Abstract

Background: Surgical site infection following spinal surgery causes prolonged delay in recovery after surgery, increases cost, and sometimes leads to additional surgical procedures. We investigated risk factors for the occurrence of surgical site infection events in terms of patient-related, surgery-related, and postoperative factors.

Methods: This retrospective study included 1000 patients who underwent spinal surgery in our hospital between April 2016 and March 2019. Before September 2015, we observed multiple occurrences of spinal surgical site infections caused by methicillin-resistant *Staphylococcus aureus*, and we have since been culturing swabs taken from inside and outside the wound before postoperative wound closure as a form of surgical site infection surveillance.

Results: The patient-related factors of dementia, length of preoperative hospital stay (≥14 days), diagnosis at the time of surgery (traumatic injury or deformity), surgery-related factor of multilevel surgery (≥9 intervertebral levels), and postoperative factor of time to ambulation (≥7 days) were statistically significant risk factors for spinal surgical site infection. A retrospective study of 392 patients who underwent spinal surgery between June 2009 and August 2011, before surgical site infection surveillance was implemented, showed that the incidence of surgical site infection was 4.59%, although in this study, it had dropped to 2.0%.

Conclusion: The introduction of surgical site infection surveillance thus helps reduce the incidence of surgical site infection through measures taken by medical staff to prevent them and to improve associated problems. One risk factor identified in this study that is amenable to intervention is the time to ambulation. As delayed ambulation is a risk factor for postoperative surgical site infection, how medical staff can intervene in postoperative ambulation to further reduce the incidence of surgical site infection is a topic for future research.

Background

Surgical site infection (SSI) occurs in 0.6–13% of cases following spinal surgery, with the incidence varying depending on the type of surgery and definition of SSI [1–3]. Spinal SSIs cause long-term delays in postoperative recovery, increase medical costs by prolonging the length of hospital stay, and require long-term intravenous antibiotic administration and may require further surgical procedures, such as debridement [4]. Following spinal instrumentation surgery in particular, implant removal can result in the loss of correction, reducing patient satisfaction [5–7]. Therefore, early screening and measures to prevent SSI following spinal surgery are required. Recently, several studies have reported that spreading vancomycin powder (VP) inside the wound before wound closure is effective against spinal SSI [8–10], and before September 2015, our hospital recorded multiple occurrences of spinal SSI caused by methicillin-resistant *Staphylococcus aureus* (MRSA). In this study, we cultured swabs taken from inside and outside the wound before postoperative wound closure as part of SSI surveillance, with the objective of investigating the necessity of VP use and determining future intraoperative SSI preventive measures. In addition, risk factors for spinal SSI need to be identified to significantly reduce the incidence of spinal SSI. Regarding the risk factors for spinal SSI, many patient-related and surgery-related factors have been reported [11–14]. However, there are few reports on postoperative factors, such as leaving the bed, although postoperative factors may be involved in the occurrence of spinal SSI. Further reduction of spinal SSI can be expected by clarifying the risk factors and intervening in the possible risk factors. Our objectives were to investigate patient-related, surgery-related, and postoperative risk factors, discuss the future consideration of risk factors that may be amenable to intervention and results of surveillance, verify the efficacy of surveillance and further measures.

Methods

Participants

We conducted a retrospective study on 1000 patients (583 men and 417 women) who underwent spinal surgery at Kurume University Hospital between April 2016 and March 2019. Patients who underwent pin removal, surgery for pyogenic spondylitis, and balloon kyphoplasty were excluded.

The surgical site was the lumbar spine in 653 cases, thoracic spine in 43, cervical spine in 208, thoracolumbar spine in 73, cervicothoracic spine in nine, and cervical and lumbar spine in 14.

Ethics

The study was conducted in accordance with the ethical guidelines of the Declaration of Helsinki, as reflected in the prior approval given by institutional review board of Kurume University (approval no.20090). Informed consent was obtained by the opt-out approach, and personal information was protected during data collection.

Definition and assessment of SSI

Patients with suspected SSI were evaluated in accordance with the definition of SSI given in the Centres for Disease Control and Prevention guidelines [15]. In this study, SSI was categorised as superficial or severe, with deep incisional SSI and organ/space SSI classified as severe. SSI assessment was conducted both directly by actual observation of the surgical site by a senior spinal surgeon board-certified by the Japanese Society for Spine Surgery and Related Research, and indirectly by our hospital's infection control staff.

