Observational Study

Medicine®

OPEN

Incidence of surgical-site infection following open reduction and internal fixation of a distal femur fracture

An observational case–control study

Yanbin Bai, MD[a,b], Xiong Zhang, MD[a,b], Ye Tian, MD[a,b], Dehu Tian, MD[a,b], Bing Zhang, MD[a,b,*]

Abstract

Surgical-site infection (SSI) is a common complication in orthopedic surgery; however, SSI after surgically managed distal femur fractures was not well studied. The aim of this study was to investigate the incidence of SSI and identify some modifiable and nonmodifiable risk factors.

The patients' electronic medical records (EMRs) were reviewed to identify those who sustained a distal femur fracture and treated by open reduction and internal fixation (ORIF) between March 2014 and February 2018. SSI was defined based on the Centers for Disease Control criteria and confirmed according to the descriptions in EMR. Univariate and multivariate logistic regression models were used to determine the independent risk factors associated with SSI.

Totally, EMRs of 665 patients who underwent ORIF of distal femur fractures were reviewed and 24 SSIs were found, indicating the overall incidence of SSI was 3.6%. The rate of deep SSI was 1.2% and superficial SSI was 2.4%. *Staphylococcus aureus* was the most common causative pathogen, either alone (7/15, 46.7%) or as a mixed infection (3/15, 20%), followed by mixed bacterial (4/15, 26.7%) and *S epidermidis* (2/15, 13.3%) and others. Patients with SSI had approximately twice the length of hospital stay as those without SSIs (29.0 vs 16.0 days, $P < .001$). Open fracture, temporary use of external fixation, obesity, smoking, diabetes mellitus, and preoperative reduced albumin level were identified as independent risk factors associated with SSI, and current smoking and preoperative reduced albumin level were the true modifiable factors.

Patients should be encouraged to cease smoking as early as possible and increase the good-quality protein intake to reduce or prevent the occurrence of SSI. An explanation of the nonmodifiable risk factors should be included when patients are counseled about their increased risk of SSI.

Abbreviations: ALB = albumin, ASA = American Society of Anesthesiologists, BMI = body mass index, CDC = Centers for Disease Control, EMRs = electronic medical records, HGB = hemoglobin, LYM = lymphocyte, NEUT = neutrophile granulocyte, ORIF = open reduction and internal fixation, PLT = platelet, RBC = red blood cell, SSI = surgical-site infection, TP = total protein, WBC = white blood cell.

Keywords: distal femur fracture, open reduction and internal fixation, reduced albumin level, risk factors, smoking, surgical-site infection

1. Introduction

Surgical-site infection (SSI) represents a very common complication in orthopedic operations of various types, including internal fixation of fractures,[1–3] arthroplasty for intra-articular fracture, severe osteoarthritis, ischemic osteonecrosis or tumor removal,[4–6] correction and fixation of congenital deformities or degenerative diseases.[7,8] Depending on the definitions of SSI, type of operation, location of operation and the study design, the SSI incidence was reported to vary widely. Anyhow, orthopedic SSIs prolong the total hospital stays by 7 to 14 days per patient,[9,10] double readmission rates, and increase healthcare costs by 3 times.[11] In addition, SSIs, especially following intra-articular fractures, are always associated with joint stiffness, traumatic osteoarthritis, and formation of heterotopic ossification and the resultant functional restrictions.[11–13]

The primary task of epidemiologic study is to explore and identify the associated risk factors for 1 clinical event. With these risk factors, we could construct the risk prediction model, thereby, screen out patients who are at high risk and will benefit most from the given targeted interventions. From the perspective of cost performance, it is a most simple and cost-effective measure to reduce or prevent SSI. Although numerous studies have assessed risk factors associated with SSI following traumatic orthopedic surgeries, very few of them focued on distal femur fractures. A major reason for this is the rarity of this type of

Editor: Johannes Mayr.

YB and XZ contributed equally to this study.

The authors have no funding and conflicts of interest to disclose.

[a] Department of Orthopaedic Surgery, [b] Department of Hand Surgery, The 3rd Hospital of Hebei Medical University, Shijiazhuang, Hebei, China.

