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Surgical site infection following elective orthopaedic surgeries in geriatric patients: Incidence and associated risk factors

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The purposes of this study were to investigate the incidence of surgical site infection (SSI) following geriatric elective orthopaedic surgeries and identify the associated risk factors This was a retrospective two-institution study. Between January 2014 and September 2017, patients aged 60 years or older undergoing elective orthopaedic surgeries were included for data collection and analysis. SSI was identified through the review of patients' medical records for the index surgery and through the readmission diagnosis of SSI. Patients' demographics, characteristics of disease, surgery-related variables, and laboratory examination indexes were inquired and documented. Univariate and multivariate logistic analyses were performed to determine independent risk factors for SSI. There were 4818 patients undergoing elective orthopaedic surgeries, and within postoperative 1 year, 74 patients were identified to develop SSIs; therefore, the overall incidence of SSI was 3.64%, with 0.4% for deep and 1.1% for superficial infection. *Staphylococcus aureus* (25/47, 53.2%) and coagulase-negative *staphylococci* (11/47, 23.4%) were the most common causative pathogens; half of *S. aureus* SSIs were caused by Methicillin-resistant Staphylococcus aureus (MRSA) (12/25, 48.0%). Five risk factors were identified to be independently associated with SSI, including diabetes mellitus (odds ratio [OR], 3.7; 95% confidence interval [95% CI], 1.7-5.6), morbid obesity (OR, 2.6; 95% CI, 1.3-3.9), tobacco smoking (OR, 4.2; 95% CI, 2.1-6.4), surgical duration>75th percentile (OR, 1.9; 95% CI, 1.0-2.9), and ALB < 35.0 g/L (OR, 2.3; 95% CI, 1.3-3.4). We recommend the optimisation of modifiable risk factors such as morbid obesity, tobacco smoking, and lower serum albumin level prior to surgeries to reduce the risk of SSI.

KEYWORDS
elderly patients, elective orthopaedic surgeries, modifiable, risk factors, SSI

1 | INTRODUCTION

Surgical site infections (SSIs) following elective orthopaedic surgeries, such as total joint arthroplasty or orthopaedic spine surgeries, are rare but are associated with inferior outcomes and increased health care costs.[1,2] With China's entering aging society, the demand for elective orthopaedic surgeries is expected to increase significantly in the future decades. In 2017, over 241 million (17.3%) people in China were 60 years of age or older (http://www.stats.gov.cn/tjsj/pcsj/); approximately 530 000 patients underwent TJA surgeries in 2017, and this number is expected to increase significantly at a 20% rate in the coming years. As was reported, SSI following TJA ranged from 0.5% to 1.8%[1–3] and, following spinal orthopaedic surgeries, was 0.1% to 4.2%.[4] A prediction is made that the high volume and increased demand for orthopaedic surgeries in the elderly will result in a significant predicted future cost burden because of infection complications.

Compared with the younger patients, older patients have more prevalence of the comorbid conditions, such as

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hypertension, diabetes mellitus, poor nutrition, etc. Furthermore, older patients are more vulnerable than younger patients to adverse health or functional effects of postoperative SSIs or other complications. Mcgarry et al[2] reported that SSI was associated with greater than fivefold mortality rate and twofold prolonged duration of hospitalisation in elderly patients than that of younger patients. Lee et al[1] demonstrated that SSI was an independent risk factor for mortality (odd ratio [OR], 3.8) and increased hospitalisation duration (multiplicative effect, 2.49) after adjustment for the effects of confounding variables.

Efforts have always been made to reduce the incidence of SSI following surgeries, such as antibiotic prophylaxis, surgical site preparation, laminar airflow in operating room, and screening for *Staphylococcus aureus* carriers preoperatively.[3] In addition, a variety of studies provided useful information about the risk factors for SSI following orthopaedic surgeries. However, many of the studies were designed as single-institution and might be limited by the inadequate sample size. In addition, some studies included only a fraction of potential risk factors for SSI in the analyses, and therefore, the findings might be less generalisable to multiple settings. In order to more accurately identify independent risk factors for SSIs, studies with a relatively large sample size of patients, including a wide variety of risk factors, and controlling for multiple risk factors within individuals should be warranted.