Preoperative cleaning

During preoperative cleaning, the skin of the surgical field was cleaned by brushing with benzalkonium chloride, after which it was disinfected with alcohol. As part of surveillance, before wound closure, 1 cm area of skin to the side of the wound was wiped twice with a swab, which was submitted to the clinical laboratory for bacterial culture (periwound culture). Similarly, the interior of the wound was also wiped twice with a swab, which was submitted for bacterial culture (intrawound culture).

Investigated parameters

In this study, we investigated the following patient-related factors: age, sex, steroid use, body mass index (BMI), preoperative urinary tract infection (UTI), antibiotic allergy, length of preoperative hospital stay, diagnosis at surgery (degenerative disease, trauma, tumour, or deformity), medical history (heart disease, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, bronchial asthma, rheumatoid arthritis, gastrointestinal ulcer, liver dysfunction, diabetes mellitus, paralysis, chronic kidney disease, malignant tumour, hypertension, metastatic tumour, and acquired immunodeficiency syndrome), and American Society of Anaesthesiologists performance status. Further, the following surgery-related factors were investigated: type of prophylactic antibiotic used, operator, spinal fusion, spinal decompression, number of intervertebral levels affected (multilevel surgery), surgical methods (conventional, minimally invasive, microscopic, or endoscopic), level at which surgery was performed, operating time, amount of haemorrhage, blood transfusion, time to ambulation, extrawound culture, and intrawound culture. Blood tests were performed to measure the following parameters: white blood cell and neutrophil counts, C-reactive protein, serum albumin, haemoglobin (Hb), aspartate transaminase, and alanine aminotransferase levels. Estimated glomerular rate and sedimentation were measured preoperatively and at 3, 7, and 14 days postoperatively. In addition, preoperative total protein, urinary protein, HbA1c, blood glucose levels, and prothrombin time/international normalised ratio were also measured. Dementia was defined as either an existing dementia diagnosis on admission or a score of ≥19 points on the revised Hasegawa Dementia Scale administered after admission for suspected cognitive decline. Time to ambulation was defined as the time until the patient was able to walk with an aid. Tissue samples were collected and cultured from patients who underwent debridement of an SSI.

Statistical analyses

We used the JMP® Pro 13.0.0 software (SAS Institute Inc., America) for the statistical analyses. Statistical analyses were performed in co-operation with experts, including a professor at the biostatics centre at Kurume University.

The risk factors for SSI were examined using the following procedure. First, the risk factors investigated were classified into patient-related, surgery-related, and blood test factors. Next, a logistic regression model with SSI as the response variable was applied to each risk factor group, and variables were selected in a stepwise method.

The minimum Bayesian information criterion method was used as the stopping rule for variable selection. To facilitate clinical interpretation of each continuous variable selected in the analysis of each risk factor group, binarization was performed using a tree model (CART) with SSI as the response variable for each variable. To finally construct the multivariate model, all the selected risk factors were subjected to variable selection again using the stepwise method. The SSI logistics model, including all risk factors selected by variable selection, was applied, and the effect of each factor was examined using the adjusted odds ratio. A p-value of < 0.05 was considered to show significant difference for all tests.

Results

Demographic data

Study participants' mean age was 65.45 ± 15.28 years and mean BMI was 24.23 ± 4.03. The mean follow-up time was 13.9 ± 11.0 months. The type of antibiotic used in 990 cases (99%) was cefazolin. Ten patients (1.0%) were allergic to cephem antibiotics, and these patients were treated with either clindamycin (five cases, 0.5%) or fosfomycin (five cases, 0.5%). Steroids were used in 44 patients (4.4%). A preoperative UTI was present in 45 patients (4.5%). Fusion was performed in 268 patients (26.8%) and decompression in 946 (94.6%) patients; the diagnosis at surgery was degenerative disease in 856 patients, trauma in 50, tumour in 64, and deformity in 30. Revision surgery was performed in 26 patients (2.6%). The mean operating time was 143.72 ± 83.47 min and the mean amount of haemorrhage was 170.74 ± 5.4 g. Overall, SSI occurred in 20 patients (2.0%), of which seven (0.7%) were superficial, and 13 (1.3%) were severe (Table 1).