[*] Correspondence: Bing Zhang, Department of Hand Surgery, The 3rd Hospital, Hebei Medical University, No 139, Ziqiang Road, Shijiazhuang 050051, China (e-mail: drzhangbing2013@126.com).

Medicine (2019) 98:7(e14547)

Received: 28 August 2018 / Received in final form: 10 January 2019 / Accepted: 12 January 2019

http://dx.doi.org/10.1097/MD.0000000000014547

fracture, which accounts for only 4.0% of all femoral fractures[14,15] and <1% of fractures in adults.[14] Even so, we should not neglect these injuries, because over 50% of them involved the articular surface[14] and if not well-managed, they would have a destructive consequence on the function of the knee.

The gold standard of treatment of distal femur fractures is open reduction and internal fixation (ORIF) by metal plates and screws. However, patients who undergo this surgery will have a relatively high rate of SSIs,[15,16] most likely due to the soft-tissue damage upon the accident, fracture severity, systematic comorbidities, tissue dissection during operation, wound contamination, and other patient- or surgery-related factors. In the latter study, Hoffmann et al[16] evaluated 106 patients who underwent locked plating for treatment of distal femoral fractures, and found 9 SSIs, including 8 deep infections and 1 superficial infection; they also identified open injury and current smoking as the associated risk factors. Except for this, we have not found other studies for investigation of risk factors associated with SSI following ORIF of a distal femur fracture.

Given that, we conducted this study, based on our experience to treat distal femur fractures. The main aims of this study were to: determine the incidence of SSIs following ORIF of distal femur fractures; determine whether modifiable and nonmodifiable risk factors were associated with the development of SSIs. A better understanding of the modifiable and nonmodifiable risk factors would aid in counseling patients and contribute to improved practices.

2. Patients and methods

2.1. Inclusion and exclusion criteria

This study was approved by the Institutional Review Board of the 3rd Hospital of Hebei Medical University (no: 2018-012-1). This is an academic hospital, equipped with over 1200-beds in the department of orthopedics and the occupancy rate was 150% in the last 5 years. The number of the orthopedic operations was about 40,000 each year, which allowed evaluation of some uncommon cases. In this study, we set the review period as 4 years, from March 2014 to February 2018. All patients aged 18 or older with acute distal femur fractures (AO/OTA 33) treated by ORIF with screws/plates or only screws were included. The exclusion criteria were as follows: age <18 years, pathologic fractures, metastatic fracture, patients who had implant removal only, patients who underwent surgical treatment of distal femur fracture at an outside hospital or who presented with SSI after being treated at another hospital, and those with incomplete data.

2.2. Variables of interest and definition

Two researchers (YB and BZ), not involved in the patients' care, reviewed the patients' electronic medical records (EMRs), radiographs, and operative reports for data collection. Demographics and preoperative data included: gender, age, height, weight, living places (rural or urban), injury mechanism, affected side, injury type (closed or open), fracture type according to AO/OTA classification system, coexisting injuries, lifestyles (smoking, alcohol consumption), comorbidities (diabetes mellitus, hypertension, and cardiac disease), and chronic steroid use. Surgery-related data included the preoperative stay (days), American Society of Anesthesiologists (ASA) score, anesthesia type (regional, general, or combination), wound classification (I, clean; II, clean-contaminated; III, contaminated; IV, infected-dirty), the solution used to clean and prepare the skin, attending surgeon, temporary use of external fixation before definitive surgery, prophylactic use of antibiotics, intraoperative blood loss, postoperative use of antibiotics, and postoperative drainage tube use. We also documented the values of biochemistry indexes within preoperative 24 hours, and accordingly divided them into normal, above normal and below normal. These variables included white blood cell (WBC) count, neutrophile granulocyte (NEUT) count, lymphocyte (LYM) count, red blood cell (RBC) count, hemoglobin (HGB) level, platelet (PLT) count, serum total protein (TP) level, and albumin (ALB) value.