The aims of this study were to describe the incidence of SSI following elective orthopaedic surgeries; second to describe the epidemiological characteristics of SSIs, including the timing of SSI development and the causative bacteria; and to identify the independent risk factors associated with SSI.

Key Points

- in elderly patients, the incidence rate of SSI following elective orthopaedic surgery was 1.5% within 1 year postoperatively
- the diagnosis of SSI was at the median of the 17th day, with the earliest at the 2nd day and latest at the 166th day, postoperatively
- *Staphylococcus aureus* and coagulase-negative *staphylococci* were the most common causative pathogens, causing approximately 80% of the SSIs
- diabetes mellitus, morbid obesity, smoking, prolonged surgical duration, and lower preoperative albumin level (<35 g/L) were significantly associated with SSI
- preoperative active supplementation of nutrition, appropriate weight loss, smoking cessation, and optimisation of the operative plan might be effective to reduce SSIs

2 | PATIENTS AND METHODS

2.1 | Study design and inclusion and exclusion criteria

We performed a retrospective case-control study at two tertiary-care university-affiliated hospitals (the First Hospital of Jilin University and Traditional Chinese Hospital Affiliated to Xinjiang Medical University) after obtaining approval from the institutional review board of both hospitals. From January 2014 to September 2017, all patients aged 60 years or older who underwent elective orthopaedic surgeries because of deformity, degenerative, or osteopathy disease were included in this study. The exclusion criteria were: patients younger than 60 years, patients with fractures for any reason, patients with incomplete medical data, patients undergoing only minimally invasive surgery such as arthroscopic debridement or percutaneous vertebroplasty, patients admitted only for treatment of SSI but without index surgery performed in our institutions, patients admitted for revision surgery because of reasons other than infections, and patients who died during the study period.

2.2 | Definition of SSI and identification of SSIs

Based on SSI definition criteria put forth by the Centers for Disease Control and Prevention,[5] a patient is judged to have an SSI. Superficial SSI was defined as an infection developing within 30 days after the surgery and involving only the skin or subcutaneous tissues. Deep SSI was defined as an infection occurring within 1 year after the surgery and involving the deep soft tissue (muscle, bone, or others). The deep SSI was further characterised based on one or more of the following conditions: (a) persistent wound discharge or dehiscence from the deep incision; (b) visible abscess or gangrenosis requiring surgical debridement and implants removal or exchange; and (c) culture-positive excretions from the deep incision site.

Patients likely to have an SSI were identified by searching the electronic medical records (EMRs) for index surgery and a readmission diagnosis of infection within 1 year after discharge from hospital. The two reviewers were responsible for searching patients' EMRs for signs of SSI based on the descriptions of wound, the prescribed antibiotics and dose, or definitive diagnosis of SSI by the attending surgeon.

2.3 | Data collection for variables of interest

For each patient, the related demographic and medical data were extracted from the EMRs, operative reports, and biochemical test reports. Variables of interest included four aspects: sociodemographic characteristics: age, gender, height, weight, the estimated BMI (kg/m^2), living places (rural or urban), smoking status, alcohol consumption, previous surgery at any site, preoperative and total hospital stay; comorbidities: diabetes mellitus, hypertension, heart disease, anaemia, rheumatoid disease, renal disease, steroid use, liver disease, chronic obstructive pulmonary disease (COPD) or asthma, and allergy to food/medication; surgery-related characteristics: disease type, surgery type, preoperative hospital stay, surgeon level, American Society of Anesthesiologists Index (ASA), anaesthetic type, disinfectant solution to prepare the skin, surgical duration, intraoperative blood loss, perioperative transfusion, postoperative use of antibiotics, drainage use; and preoperative laboratory indexes: white blood cell (WBC) count, neutrophile granulocyte (NEUT) count, lymphocyte (LYM) count, red blood cell (RBC), haemoglobin (HGB) level, platelet (PLT) count, serum total protein (TP) level, albumin (ALB) level, globulin (GLOB) count, and A/G value (albumin/globulin).

BMI was grouped according to the criteria suitable for Chinese people: underweight, <18.5; normal, 18.5 to 23.9; overweight, 24 to 27.9; obesity, 28 to 31.9; morbid obesity, 32; and more.[6] Tobacco use or alcohol consumption was defined as positive if patients acknowledged they had at least one use or consumption within 1 month prior to surgery.[7] The 75th percentile of the surgical duration required for one certain surgery type (hip replacement, knee replacement, and others) was selected as the cut-off value.[8] Preoperative stay was defined as the interval between admission and operation. Biochemical indexes were divided into two or more groups as needed based on their normal range of reference values.