Table 1
Demographic data

Parameter		Total	%
Number of patients		1000	
Sex	Male	583	58.3
	Female	417	41.7
Age*		65.44 ± 15.27	
BMI*		24.23 ± 4.03	
ASA score	1	112	11.2
	2	776	77.6
	3	111	11.1
	4	1	0.1
Diabetes patients		225	22.5
Preoperative steroid users		44	4.4
Surgical site	Cervical spine	208	20.8
	Thoracic spine	43	4.3
	Lumbar spine	653	65.3
	Cervicothoracic spine	9	0.9
	Cervical and lumbar spine	14	1.4
	Thoracolumbar spine	73	7.3
Disorder treated	Degenerative disease	856	85.6
	Traumatic injury	50	5.0
	Tumour	64	6.4
	Deformity	30	3.0
Revision surgery		26	2.6
Fusion		268	26.8
Decompression		946	94.6
Operating time*		143.72 ± 83.47 min	

*Mean ± standard deviation

Parameter		Total	%
Haemorrhage amount*		170.74 ± 5.4 g	
Antibiotic used	CEZ	990	99.0
	Other	10	1.0
SSI		20	2.0
	Superficial	7	0.7
	Severe	13	1.3
*Mean ± standard deviation			

Statistical analyses

The analysis was conducted using the stepwise method. Statistically significant differences were evident for the following patient-related factors: length of preoperative hospitalisation, dementia, and diagnosis; surgery-related factor: multilevel surgery; and postoperative factor: time to ambulation. None of the blood test factors were statistically significant. The following factors were found to be significant: preoperative hospitalisation for ≥14 days (odds ratio (OR): 12.58, 95% confidence interval (95% CI) 3.40–46.59, p = 0.0001), dementia (OR: 12.06, 95% CI: 3.06–47.59, p = 0.0004), trauma or degenerative disease (OR 3.31, 95% CI: 1.03–10.65 p = 0.045), surgery involving ≥9 intervertebral levels (OR 12.48, 95% CI: 2.47–62.99, p = 0.0023), and time to ambulation ≥7 days (OR 5.59, 95% CI: 1.90–16.47, p = 0.0018) (Table 2).

Table 2
Results of stepwise analysis

Parameter	*p*	Odds ratio	95% CI
Length of preoperative hospital stay	0.0001	12.58	3.40–46.59
Traumatic injury or deformity	0.045	3.31	1.03–10.65
Dementia	0.0004	12.06	3.06–47.59
Multilevel surgery	0.0023	12.48	2.47–62.99
Time to ambulation	0.0018	5.59	1.90–16.47

Bacterial cultures

Intrawound and extrawound cultures were performed in 972 (97.2%) of the 1000 patients. Bacteria were detected in 21 intrawound (2.16%) and 54 extrawound cultures (5.56%). Of the strains isolated from intrawound cultures, *Propionibacterium acnes* was identified in four cases, *Staphylococcus capitis* in five, *S. epidermidis* in five, *S. hominis* in one, *S. intermedius* in one, and methicillin-resistant *S. epidermidis* in one. Of the strains isolated from the extrawound cultures, *P. acnes* was identified in six cases, *S. aureus* in two, *S. capitis* in five, *S. epidermidis* in eight, methicillin-resistant *S. epidermidis* in six, *S. hominis* in one, *S. lugdunensis* in one, and *S. simulans* in one. The isolated strains sum up to a total of 24 cases of *Staphylococcus sp.* (Table 3). Of the seven SSIs classified as superficial, bacteria were not identified in any intrawound culture (0%) and were identified in one extrawound culture alone (*S. epidermidis*, 14.2%). Furthermore, of the 13 SSIs classified as severe, bacteria were similarly not identified in any intrawound culture (0%) and were identified in one extrawound culture, alone (methicillin-resistant *S. epidermidis*, 7.69%). Of the 20 patients who developed SSI, 11 (55.0%), who were classified as severe, underwent debridement. The causative pathogen was *S. aureus* in 3/11 cases (27.27%), and methicillin-resistant *S. epidermidis* or *S. lugdunensis* in 3/11 cases (27.27%). No bacteria were cultured in the other five cases. All five patients underwent antibiotic treatment before debridement.

Table 3. Percentages of bacteria identified from culture.