Coexisting injuries were defined as trauma to more than 1 system, among musculoskeletal, cardiothoracic, abdominal urogenital, and central nervous systems, and the summed digital (1, 2, 3, etc) was used to indicate the injury severity. Body mass index (BMI, kg/m^2) was divided into obesity (≥28.0) and nonobesity (<28.0), based on the reference criteria suited to the Chinese populations. Preoperative stay was defined as the time interval between the injury and the surgery, and was divided into 2 groups: group 1, <7 days and group 2, ≥7 days. Injury mechanism was classified as low-energy (fall from standing height) and high-energy (fall from height, traffic incident, mechanical injuries, and others). ASA was grouped into: I, normal healthy patient; II, mild systemic disease; III, severe systemic disease; IV, severe systemic disease that threatens life; V, moribund patient who is not expected to survive without the operation.[17] The solution to prepare the skin for surgery was defined as soap, followed by alcohol, iodine or others.

2.3. Definition of SSI and the variables

The SSI was defined on basis of Centers for Disease Control (CDC) and Prevention criteria.[18] Deep SSI was defined as an infection that involved deeper soft tissues within the 1st postoperative year (deep SSI), when an implant was left in place. In the EMRs, the signs or symptoms for SSIs might be described as follows: persistent wound discharge or dehiscence, visible abscess or gangrenosis requiring surgical debridement, and implant exchange or removal. Superficial SSI was defined as an infection that involved only skin and subcutaneous tissues of the incision within 30 days after the operation (superficial SSI), regardless of presence of an implant. SSI that resolved with a single course of oral antibiotics or physiotherapy for wound problems (pain or tenderness, localised swelling, redness, or heat) but did not meet the criteria for deep infection was deemed to be a superficial SSI.

2.4. Statistical analysis

Mann–Whitney *U* test was used to compare total hospital stays between SSI and non-SSI groups. Univariate logistic analysis was used to evaluate the association of each categorical variable with the risk of SSI. Significant ($P < .05$) or near-significant variables ($P < .2$) identified in the univariate analysis were further entered into the multivariate logistic regression model to determine the adjusted results. A stepwise backward elimination method was used to exclude confounding covariates, and variables with a $P < .05$ retained at the final models. Odds ratio (OR) and 95% confidence interval (95% CI) were used to indicate the correlation between variables and SSI risk. The goodness-of-fit of the final multivariate regression model was evaluated by the Hosmer–Lemeshow test, with a $P > .05$ being an acceptable result and larger *P*-value meaning better fitness and reliability. All statistical analyses were performed by SPSS19.0 (IBM, Armonk, NY).

3. Results

During the 4-year observation period, a total of 1037 patients with distal femur fractures were admitted for surgical treatment. After our strict inclusion and exclusion criteria, 372 patients were excluded, leaving 665 patients (665 cases of distal femur fractures) eligible for data extraction and analysis. There were 372 men and 293 females, with the average age of 49.4±15.7 years (range, 18–77 years). There were 57 (8.6%) cases of open fractures, and 67 (10.0%) patients had coinjuries of other systems. Based on the AO/OTA classification system, there were 299 type A, 153 type B and 213 type C fractures of distal femur. Over 70% (73.1, 486/665) of the patients could be operated within 1 week, and the mean preoperative stay was 6.2±5.5 days (range, 0–37 days). The total hospital stay in SSI group was 16.5 days in average (standard deviation, 9.6 days), with 16.0 days in those non-SSI patients and 29.0 days in those SSI patients; and the difference was statistically significant ($P<.001$).

3.1. SSI characteristics

There were 24 cases of SSIs, indicating an accumulated incidence of 3.6% (24/665) (95% CI, 2.2–5.0%). Of them, 19 cases of SSIs were found during patients' initial hospitalization for treatment of distal femur fractures; and the remaining 5 cases were confirmed when patients were readmitted for treatment of SSIs. There were 8 deep and 16 superficial SSIs, indicating the respective incidence being 1.2% (95% CI, 0.4–2.0%) and 2.4% (95% CI, 1.2–3.6%). The earliest diagnosis of SSI was at the 4th day while the latest was at the 142th day postsurgery, with median time of 11.5 days. Swabs from wound of 15 cases of SSIs (6 deep and 9 superficial SSIs) were cultured positive for bacterial species. *Staphylococcus aureus* was the most common causative bacteria, either alone (7, 46.7%) or as a mixed infection (3, 20%), followed by mixed bacterial (4, 26.7%) and *S epidermidis* (2, 13.3%) and others.