2.4 | Statistical analysis

The *t*-test or Whitney *U*-test was used to compare the difference of continuous variables between SSI and non-SSI groups. Univariate logistic regression analysis was used to evaluate the association between categorical variables and the risk of SSI. Factors that were found to be approximately significant ($P < 0.2$) or significant ($P < 0.05$) in the univariate analyses were entered into the multivariate logistic regression model to identify the independent risk factors. Stepwise backward elimination method was used to exclude the confounding covariates from the final multivariate logistic model, and covariates with $P \leq 0.10$ were retained in the final model. We used odd ratio (OR) and 95% confidence interval (95% CI) to indicate the association magnitude between each variable and the risk of SSI. The statistical significance threshold was set as $P < 0.05$. The Hosmer–Lemeshow test was performed to evaluate the goodness of fit of the final multivariate logistic model, with $P > 0.05$ indicating an acceptable fitness. The value of *c*-statistic (0%-100%) was used to indicate the predictive ability of the final model, with a higher value indicating the higher predictive probability of the outcome. All analyses were performed by SPSS software version 19 (IBM Corporation, Armonk, New York).

3 | RESULTS

3.1 | Characteristics of study sample

During the study time frame, a total of 5763 elderly patients underwent the elective orthopaedic surgeries, and 945 patients were excluded based on our strict criteria, with the remaining 4818 patients included for data analysis. There were 2203 men and 2615 women, and their average age was 69.7 years (SD, 11.2; range, 60-97). Most cases were involved in degenerative disease (3090), followed by osteopathy (1031), deformity (409), and other musculoskeletal disorders (288). The average preoperative hospital stay was 2.9 days (SD, 2.6; range, 0-19); 3262 patients were operated on within 2 days, 1094 patients were operated on the third day to seventh day, and the remaining 462 patients were operated above 7 days after admission. Orthopaedic procedures were hip replacement (1669), knee replacement (1024), spinal arthrodesis ± instrumentation (827), laminectomy ± discectomy (869), and others (429).

3.2 | Characteristics of SSI

During the following year after surgeries, 74 SSIs were identified, indicating the cumulative incidence of SSI of 1.5% (95% CI, 1.2%-1.9%). There were 48 (64.9%) SSIs that were identified during patients' hospitalisation stay for the index surgery, and the remaining 26 (35.1%) SSIs were confirmed at readmission for treatment of the SSIs. A total of 54 cases were classified as superficial SSIs and 20 as deep SSIs, and accordingly, their incidence was 1.1% (95% CI, 0.8%-1.4%) and 0.4% (95% CI, 0.2%-0.6%), respectively. The diagnosis of SSI was at the median of the 17th day, with the earliest on the 2nd day and the latest at the 166th day postoperatively. The total duration of hospitalisation stay of patients for the index surgery was 10.8 days on average (SD, 6.6; range, 3-41), with 18.8 days in patients with SSI and 10.7 days in those without SSIs, and the difference was significant ($P < 0.001$).

Microbiological cultures of specimens from the wound were performed in 57 patients, with positive results in 47 (82.4%) patients. The most common pathogen causing the SSI was *S. aureus* ($n = 25$, 53.2% of SSIs), and approximately half of those isolates were methicillin-resistant ($n = 12$, 48.0% of *S. aureus* SSI). Other organisms included coagulase-negative *staphylococci* ($n = 11$, 23.4%), *Enterococcus faecalis* ($n = 6$, 12.8%), *Staphylococcus epidermidis*, *Escherichia coli* ($n = 3$, 6.4%), *Pseudomonas aeruginosa* ($n = 1$, 2.1%), and *Enterobacter cloacae* ($n = 1$, 2.1%).