	Bacteria identified from culture	%
Intrawound culture	*Propionibacterium acnes*	0.412%
	S. capitis	0.514%
	S. epidermidis	0.514%
	S. hominis	0.103%
	S. intermedius	0.103%
	Methicillin-resistant *S. epidermidis*	0.103%
	Bacteria identified from culture	%
Extrawound culture	*Propionibacterium acnes*	0.617%
	S. aureus	0.206%
	S. capitis	0.514%
	S. epidermidis	0.823%
	Methicillin-resistant *S. epidermidis*	0.617%
	S. hominis	0.103%
	S. lugdunensis	0.103%
	S. simulans	0.103%
	Staphylococcus spp.	2.47%

Discussion

Patient-related factors

In this study, the length of preoperative hospitalisation, dementia, and diagnosis at the time of surgery were found to be statistically significant patient-related factors. We identified preoperative hospitalisation for ≥14 days as a risk factor. In a retrospective study of risk factors for SSI among 358 patients who underwent spinal surgery, Cooper *et al.* [16] found that hospitalisation for ≥3 days was a risk factor. No previous study has identified dementia as a risk factor for spinal SSI, although in a systematic review, the American Academy of Orthopaedic Surgeons found a strong correlation between dementia and SSI in geriatric fractures [17]. An association between dementia and SSI in hip fracture surgery has also been reported, with patients with dementia having higher rates of SSI and other postoperative complications after hip fracture surgery [14]. In terms of diagnosis at the time of surgery, statistically significant differences were identified for traumatic injury and deformity. Several previous studies have identified traumatic spinal injury as a risk factor for spinal SSI [18, 19]. Watanabe *et al.* [20] reported that patients undergoing surgery for traumatic spinal injury are at a higher risk of SSI than those undergoing other types of spinal surgery. Blam et al. [19] reported that a longer preoperative waiting time for traumatic spinal injury is associated with SSI in US hospitals, with the incidence of SSI among patients waiting >160 h for surgery more than eight times higher than that of patients who undergo surgery within 48 h. In general, surgeries for the treatment of degenerative spinal disorders (scoliosis or kyphosis) have a long duration, cause a large amount of blood loss, and involve a large number of intervertebral levels, implying that the risk of SSI is higher than other types of spinal surgery [21–25]. It is probable that the same reasons also underlie the identification of degenerative disease as a risk factor in this present study.

Surgery-related factors

Surgery-related risk factors for spinal SSI have been widely reported, with operating time, posterior approach, amount of haemorrhage, and blood transfusion being among the identified important risk factors associated with SSI [11–14]. Highly invasive procedures are believed to increase the risk of SSI. In this study, multilevel surgery (≥9 intervertebral levels) was identified as a surgery-related risk factor for SSI. A longer operating time and multilevel surgery increase the amount of intraoperative haemorrhage and increase the risk of SSI; multilevel surgery requires a longer operating time, which increases tissue regression, leading to ischaemia and necrosis of the wound tissue and an increase in the risk of SSI [13]. Pesenti *et al.*[11] also reported that multilevel surgery is a risk factor for SSI because the fusion of more intervertebral levels requires a longer operating time, and they stated that the complex interrelations among surgery-related risk factors for SSI make individual assessment impossible. In this study, the mean operating time for patients who underwent multilevel surgery (≥9 intervertebral levels) was 350.06 ± 90.16 min, and mean amount of haemorrhage was 627.25 ± 520.86 g. In patients who did not undergo multilevel surgery (≥9 intervertebral levels), the mean operating time was 140.37 ± 79.08 min, and mean amount of haemorrhage was 108.82 ± 145.54 g. Surgery involving ≥9 intervertebral levels required a longer operating time and caused more haemorrhage, suggesting that surgery-related SSI risk factors may be interrelated in complicated ways.

Postoperative factors

In this study, time to ambulation was found to be a statistically significant postoperative risk factor for SSI. We identified the time to ambulation of ≥7 days as a risk factor. Dementia, a patient-related risk factor, also causes delayed ambulation. Diminished cognitive function may lead to the inability of patients to remain calm or comply with prohibitions, making postoperative wound hygiene more difficult to maintain compared with patients without dementia. No previous study has identified time to postoperative ambulation as a risk factor for spinal SSI. Patients with dementia have difficulties in following instructions from physiotherapists. Therefore, their postoperative rehabilitation may be prolonged, and the consequent delay in acquiring the ability to walk may lead to postoperative pneumonia or UTI and increase the risk of SSI [26]. Increase in the average lifespan due to the recent rapid medical developments and the consequent ageing population may lead to an expected increase in the number of spinal surgeries among the older population in future. The association between SSI and dementia and postoperative time to ambulation are topics for future studies assessing the need for interventions.