3.2. Univariate and multivariate analysis

Table 1 presents the results of univariate analysis for the categorical variables. Obesity, chronic steroid use, diabetes mellitus, open fracture, smoking, wound class, and use of temporary external fixation before definitive fixation were demonstrated to be significantly associated with SSI occurrence, and were to be entered into the multivariate logistic regression model. In addition, some approximately significant variables ($P<.20$) including cardiac disease, history of previous operation at any site, coinjuries ≥2 systems, prophylactic use of antibiotics, RBC, HGB, platelet, and ALB were identified, and were entered into the multivariate logistic regression model.

Table 2 presents the results of the multivariate logistic regression analysis. We identified 6 factors that were significantly associated with SSI: open fracture (OR, 5.2; $P<.001$), temporary external fixation (OR, 2.4; $P=.005$), obesity (OR, 3.2; $P=.002$), current smoking (OR, 2.8; $P=.021$), diabetes mellitus (OR, 2.2; $P=.004$), and preoperative reduced ALB (<35 g/L). Of them, smoking and preoperative reduced ALB level were modifiable factors. The final multivariate predictive model of SSI was reliable (Hosmer–Lemeshow test, $X^2=3.94$, $P=.656$).

4. Discussion

By far, there remains scarce of data on epidemiologic characteristics of SSI following an operated distal femur fracture. With 665

Table 1

Univariate analysis of variables potentially associated with surgical-site infection (SSI).

Variables	Number (%) of patients without SSI (n=641)	Number (%) of patients with SSI (n=24)	P
Gender (males)	357 (55.7)	15 (62.5)	.510
Age, yr			.669
18–45	323 (50.4)	10 (41.7)	
45–64	263 (41.0)	12 (50.0)	
≥65	55 (8.6)	2 (8.3)	
Living place (rural)	373 (58.2)	13 (54.2)	.695
Obesity (BMI ≥ 28.0)	127 (19.8)	9 (37.5)	.035*
Diabetes mellitus	58 (9.0)	7 (29.2)	.001*
Hypertension	141 (22.0)	6 (25.0)	.728
Cardiac disease	37 (5.8)	3 (12.5)	.174
Chronic steroid use	29 (4.5)	4 (16.7)	.007*
History of previous operation at any site	93 (14.5)	6 (25.0)	.156
Smoking	138 (21.5)	10 (41.7)	.020*
Alcohol consumption	252 (39.3)	11 (45.8)	.521
Open fracture	51 (8.0)	6 (25.0)	.003*
Mechanism (high energy)	497 (77.5)	20 (83.3)	.503
Side (left)	326 (50.9)	14 (58.3)	.472
Fracture type			.880
AO type A	287 (44.8)	12 (50.0)	
AO type B	148 (23.1)	5 (20.8)	
AO type C	206 (32.1)	7 (29.2)	
Coinjuries (≥2 system)	63 (9.8)	4 (16.7)	.085
Preoperative stay (≥7 d)	171 (26.7)	8 (33.3)	.470
Surgeon level (chief)	532 (83.0)	19 (79.2)	.625
Wound class			.001*
I–II	596 (93.0)	18 (75)	
III–IV	45 (7.0)	6 (25)	
ASA class			.275
I–II	557 (86.9)	19 (79.2)	
III–IV	84 (13.1)	5 (20.8)	
Anesthesia			.621
General	193 (30.1)	5 (20.8)	
Local anesthesia	402 (62.7)	17 (70.8)	
Combined anesthesia	46 (7.2)	2 (8.3)	
Solution to prepare the skin			.497
Alcohol	292 (45.6)	8 (33.3)	
Iodine	328 (51.2)	15 (62.5)	
Others	21 (3.3)	1 (4.2)	
Temporary external fixation use	89 (13.9)	7 (29.2)	.036*
Prophylactic antibiotics use	621 (96.9)	22 (91.7)	.186
Postoperative antibiotics use	592 (92.4)	21 (87.5)	.384
Drainage use	478 (74.6)	18 (75.0)	.962
Intraoperative blood loss (≥400 mL)	202 (31.5)	7 (29.2)	
Surgical duration			.995
<90 min	102 (15.9)	4 (16.7)	
90–150 min	459 (71.6)	17 (70.8)	
>150	80 (12.5)	3 (12.5)	
WBC (10^9/L)			.228
References (4–10)	504 (78.6)	17 (70.8)	
<4	52 (8.1)	1 (4.2)	
>10	85 (13.3)	6 (25.0)	
NEUT (10^9/L)			.576
References (1.8–6.3)	487 (76.0)	16 (66.7)	
<1.8	41 (6.4)	2 (8.3)	
>6.3	113 (17.6)	6 (25)	
LYM (10^9/L)			.373
References (1.1–3.2)	528 (82.4)	19 (79.2)	
<1.8	27 (4.2)	0	
>3.2	86 (13.4)	5 (20.8)	
RBC (10^{12}/L)			.157
References†	532 (83.0)	17 (70.8)	
<Lower limit	76 (11.9)	6 (25.0)	
>Upper limit	33 (5.1)	1 (4.2)	
HGB			.185
References‡	540 (84.2)	17 (70.8)	
<Lower limit	64 (10.0)	5 (20.8)	
>Upper limit	37 (5.8)	2 (8.3)	
Plt			.142
References (100–300 × 10^9/L)	584 (91.1)	19 (79.2)	
<Lower limit	22 (3.4)	2 (8.3)	
>Upper limit	35 (5.5)	3 (12.5)	
TP (<60 g/L)	104 (16.2)	6 (25.0)	.256
ALB (<35 g/L)	117 (18.3)	8 (33.3)	.063