3.3 | Risk factors for SSI

In the univariate analysis (Table 1), 13 variables were tested to be significantly associated with SSIs. They included preoperative stay, diabetes mellitus, chronic nephrosis, use of steroid within preoperative 1 month, smoking, ASA class, disinfectant solution to prepare skin, perioperative allogenic blood transfusion, surgical procedure, surgical duration, HGB, ALB, and fasting blood glucose (FBG) ($P < 0.05$ for all comparisons). Ten variables, including age, BMI, liver disease, rheumatic diseases, grade of surgeon, drainage use,

TABLE 1 Association between potential risk factors and postoperative SSIs in elderly patients (n = 4818) undergoing elective orthopaedic surgery

Variables	Number (%) of patients without SSI (n = 4744)	Number (%) of patients with SSI (n = 74)	P
Gender (male)	2172 (45.8)	31 (41.9)	0.505
Age	69.7 ± 10.7	72.1 ± 13.5	0.082
Living place (rural)	2593 (54.7)	42 (56.8)	0.719
BMI (kg/m^2)			0.159
18.5 to 23.9	2021 (42.6)	26 (35.1)	
<18.5	273 (5.8)	2 (2.7)	
24.0 to 27.9	1478 (31.2)	23 (31.1)	
28.0 to 31.9	647 (13.6)	14 (18.9)	
≥32.0	325 (6.9)	9 (12.2)	
Diabetes mellitus	746 (15.7)	23 (31.1)	0.001
Hypertension	1064 (22.4)	19 (25.7)	0.507
Cardiac disease	622 (13.1)	12 (16.2)	0.433
Chronic pulmonary disease	438 (9.2)	10 (13.5)	0.208
Chronic nephrosis	274 (5.8)	9 (12.2)	0.020
Chronic liver disease	303 (6.4)	8 (10.8)	0.124
Cerebrovascular disease	793 (16.7)	16 (21.6)	0.263
Rheumatic diseases	573 (12.1)	13 (17.6)	0.152
Chronic steroid use	616 (13)	18 (24.3)	0.004
History of previous operation at any site	1276 (26.9)	21 (28.4)	0.776
Current smoking	759 (16)	22 (29.7)	0.001
Alcohol consumption	1023 (21.6)	19 (25.7)	0.394
History of allergy to medications/food	392 (8.3)	8 (10.8)	0.431
Disease type			0.202
Degenerative disease	3051 (64.3)	39 (52.7)	
Osteopathy	1009 (21.3)	22 (29.7)	
Deformity	402 (8.5)	7 (9.5)	
Others	282 (5.9)	6 (8.1)	
Preoperative stay (d)			<0.001
1 to 2	3231 (68.1)	31 (41.9)	
3 to 7	1070 (22.6)	24 (32.4)	
>7	443 (9.3)	19 (25.7)	
ASA class			0.003
I-II	3587 (75.6)	45 (60.8)	
III-IV	1157 (24.4)	29 (39.2)	
Anaesthesia (general versus others)	2439 (51.4)	39 (52.7)	0.826
Solution to prepare the skin (alcohol versus others)	3071 (64.7)	36 (48.6)	0.004
Perioperative allogenic blood transfusion	498 (10.5)	13 (17.6)	0.05
Surgeon level (visiting and residents versus others)	1776 (37.4)	34 (45.9)	0.134
Surgical procedure			<0.001
Hip replacement	1657 (34.9)	12 (16.2)	
Knee placement	1017 (21.4)	7 (9.5)	
Spinal arthrodesis ± instrumentation	796 (16.8)	31 (41.9)	
Laminectomy ± discectomy	854 (18)	15 (20.3)	
Others	420 (8.9)	9 (12.2)	
Intraoperative blood loss			
Surgical duration > 75th percentile	1176 (24.8)	28 (37.8)	0.010
Postoperative antibiotics use	4426 (93.3)	67 (90.5)	0.348
Postoperative drainage use	2817 (59.4)	52 (70.3)	0.058
WBC (>10 × 10^9/L)	872 (18.4)	18 (24.3)	0.191
NEUT (>6.3 × 10^9/L)	698 (14.7)	16 (21.6)	0.097
LYM (10^9/L)			0.051

(Continues)

TABLE 1 (Continued)

