Original Article

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

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Summary: ***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.

***Results*:** Patient-related factors were dementia, length of preoperative hospital stay ($\geq$ 14 days), and diagnosis at the time of surgery (traumatic injury or deformity). The one surgery-related factor was multilevel surgery ($\geq$ 9 intervertebral levels), and the one postoperative factor was time to ambulation ($\geq$ 7 days) were statistically significant risk factors for spinal surgical site infection.

***Conclusion*:** One risk factor identified in this study that is amenable to intervention is 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.

Keywords spinal surgery, surgical site infection, complication, risk factor

INTRODUCTION

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, 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, risk factors for spinal SSI need to be identified so as to facilitate early screening and implementation of measures 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 [8-11]. 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. We hope to achieve a further reduction of spinal SSI by clarifying the risk factors and identifying possible risk factors for intervention. 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 surveillance, and further measures.

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Abbreviations: BMI, body mass index; Hb, haemoglobin; MIS, Minimally invasive surgery; SSI, Surgical site infection; UTI, preoperative urinary tract infection.

MATERIALS AND 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's University (approval no.20090). Informed consent was obtained by the opt-out approach, and personal information was protected during data collection.

(*The name of university has been deleted for the review process*.)

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 [12]. 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.

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 tumor, 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, and time to ambulation. 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 $\leqq$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.

Statistical analyses

We used 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 construct the final 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 be statistically significant.

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 117.11 ± 170.74 mg. Overall, SSI occurred in 20 patients (2.0%), of which seven (0.7%) were superficial, and 13 (1.3%) were severe (Table 1, 2).

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. Multilevel surgery was the only significant surgery-related factor. Time to ambulation was the only significant postoperative factor. None of the blood test factors were significant. The following factors were found to be significant: preoperative hospitalisation for $\geq$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 $\geq$9 intervertebral levels (OR 12.48, 95% CI: 2.47–62.99, $p = 0.0023$), and time to ambulation $\geq$7 days (OR 5.59, 95% CI: 1.90–16.47, $p = 0.0018$) (Table 3).

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 $\geq$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*. [13] found that hospitalisation for $\geq$3 days was a risk factor. Blam *et al*. [14] reported that SSI in traumatic spinal injury was associated with a longer preoperative waiting time for 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. There is a possibility that these patients tend to have multiple vascular access lines, chest tubes, and similar devices that can cause SSI. In addition, in this study, patients with long preoperative hospitalized periods tended to show relatively high immuno-deficient conditions, such as poor glycemic control that needed patient-education.

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 [15]. 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 [11].

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 [14,16]. Watanabe *et al*. [17] reported that patients undergoing surgery for traumatic spinal injury are at a higher risk of SSI than those undergoing other types of spinal surgery. 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 [18-22]. 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 hemorrhage, and blood transfusion being among the identified important risk factors associated with SSI [8-11]. Highly invasive proce-

TABLE 1.
Demographic data

Parameter		All (%)	No SSI (%)	SSI (%)	p value
No. patient		1000	980	20	
Mean age ±SD, yrs		65.44±15.27	65.57±15.23	58.95±16.28	0.058
Males		583 (58.3)	570 (58.2)	13 (65.0)	0.54
Mean BMI± SD		24.23±4.03	24.62±8.84	23.02±4.73	0.17
ASA	I	112 (11.2)	111 (11.3)	1 (5.0)	
	Ⅱ	776 (77.6)	761 (77.7)	15 (75.0)	1.0
	Ⅲ	111 (11.1)	108 (11.0)	3 (15.0)	
	IV	1 (0.01)	0	1 (5.0)	
Diabetes		225 (22.5)	222 (22.7)	3 (15.0)	0.40
heart disease		36 (3.6)	34 (3.5)	2 (10.0)	0.19
cerebrovascular disease		59 (5.9)	57 (5.8)	2 (10.0)	0.47
dementia		26 (2.6)	22 (2.2)	4 (20.0)	0.0004
chronic pulmonary disease		20 (2.0)	20 (2.0)	0	0.37
bronchial asthma		63 (6.3)	62 (6.3)	1 (5.0)	0.80
rheumatoid arthritis		35 (3.5)	34 (3.5)	1 (5.0)	0.73
gastrointestinal ulcer		48 (4.8)	47 (4.8)	1 (5.0)	0.97
Cirrhosis		6 (0.6)	5 (0.5)	1 (5.0)	0.10
paralysis		6 (0.6)	5 (0.5)	1 (5.0)	0.10
chronic kidney disease		57 (5.7)	56 (5.7)	1 (5.0)	0.89
malignant tumour		143 (14.3)	140 (14.3)	3 (15.0)	0.93
hypertension		438 (43.8)	433 (44.2)	5 (25.0)	0.078
metastatic tumour		21 (2.1)	20 (2.0)	1 (5.0)	0.44
AIDS		0			–
Preoperative steroid users		44 (4.4)	43 (4.4)	1 (5.0)	0.90
Length of preoperative hospital stay	≧ 14	28 (2.8)	24 (2.4)	4 (20.0)	0.0001
Disorder treated	Degenerative disease	856 (85.6)	847 (86.4)	10 (50.0)	
	Traumatic injury	50 (5.0)	46 (4.7)	4 (20.0)	0.045
	Tumor	64 (6.4)	62 (6.3)	2 (10.0)	
	Deformity	30 (3.0)	25 (2.6)	4 (20.0)	
Surgical approach	Anterior	36 (3.6)	36 (3.7)	0	0.22
	Posterior	964 (96.4)	944 (96.3)	20 (100.0)	
Revision surgery		26 (2.6)	24 (2.4)	2 (10.0)	0.10
Fusion		268 (26.8)	258 (26.3)	10 (50.0)	0.37
Operating time*		143.72±83.47 min	143.08±83.12 min	175.1±96.7 min	0.09
Hemorrhage*		117.11±170.74 mg	115.42±170.39 mg	171.65±38.38 mg	0.89
Multilevel surgery	≧ 9	15 (1.5)	12 (1.2)	3 (15.0)	0.0023
Time to ambulation	≧ 7	82 (8.2)	74 (7.6)	8 (40.0)	0.0001