ALB=albumin, ASA=American Society of Anesthesiologists, BMI=body mass index, HGB=hemoglobin, LYM=lymphocyte, NEUT=neutrophile granulocyte, Plt=platelet, RBC=red blood cell, TP=total protein, WBC=white blood cell.

* Significant variable.

† Reference range: female, 3.5–5.0/10^{12}; males, 4.0–5.5/10^{12}.

‡ Reference range: females, 110–150 g/L; males, 120–160 g/L.

Table 2

Significant risk factors associated with surgical-site infection after adjustment of confounding variables.

Variable	Multivariable logistic regression model	
	Adjusted OR (95% CI)	P
Open fracture	5.2 (2.1–9.0)	<.001
Temporary external fixation	2.4 (1.2–6.2)	.005
Obesity (BMI ≥28.0 kg/m^2)	3.2 (1.7–7.4)	.002
Smoking	2.8 (1.1–6.5)	.021
Diabetes mellitus	2.2 (1.3–4.2)	.004
Preoperative ALB <35 g/L	1.9 (1.0–5.8)	.037

ALB = albumin, BMI = body mass index, CI = confidence interval, OR = odds ratio.

fractures included, this study demonstrated the overall incidence of SSI following ORIF of a distal femur fracture was 3.6% (deep, 1.2%; superficial, 2.4%); the modifiable risk factors were smoking and preoperative reduced ALB level and the nonmodifiable ones were open fracture, temporary external fixation, obesity (BMI ≥ 28.0) and diabetes mellitus, respectively. S*taphylococcus aureus* was the most common causative bacterium for SSI, closely followed by mixed bacterial infections. We found patients with SSI had approximately twice the mean length of hospital stay as those without SSIs (29.0 vs 16.0 days, $P < .001$).

The incidence of SSI following orthopedic surgery varied, depending on the definition criteria of SSI, study design, and treatment modalities. We found a 3.6% incidence of SSI after ORIF of a distal femur fracture, which was in range with data reported by the National Nosocomial Infections Surveillance for orthopedic patients[19] and other studies for evaluating traumatic fractures of tibial plateau,[20] ankle,[21] or calcaneus.[22] Regarding distal femur fracture, there was lack of similarly well-studied data; instead, most researchers gave only passing mention to the SSI incidence. For example, Downs et al[23] and Jain et al[24] reported the incidence of SSI after surgical distal femur fractures was 0.1–11.2%, in their book or article. Hoffmann et al[16] also found 9 SSIs in 106 patients of distal femur fractures treated by locked plates and screws, indicating an incidence of 8.5%, which was more than twice as ours.