Variables	Number (%) of patients without SSI ($n = 4744$)	Number (%) of patients with SSI ($n = 74$)	P
References (1.1-3.2)	4026 (84.9)	57 (77)	
<1.8	351 (7.4)	11 (14.9)	
>3.2	367 (7.7)	6 (8.1)	
&RBC < lower limit (10^{12}/L)	793 (16.7)	17 (23)	0.153
#HGB < lower limit (g/L)	902 (19)	21 (28.4)	0.042
PLT (10^9/L)			0.082
References (100-300)	3845 (81)	53 (71.6)	
<100	527 (11.1)	14 (18.9)	
>300	372 (7.8)	7 (9.5)	
TP (<55 g/L)	838 (17.7)	16 (21.6)	0.376
ALB (<35 g/L)	1043 (22)	26 (35.1)	0.007
GLOB >30 g/L	684 (14.4)	13 (17.6)	0.347
FBG > 125 mg/dL	527 (11.1)	17 (23)	0.001

Abbreviations: &RBC, red blood cell. reference range: female, 3.5 to 5.0/10^{12}/L; males, 4.0 to 5.5/10^{12}/L. #HGB, haemoglobin, reference range: females, 110 to 150 g/L; males, 120 to 160 g/L; WBC, white blood cell; NEUT, neutrophile; LYM, PLT, platelet; TP, total protein; ALB, albumin; GLOB, globulin; FBG, fasting blood glucose.

WBC, LYM, RBC, and PLT, were tested and found to be approximately significant ($P < 0.20$, >0.05).

In the multivariate logistic regression model, 21 potential risk factors were entered for adjustment of their effects on SSIs. The results showed that diabetic mellitus (odds ratio [OR], 3.7; 95% CI, 1.7-5.6), morbid obesity (versus normal BMI) (OR, 2.6; 95% CI, 1.3-3.9), smoking (OR, 4.2; 95% CI, 2.1-6.4), surgical duration >75th percentile (OR, 1.9; 95% CI, 1.0-2.9), and preoperative ALB <35 g/L (OR, 2.3; 95% CI, 1.3-3.4) were independent risk factors associated with the SSIs (Table 2). The Hosmer-Lemeshow test demonstrated the adequate fitness of the final model ($X^2 = 7.766$, $P = 0.392$), and the model had good predictive ability, with a c-statistic of 0.816.

4 | DISCUSSION

Investigation of the effects of risk factors on SSIs is always a focus subject, and in the current study, we reviewed a large number of patients from two tertiary-care university-affiliated hospitals to continue this research. We found that the accumulated incidence rate of SSI within 1 year following the elective orthopaedic surgeries was 1.5%; the most common causative bacterium was *S. aureus*. Five independent risk factors for SSIs were identified, including diabetes mellitus, morbid obesity, smoking, prolonged surgical duration, and lower preoperative albumin level (<35 g/L).

TABLE 2 Multivariate logistic regression analysis of risk factors for postoperative SSI following elective surgery in elderly patients

Variables	OR and 95% CI	P value
Diabetic mellitus	3.7 (1.7-5.6)	0.002
BMI (kg/m^2)		
18.5 to 23.9	Reference	
<18.5	1.3 (0.8-1.7)	0.421
24.0 to 27.9	1.1 (0.9-1.3)	0.714
28.0 to 31.9	1.8 (0.9-2.7)	0.083
≥32.0	2.6 (1.3-3.9)	0.004
Current smoking	4.2 (2.1-6.4)	<0.001
Surgical duration > 75th percentile	1.9 (1.0-2.9)	0.044
ALB (<35 g/L)	2.3 (1.3-3.4)	0.027

Abbreviation: ALB, albumin, BMI, body mass index; OR, odd ratio.

The incidence of SSIs following the elective orthopaedic surgeries was reported to be greatly varied depending on the treated patients, study design, the type of surgery, the definition of SSI, and the follow-up time. Ishii et al[9] performed a retrospective multicentre study of 3462 instrumented lumbar surgeries and found a 1.1% occurrence of deep wound infection. Klemencsics et al[10] found a 3.6% prevalence of SSIs in a prospective study of 1030 elective degenerative lumbar surgeries. In another prospective study, Lee et al[11] reported that the prevalence of SSI was 4.3% within 2 years following the spinal surgeries in a cohort of 1532 patients. As for arthroplasty, Zhu et al[12] reported that the combined postoperative SSI incidence rate was 1.1% in a meta-analysis of six studies including 24 069 patients undergoing arthroplasty surgery. In this study, we found a comparable result that the incidence of SSI after elective spinal surgeries was 2.7% (46/1696) and after hip or knee arthroplasty was 0.7% (19/2674) (Table 1). In addition, despite a relatively short follow-up (1 year), we found that over one third of the SSIs were detected after patients' discharge from hospital. These results suggest the importance of closely monitoring the surgical site for a relatively long time, especially for the vulnerable group.