Antibiotic used	CEZ	990 (99.0)	970 (99.0)	20 (100.0)	0.96
	Other	10 (1.0)	10	0	
SSI		20 (2.0)			
	Superficial	7 (0.7)			
	Severe	13 (1.3)			

*Mean ± standard deviation

TABLE 2.
Details of infected person

Age(yrs), Sex	DM	dementia	ASA class	Disorder treated	Surgical site	Fusion	Approach	Op time (min)	Strain
79, F	No	No	2	Traumatic injury	Thoracic spine	Yes	Posterior	107	MRS
70, F	No	No	3	Traumatic injury	Thoracolumbar spine	No	Posterior	103	none*
80, F	Yes	Yes	2	Traumatic injury	Thoracolumbar spine	No	Posterior	170	S. aureus
68, M	Yes	Yes	2	Deformity	Thoracolumbar spine	Yes	Posterior	358	none*
77, M	No	Yes	2	Degenerative disease	Cervical spine	No	Posterior	111	S. aureus
69, F	No	No	2	Degenerative disease	Thoracolumbar spine	Yes	Posterior	187	none*
81, M	No	No	2	Tumor	Lumbar spine	No	Posterior	80	MRS
45, M	Yes	No	2	Degenerative disease	Cervical spine	No	Posterior	236	S. aureus
59, M	No	No	2	Degenerative disease	Lumbar spine	No	Posterior	129	S. epidermidis
63, F	No	No	2	Degenerative disease	Lumbar spine	Yes	Posterior	126	S. aureus
55, M	No	No	2	Deformity	Lumbar spine	Yes	Posterior	169	MRS
54, M	No	No	2	Degenerative disease	Cervical spine	No	Posterior	53	MRSA
16, F	No	No	2	Tumor	Cervical spine	Yes	Posterior	387	none*
52, M	No	No	2	Degenerative disease	Lumbar spine	No	Posterior	87	none*
52, M	No	Yes	3	Tumor	Lumbar spine	Yes	Posterior	218	ESBL
42, M	No	No	1	Degenerative disease	Cervical spine	Yes	Posterior	99	S. aureus
53, M	No	No	2	Degenerative disease	Lumbar spine	No	Posterior	96	MRSA
73, F	No	No	2	Deformity	Thoracolumbar spine	Yes	Posterior	317	none*
46, M	No	No	4	Traumatic injury	Thoracolumbar spine	Yes	Posterior	189	MRSA
45, M	No	No	3	Degenerative disease	Thoracolumbar spine	No	Posterior	280	S. aureus

none* : Bacterial culture with negative culture.

dures 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 [10]. Pesenti *et al*. [8] 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 ($\geq$9 intervertebral levels), the mean operating time was 140.37 ± 79.08 min, and mean amount of haemorrhage was 117.11 ± 179.74 mg. Surgery involving $\geq$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.

Surgical approach is another factor of SSI. Several studies have reported higher incidence of SSI in patients who underwent posterior surgery compared with anterior surgery. Levi *et al*. [23] reported that there was a significant difference in incidence of SSI between anterior and posterior surgery. According to their report, infections did not occur with anterior instrumentation surgery, whereas relatively higher rates of infection were recognized in posterior instrumentation surgery. Posterior spinal instrumentation requires extensive muscle excision to expose the posterior elements of the spinal column. On the other hand, exposure of the anterior spinal column can be accomplished through relatively avascular tissue planes. So, the anterior approach would avoid extensive muscle dissection and reduce de-vascularized and necrotic soft tissue that can be a nidus for infection. However, we could not show any significant difference between these two surgical approach groups. This might be because we had a small number of cases via the anterior approach.

Many authors reported instrumentation as a major factor of SSI in surgery. However, we did not find any significant difference between the instrumentation surgery group and decompression surgery alone group. Saleh *et al*. [24] reported SSI occurred more often in instrumentation surgery group than decompression surgery alone group. Arthrodesis and instrumentation procedures often require more extensive exposure, increased blood loss, and longer operation times, that lead to an increase in the risk of SSI. In recent years, minimally invasive spine surgery has become more common. Minimally invasive surgery (MIS) was effective for prevention of SSI in spine surgery [25,26]. Ee *et al*. [27] reported that MIS theoretically minimizes tissue injury and may have contributed to lowered rates of postoperative SSI. Additionally, minimally invasive surgery tends to reduce operation time and blood loss, which would lead to a decreased incidence of SSI. Our study did not show any significant risk factor of SSI associated with instrumentation surgery.

TABLE 3.
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

CI, confidence interval

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 $\geq$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 [28]. Increase in the average lifespan due to recent medical developments and the consequent aging of society may lead to an 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.

Limitations

This study had some limitations. First, the diagnosis at the time of surgery was degenerative disease in most cases, making the 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 a postoperative risk factor for spinal SSI. Among the risk factors identified, time to ambulation may be amenable to intervention by medical staff. Development and implementation of strategies to facilitate postoperative ambulation could help to reduce the incidence of spinal SSI in the future.

CONFLICT OF INTEREST: None.

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