Open fracture and diabetes have also been identified as strong nonmodifiable risk factors associated with SSI, consistent with most studies.[20,21,25] Undoubtedly, the high-energy mechanism and the resultant serious soft-tissue damage and poor blood supply contribute to a greater risk of SSI. Although contaminated or dirty wound is known to represent a well-established risk factor for SSI in various surgical fields, in this study, it was not a significant result in the multivariate model. We hypothesize that the effect of wound contamination or dirtiness was covered by the stronger risk factors, such as open fracture, because both variables have much overlapping effect on SSI. We used the medical history section of patients' EMR to identify the diabetic status, but did not account for the level of glycemic control. Gulcelik et al[26] also suggested elevated HbA1c level was an important index factor in patients with diabetes, for predicting SSI or even death. Despite the crude binary classification, diabetes was identified as a strong risk factor for SS; however, we might underestimate the impact of poor glycemic level on SSI development, because not all diabetes patients had a higher HbA1c level.

Temporary external fixation and obesity (BMI > 28.0 kg/m^2) were nonmodifiable in emergent or elective trauma surgeries. On one hand, it is almost impossible to adjust or modify our patients' BMI in several or a dozen days before the surgery. On the other hand, obesity might also be a mixed factor that contributed to the increased risk of SSI. Besides its direct negative effect on SSIs, obesity was reported to be significantly associated with multiple surgery-related variables or morbidities, such as postoperative venous thromboembolism, increased intraoperative blood loss, longer surgical time, diabetes, or cardiac diseases,[27–29] which were also important contributors for development of SSI. The fact that use of temporary external fixation was associated with increased SSI risk did not implicate the external fixation itself, but more likely indicated the soft-tissue damage or soft-tissue problems. In other words, if Gustilo–Anderson classification for severity of soft tissues/bone as 1 variable is entered into the multivariate regression model, the results might be very likely different. Accordingly, we believe both risk factors reflect patient medical conditions or trauma severity, rather than factors amenable to intervention.

Smoking and preoperative reduced ALB were identified as the modifiable risk factors, which was consistent with most previous findings.[30–33] The mechanism that smoking increases the risk of SSI is related to reduced tissue perfusion and oxygenation and impaired inflammatory response.[30,31] Otherwise, temporary smoking cessation before the surgery could significantly reduce the risk of SSI. In a subgroup meta-analysis of 4 randomized controlled trials, authors found smoking cessation intervention was associated with 57%reduced risk of SSI.[32] Another meta-analysis of 25 studies showed smokers who quit smoking several weeks before surgery had reduced risk of wound-healing complications by 31% and respiratory complications by 23%, compared to current smokers. In our clinical practices, patients will be proactively informed of the harm of smoking on wound healing and the benefits from immediate smoking cessation upon their admission to our center; smokers are encouraged to cease smoking as early as possible before the surgery. In a meta-analysis of 13 studies including over 112,000 orthopedic patients, Yuwen et al[33] found perioperative serum ALB < 35 g/L was associated with 2.5-fold increased risk of SSI. Buteera[34] advised preoperative supplementation to increase ALB levels before elective surgery, and ALB > 30 g/L was demonstrated to promote adequate healing.

There are several limitations that should be mentioned in this study. The 1st was the retrospective nature. We were not able to evaluate the impact of some important variables on SSI, such as the flow of operating room personnel and visitors and air cleanliness of the operating room, which had been reported to be associated with bacterial colonization and loading.[35] We were not able to analyze some of the identified variables, such as daily amount of cigarettes and the days for use of temporary external fixation before the definitive fixation. The 2nd was merely relying on the EMR to collect data, which may weaken the reliability of data. The 3rd limitation involved the single-center design. Our orthopedic center represents a tertiary referral center, providing the highest treatment level for traumatic fractures in Hebei province with a catchment population over 75 million. Therefore, patients admitted frequently presented with more severe or refractory fractures, which likely resulted in a selection bias. Third, the postoperative 1-year for surveillance of SSI was not mandatory. We assumed a patient who was not diagnosed with an infection during hospitalization stay and did not return specifically for treatment of SSIs in the next 12 months did not have a SSI. As such, some patients with slight superficial SSI which resolved by physical therapy or oral antibiotics might not to be readmitted for treatment. Therefore, some patients suffering from subacute SSI might have been missed.