In our cohort, *S. aureus* and coagulase-negative *staphylococci* were the most common causative pathogens, being part of the normal skin flora and responsible for most SSIs; approximately half (12/25) of the *S. aureus*-induced SSIs were caused by Methicillin-resistant Staphylococcus aureus (MRSA). These findings were consistent with previous studies.[7,13,14] It is estimated about one fifth of the general population is colonised with *S. aureus,*[15] and the development of SSI involving *S. aureus* is associated with preoperative nasal colonisation.[5] Yano et al reviewed 2423 consecutive patients undergoing orthopaedic surgery and demonstrated that the risk of SSI development in nasal MRSA carriers was 11-fold higher than those without MRSA.[16] Accordingly, we support the concept of preoperative screening patients for nasal colonisation of *S. aureus* and the prescribing of appropriate antibiotics for nasal decolonisation to reduce the infection complications.[7] Especially for patients with MRSA nasal carriage, preoperative prophylactic vancomycin could be administered as a compulsory measure, if necessary.

Obesity or morbid obesity as an independent risk factor of SSI has previously been described in studies of spinal, traumatic, or arthroplasty surgery patients,[17–19] which was re-demonstrated in this study of geriatric orthopaedic patients. Falagas et al[20] suggested that the adipose tissues participate actively in inflammation and immunity via a variety of inflammatory cytokines and immune mediators and deemed this the primary pathophysiological mechanism that predisposed obese patients to infection. In surgical operation, obesity was commonly associated with more soft tissue dissection, excessive tissue distraction, more difficulty with implant positioning, and prolonged surgical duration, all of which increased the local tissue trauma and therefore allowed bacteria prolonged access to the exposed deeper tissue.[17,21,22] It should be noted that preoperative weight loss to modify a patient's BMI is possible in elective orthopaedic surgery but should be performed in a more balanced matter to avoid malnutrition, a well-established risk factor for SSI or other complications.[23,24]

Serum albumin level had important significance in the development of SSI as this is a potentially modifiable risk factor. Compared with younger patients, elderly patients more frequently presented a perioperative malnutrition status. Junqueira et al[25] prospectively evaluated 70 patients aged 60 years or older undergoing major elective surgery and found a 20.3% rate of lower serum albumin. For traumatic patients, the prevalence of low serum albumin was higher, up to 55% in elderly hip fracture patients, on their admission to hospital.[26] This might be attributable to its dual role, being a surrogate of the patient's nutritional status and a surrogate for illness severity during acute-phase reacting. In this study, the rate of low albumin level was 22.0% in non-SSI patients and 35.1% in SSI patients; preoperative lower serum albumin was associated with a 2.3-fold increased risk of SSI after adjustment for other variables. In an RCT of elderly patients with hip fracture, Myint et al[24] found the significant reduction of SSI via preoperative supplement of 18 to 24 g protein and 500 kcal per day. In a prospective study of 995 cases of elective total knee and hip arthroplasty, the implementation of four preoperative nutrition-related screening criteria (HGB A1c $\leq$ 7, HGB $\geq$ 11, BMI $\leq$ 35, and albumin $\geq$ 3.5) was associated with the reduction of 70% SSIs (4.4% versus 1.3%).[27] These results indicate the importance and the feasibility of a preoperative nutrition supplement for the reduction of infection complications; especially in high-risk patients with several risk factors combined, compulsory preoperative optimisation should be considered.

Prolonged surgical duration as a risk factor for SSI was well established in literature,[28–30] and in this study, use of the 75th percentile as a cut-off value also yielded a significant result (OR, 1.9; 95% CI, 1.1-3.2). Despite this, the role of prolonged surgical duration on SSI development should be treated dialectically. On one hand, as for the surgical operation itself, prolonged surgical duration more likely reflected the complexity of surgery, including technical difficulty, extensive soft stripping, and extensive exposure of the wound. On the other hand, multiple external factors would have influence on surgical duration, such as experience and proficiency of the operative doctor, experience of operating room staff, preoperative planning, etc. It should be noted that not all of these variables could be manipulated, and surgeons should be aware of the effect of surgical duration on the SSI occurrence and accordingly optimise their workflow and preoperative plan.