Surveillance

Results of the swab cultures of patients with postoperative SSIs conducted as part of routine surveillance in this study revealed no intrawound swab and one extrawound swab alone from the patients with superficial SSIs was positive for *S. epidermidis* (0.01%). No intrawound swab and one extrawound swab alone from the patients with severe SSIs was positive for methicillin-resistant *S. epidermidis* (0.01%). Debridement was performed on a patient with severe SSI who had methicillin-resistant *S. epidermidis* in an external swab, and the causative pathogen was methicillin-resistant *S. epidermidis*. Although it is easy to obtain bacterial culture samples by swabbing superficial SSIs, they also contain resident skin flora, and this can easily affect the test results [27]. There are extensive reports on the effectiveness of SSI surveillance in orthopaedic surgery. Mabit *et al.* [28] analysed 2 years of SSI surveillance data from orthopaedic and trauma surgeries in 7156 patients and found that the incidence of SSI decreased from 1.86–0.66%. Yamada *et al.* [29] also reported that the provision of appropriate interventions based on SSI surveillance data for high-risk patients undergoing spinal surgery reduced the incidence of SSI. A previous study on 392 patients in our hospital who underwent spinal surgery between June 2009 and August 2011 before the surveillance began, found that the incidence of SSI was 4.59% [30], although in the present study, the incidence dropped to 2.0%. The value of surveillance is that its implementation provides opportunities to review perioperative infection control measures and identify and improve issues, leading to improvements in the infection control measures taken by medical staff [29, 31]. On the other hand, an analysis of SSI surveillance data from a 10-year study in Denmark that began in 1985 of 12364 patients who underwent orthopaedic surgery found that there was no change in the incidence of SSI during the study period [32], and further studies on surveillance are required to verify its effect. In the other 10 patients who underwent debridement, the causative pathogen was differed between the intrawound and extrawound cultures. This suggests that with the exception of the patient from whom methicillin-resistant *S. epidermidis* was isolated from the extrawound swab, the intraoperative wound environment in the operating field was and remained hygienic before wound closure. Although *S. aureus* and MRSA were isolated from the bacterial cultures of patients who underwent debridement, MRSA was not detected. Because vancomycin (VCM) is poorly absorbed by the tissue, it tends to accumulate locally in high concentrations, making it effective in suppressing SSI [8, 33], and because locally administered VCM has low tissue distribution, it has a low risk of systemic adverse drug reactions [8]. However, Tsubaki *et al.* [34]

reported that the local administration of VP did not significantly decrease the incidence of SSI in spinal surgery, and if the incidence of infections is low, the use of VP may not necessarily be effective. The administration of VP to all patients is unrealistic, and the emergence of resistant bacteria due to the misuse of antibiotics is a concern. The appearance of VCM-resistant enterococci is a result of the oral use of VCM [35]. There is a high possibility of obtaining similar results when VP is misused. In this study, we found that the hygienic condition of the wound site before closure was maintained, and proactive VP use was thus unnecessary; it is effective when reserved for patients at high risk of infection.

Limitations

This study had some limitations. First, the diagnosis at the time of surgery was degenerative disease in most cases, making study biased. Second, preoperative bacterial screening in the form of preoperative nasal and skin swabs was not conducted, and we were therefore unable to identify bacteria that may have been present in the patients preoperatively. Third, there were only 20 cases of infection.

Conclusions

In this study, we identified length of preoperative hospital stay, diagnosis at the time of surgery, and dementia as patient-related risk factors; multiple-level surgery as a surgery-associated risk factor; and time to ambulation as the postoperative risk factor for spinal SSI. Among the risk factors identified, time to ambulation may be amenable to intervention by medical staff, and how medical staff can intervene with respect to postoperative ambulation is an important issue for reducing the incidence of spinal SSI in the future.

List Of Abbreviations

BMI, body mass index; CI, confidence interval; Hb, haemoglobin; MRSA, methicillin-resistant *Staphylococcus aureus*; OR, odds ratio; SSI, surgical site infection; UTI, urinary tract infection; VCM, vancomycin; VP, vancomycin powder

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the ethical guidelines of the Declaration of Helsinki, as reflected in the prior approval given by institutional review board of Kurume University (approval no.20090).

Informed consent was obtained from the opt-out approach, and personal information was protected during data collection.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the present study are available from the corresponding author on reasonable request.

Competing interests

None

Funding

None

Authors' contributions

RS, KS, KY participated in the study conception and design, data acquisition and interpretation, and manuscript drafting.KY, TY, and IN participated in data acquisition and interpretation. TS participated in analysis and interpretation of data. SM, KN and NS participated in data interpretation and revising the manuscript critically for important intellectual content.

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