In conclusion, we found the incidence of SSI following ORIF of a distal femur fracture was 3.6%. Six independent risk factors were identified, including open fracture, temporary use of external fixation, current smoking, obesity, diabetes mellitus, and preoperative ALB level <35 g/L. Of them, current smoking and preoperative reduced ALB level were the true modifiable factors, and patients should be encouraged to cease smoking as early as possible and to increase the good-quality protein intake to reduce or prevent the SSI occurrence. An explanation of the nonmodifiable risk factors should be included when patients are counseled about their increased risk of SSI.

Acknowledgment

The authors are grateful to S Li, J Bai, Y Xu, and Y Zhao of the Department of Orthopedics, and to S Liu and Q Zhang of the Department of statistics and applications for their kind assistance.

Author contributions

Bing Zhang designed the study; Xiong Zhang and Ye Tian abstracted and documented the data; Yanbin Bai and Dehu Tian analyzed and interpreted the data; Yanbin Bai and Xiong Zhang wrote the manuscript and Bing Zhang approved the final version of the manuscript.

Conceptualization: Bing Zhang.
Data curation: Xiong Zhang, Ye Tian.
Formal analysis: Xiong Zhang, Ye Tian, Dehu Tian.
Funding acquisition: Ye Tian.
Investigation: Yanbin Bai, Xiong Zhang, Ye Tian, Dehu Tian.
Methodology: Yanbin Bai, Xiong Zhang, Ye Tian.
Project administration: Yanbin Bai, Dehu Tian.
Resources: Dehu Tian.
Software: Yanbin Bai.
Supervision: Yanbin Bai.
Writing – original draft: Yanbin Bai, Xiong Zhang.