The role of diabetes mellitus in the development of SSI following orthopaedic surgeries has been demonstrated in several previous studies and was reconfirmed in this study.[8] However, elevated FBG (>125 mg/L) did not remain significant after we adjust for DM and other variables. Different from our results, Olsen et al[8] found that both DM and elevated serum glucose level (preoperative FBG, >125 mg/dL or a postoperative random, >200 mg/dL) were independent risk factors for SSI following orthopaedic spinal operations. Hikata et al[31] defined hyperglycaemia as a preoperative FBG >140 mg/dL and found it was associated with 3.1-fold increased risk of SSI following foot and ankle surgery in diabetic patients. The CDC guideline recommended perioperative glycaemic control and the use of a random blood glucose target level of less than 200 mg/dL in diabetic and non-diabetic patients.[32] However, there is still a lack of higher-level evidence from RCTs to confirm these findings. The focus of future research should be on the optimal timing, duration, or delivery method of perioperative glycaemic control for the prevention of SSI.

Numerous studies have reported the adverse effects of tobacco smoking on the development of SSI following orthopaedic surgeries. Singh et al[33] conducted a study of 33 336 patients undergoing elective total knee arthroplasty (TKA) or total hip arthroplasty and found that current smoking increased the risk of SSI by 1.41 times compared with those who never smoked. Crowe et al[7] reviewed 3836 cases of TKA and found that tobacco smoking was independently associated with a 3.1-fold increased risk of SSI, consistent with our result (OR, 4.2; 95% CI, 2.0-6.4). On the other hand, we should really recognise that there is a certain possibility of modification of the smoking status to prevent SSIs. In a subgroup meta-analysis of four RCTs, Sørensen et al[34] concluded that perioperative smoking cessation intervention reduced SSIs following elective surgery (TKA, total hip arthroplasty, elective general surgery) by 57%. In addition, evidence from a large cohort and RCTs have demonstrated that smoking cessation 4 to 8 weeks prior to surgery could significantly reduce wound-related complications.[35–37] Therefore, it is recommended that smokers who are undergoing elective spinal or arthroplasty surgery should cease smoking for at least 4 weeks to have a favourable surgical condition.

The advantages of this study included the two-institution design, large sample size of patients, relatively good number of SSIs, and the numerous variables included for data analysis. Despite this, there were several limitations that should be mentioned. First, it was the inherent weaknesses of a retrospective study that affected the accuracy of the data collection. Second, the observational study design challenged our ability to determine the causality between variables and SSIs. Third, there were numerous variables that could not be abstracted from patients' EMR, such as the number of the operating surgeons, operating room staff, the postoperative rehabilitation pattern and duration, etc., which were previously reported as risk factors for SSI. Therefore, there remain residual confounding effects. Fourth, post-discharge SSIs that were treated in other institutions and that occurred after postoperative 1 year were presumed to be non-SSIs, likely resulting in the underestimation of the SSI prevalence. Fifth, we did not quantify some important variables, such as the number of cigarettes per day or pack-year for smoking, which could have a significant effect on the development of SSI.

In summary, the incidence rate of SSIs following elective geriatric orthopaedic surgeries was 1.5%, with 0.4% for deep and 1.1% for superficial SSIs. *S. aureus* and coagulase-negative *staphylococci* were the most common causative pathogens, and approximately half of the *S. aureus*-induced SSIs were caused by MRSA. Five risk factors were identified to be independently associated with the development of SSI, including diabetes mellitus, morbid obesity, tobacco smoking, surgical duration>75th percentile, and ALB < 35.0 g/L. These data allow for individualised risk assessment and may improve preoperative counselling. Accordingly, optimisation of the preoperative strategy of modest weight loss, aggressive diabetes management, supplementary nutrition, and smoking cessation is recommended to reduce the incidence of SSIs.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to report.

AUTHOR CONTRIBUTIONS

Laijin Lu designed the study; Zhiquan Liang and Rui Fang inquired the EMR; Yingjie Deng, Wenfei Gu, and Kai Rong analysed and interpreted the data; Xin Yu seared the relavant literature. Zhiquan Liang and Kai Rong wrote the manuscript, and Laijin Lu approved the manuscript.

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