References

[1] Lin S, Mauffrey C, Hammerberg EM, et al. Surgical site infection after open reduction and internal fixation of tibial plateau fractures. Eur J Orthop Surg Traumatol 2014;24:797–803.
[2] Thanni LOA, Aigoro NO. Surgical site infection complicating internal fixation of fractures: incidence and risk factors. J Natl Med Assoc 2004;96:1070–2.
[3] Kelly EG, Cashman JP, Groarke PJ, et al. Risk factors for surgical site infection following operative ankle fracture fixation. Ir J Med Sci 2013;182:453–6.
[4] Urquhart DM, Hanna FS, Brennan SL, et al. Incidence and risk factors for deep surgical site infection after primary total hip arthroplasty: a systematic review. J Arthroplasty 2010;25:1216–22.
[5] Bozic KJ, Ward DT, Lau EC, et al. Risk factors for periprosthetic joint infection following primary total hip arthroplasty: a case control study. J Arthroplasty 2014;29:154–6.
[6] Edwards C, Counsell A, Boulton C, et al. Early infection after hip fracture surgery: risk factors, costs and outcome. J Bone Joint Surg Br 2008;90:770–7.
[7] Mackenzie WG, Matsumoto H, Williams BA, et al. Surgical site infection following spinal instrumentation for scoliosis: a multicenter analysis of rates, risk factors, and pathogens. J Bone Joint Surg Am 2013;95:800–6.
[8] Ishii M, Iwasaki M, Ohwada T, et al. Postoperative deep surgical-site infection after instrumented spinal surgery: a multicenter study. Global Spine J 2013;03:95–102.
[9] Thakore RV, Greenberg SE, Shi H, et al. Surgical site infection in orthopedic trauma: a case–control study evaluating risk factors and cost. J Clin Orthop Trauma 2015;6:220–6.
[10] Green JW, Wenzel RP. Postoperative wound infection: a controlled study of the increased duration of hospital stay and direct cost of hospitalization. Ann Surg 1977;185:264–8.
[11] Whitehouse JD, Friedman ND, Kirkland KB, et al. The impact of surgical-site infections following orthopedic surgery at a community hospital and a university hospital: adverse quality of life, excess length of stay, and extra cost. Infect Control Hosp Epidemiol 2002;23:183–9.
[12] Ovaska MT, Makinen TJ, Madanat R, et al. Predictors of poor outcomes following deep infection after internal fixation of ankle fractures. Injury 2013;44:1002–6.
[13] Partanen J, Syrjälä H, Vähänikkilä H, et al. Impact of deep infection after hip fracture surgery on function and mortality. J Hosp Infect 2006;62:44–9.
[14] Zhang Y. Clinical Epidemiology of Orthopedic Trauma. 2nd ed Stuttgart: Thieme; 2016.
[15] Leggon RE, Feldmann DD, Lindsey RW. Fractures of the Distal Femur. Berlin, Heidelberg: Springer; 2001.
[16] Hoffmann MF, Jones CB, Sietsema DL, et al. Clinical outcomes of locked plating of distal femoral fractures in a retrospective cohort. J Orthop Surg Res 2013;8:43.
[17] Bachoura A, Guitton TG, Smith RM, et al. Infirmity and injury complexity are risk factors for surgical-site infection after operative fracture care. Clin Orthop Relat Res 2011;469:2621–30.
[18] Horan TC, Gaynes RP, Martone WJ, et al. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. Am J Infect Control 1992;13:606–8.
[19] National Nosocomial Infections Surveillance (NNIS) SystemNational Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004. Am J Infect Control 2004;32:470–85.
[20] Zhu Y, Liu S, Zhang X, et al. Incidence and risks for surgical site infection after adult tibial plateau fractures treated by ORIF: a prospective multicentre study. Int Wound J 2017;14:982–8.
[21] Sun Y, Wang H, Tang Y, et al. Incidence and risk factors for surgical site infection after open reduction and internal fixation of ankle fracture: a retrospective multicenter study. Medicine 2018;97:e9901.
[22] Ding L, He Z, Xiao H, et al. Risk factors for postoperative wound complications of calcaneal fractures following plate fixation. Foot Ankle Int 2013;34:1238–44.
[23] Downs C, Berner A, Schütz M. Fractures of the Distal Femur. Berlin Heidelberg: Springer; 2014.
[24] Jain RK, Shukla R, Singh P, et al. Epidemiology and risk factors for surgical site infections in patients requiring orthopedic surgery. Eur J Orthop Surg Traumatol 2015;25:251–4.
[25] Momaya AM, Hlavacek J, Etier B, et al. Risk factors for infection after operative fixation of Tibial plateau fractures. Injury 2016;47:1501–5.
[26] Gulcelik NE, Bayraktar M, Caglar O, et al. Mortality after hip fracture in diabetic patients. Exp Clin Endocrinol Diabetes 2011;119:414–8.
[27] Jiang J, Teng Y, Fan Z, et al. Does obesity affect the surgical outcome and complication rates of spinal surgery? A meta-analysis. Clin Orthop Relat Res 2014;472:968–75.
[28] Kempegowda H, Richard R, Borade A, et al. Obesity is associated with high peri-operative complications among surgically treated intertrochanteric fracture of the femur. J Orthop Trauma 2017;31:352–7.
[29] Weinlein JC, Deaderick S, Murphy RF. Morbid obesity increases the risk for systemic complications in patients with femoral shaft fractures. J Orthop Trauma 2015;29:91–5.
[30] Kean J. The effects of smoking on the wound healing process. J Wound Care 2010;19:5–8.
[31] Nåsell H, Ottosson C, Törnqvist H, et al. The impact of smoking on complications after operatively treated ankle fractures–a follow-up study of 906 patients. J Orthop Trauma 2011;25:748–55.
[32] Sorensen LT. Wound healing and infection in surgery. The clinical impact of smoking and smoking cessation: a systematic review and meta-analysis. Arch Surg 2012;147:373–83.
[33] Yuwen P, Chen W, Lv H, et al. Albumin and surgical site infection risk in orthopaedics: a meta-analysis. BMC Surg 2017;17:7.
[34] Buteera AM. Prevention of perioperative wound infections. Psykhe Revista De La Escuela De Psicología 2008;13:3–7.
[35] Mchugh SM, Hill AD, Humphreys H. Laminar airflow and the prevention of surgical site infection. More harm than good? Surgeon 2015;13:52–8.