Incidence and predictors of surgical site infection after distal femur fractures treated by open reduction and internal fixation: a prospective single-center study

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Abstract

Background: There remain limited data on the epidemiological characteristics and related predictors of surgical site infection (SSI) after open reduction and internal fixation (ORIF) for distal femur fractures. We designed this single-centre prospective study to explore and resolve these clinical problems.

Methods: From October 2014 to December 2018, 364 patients with distal femur fractures were treated with ORIF and followed for complete data within one year. Receiver operating characteristic (ROC) analyses, univariate Chi-square analyses, and multiple logistic regression analyses were used to screen the adjusted predictors of SSI.

Results: The incidence of SSI was 6% (22/364): 2.4% for superficial SSIs and 3.6% for deep SSIs. Staphylococcus aureus (methicillin-resistant S. aureus in 2 cases) was the most common pathogenic bacteria (7, 36.8%). In multivariate analysis, parameters independently associated with SSI were: Open fracture (OR: 7.27, p = 0.003), drain use (OR: 4.11, p = 0.037), and incision cleanliness (OR: 3.53, p = 0.002). An albumin/globulin (A/G) level $\geq$ 1.35 (OR: 0.23, p = 0.042) was an adjusted protective factor for SSI.

Conclusions: The SSI after ORIF affected approximately one in 15 patients with distal femur fractures. We recommend that maintaining A/G levels higher than 1.35 is introduced during hospitalization and elaborative evaluation of drain use is conducted for reducing the risk of post-operative SSI.

Trial registration: NO 2014-015-1, October 15, 2014. We registered our trial prospectively in October 15, 2014 before the first participant was enrolled. This study protocol was conducted according to the Declaration of Helsinki and approved by the Institutional Review Board. The ethics committee approved the Surgical Site Infection in Orthopaedic Surgery (NO 2014-015-1). Data used in this study were obtained from the patients who underwent orthopaedic surgeries between October 2014 to December 2018.

Background

Distal femur fractures (DFFs) are relatively uncommon but severe in orthopaedic trauma, comprising approximately 8.7% of all femoral fractures and 0.8% of total body fractures in Chinese adults [1]. These fractures show a bimodal distribution. On the one hand, most of the fractures in younger patients result from high-energy injuries, which are usually open and comminuted fractures [2,3]. On the other hand, fractures in older patients are caused by low-energy injuries, with a one-year mortality rate up to 13.4% [4]. Furthermore, DFFs potentially involve articular surface and may be associated with vascular or nerve injuries. Due to early mobility, pain relief, and restoration of mechanical alignment, open reduction and internal fixation (ORIF) is the most common option for these patients. However, both inevitable soft tissue dissection associated with ORIF and complex perioperative management possibly result in knee dysfunction, traumatic arthritis, bone nonunion, infection and other postoperative complications.
Of these complications, surgical site infection (SSI) is a major challenge for most orthopaedic and trauma surgeons. SSIs increase the risk of abscess formation, osteomyelitis, refracture, delayed bone healing or non-union formation, which might impair the motor function of injured limbs or peripheral joints [5,6]. Furthermore, SSIs are known to increase the length of stay by an average of 10 days and to cost the National Health Service (NHS) of the United Kingdom an estimated £700 million per year [7]. It has been reported that about 50.0% of SSI cases can be avoided by the application of evidence-based prevention strategies [8]. Therefore, the identification of SSI-related predictors and screening of at-risk patients may propose a cost-effective and simple approach for prevention of SSI occurrence.

At present, most studies have focused on SSIs in common sites of the body involving the forearm, hip, tibial plateau, and ankle [9-13]. However, researches on the epidemiological characteristics of SSIs after adult DFFs treated by ORIF are still limited, especially in the last five years. Additionally, evidence-based medicine is continuously changing. The incidence of SSI after operations for DFFs has been showed to vary from 0.3% to 11.2% [14], and most factors are not conclusive. Hoffmann et al. identified open injury and current smoking as associated risk factors [6]. Lu et al. added obesity and diabetes mellitus to the SSI-related predictors [15]. Moreover, all three studies above were retrospective and were collectively limited by untimely data selection owing to recall and response bias.

Therefore, we carried out this prospective study design with two aims: first, to summarize the epidemiological features of SSI after adult DFFs treated by ORIF with a one-year follow-up; second, to identify the SSI-related predictors and find the optimal cut-off values of continuous variables.

**Methods**

**Study design**

This was a prospective single-centre study, and data were obtained from patients who underwent open reduction and internal fixation of DFFs between October 2014 and December 2018. The ethics committee approved the Surgical Site Infection in Orthopaedic Surgery (NO 2014-015-1), and the informed consents were obtained from all participants. All patients who were 18 years old and over with acute DFFs treated by ORIF were included in this study. The exclusion criteria were listed as following: age less than 18 years old, old fractures (>21 days from earliest trauma), pathological fractures, and first treatment at other hospitals. Patients with open fractures or with multiple fractures were also involved to investigate their effect on SSIs. All enrolled patients had intraoperative antibiotic prophylaxis and were separated into two groups based on the occurrence of SSI. The case group was defined as patients with SSIs, and the control group involved patients who did not suffer from SSIs. The endpoint of the prospective study was any evidence of SSI obtained from telephone assessment, interview, or the clinical information one year after surgery.

**SSI definition**
The diagnostic criteria for SSI within one year postoperatively were based on the definition of the CDC [8]. A superficial SSI only infiltrates the skin or subcutaneous tissue of the operation site. A deep SSI was identified if it satisfied one of the following conditions: infection through the deep fascia, persistent wound effusion or dehiscence, local abscess requiring focal debridement and implant replace or retrieve. Wound exudates were sent for bacterium cultures and drug susceptibility tests. Any inpatient who commenced antibiotic treatment for wound problems (redness, swelling, hot pain) but did not conform the criteria of the deep SSI was classified as a superficial SSI, regardless of any microbiology results.

**Data collection and definition of variables of interest**

All the data mentioned below were collected by five well-trained investigators. Investigators followed the patients closely by morning work rounds and reviewed patients’ clinical data. The suture site was observed by researchers starting from the first day after ORIF until hospital discharge. After discharge, patients who had not developed SSI were followed for any evidence of SSI by telephone interview at 2, 4, 6 and 12 months postoperatively. Patients with suspicious SSI were required to return for re-examination and etiologic diagnosis. We usually recalled the patients for the radiological and clinical periodic evaluation every half a year after curative surgery. During the study period, detailed variables of interest were collected and divided into four aspects.

Demographic variables included age (18 to 45, 46 to 59, and ≥ 60 years), sex, height (m), weight (kg), location (rural, urban), cigarette consumption, alcohol consumption, diabetes mellitus, hypertension, cardiovascular disease and body mass index (BMI, kg/m$^2$). BMI was split into five groups according to the Chinese reference criteria: underweight, < 18.5; normal, 18.5 to 23.9; overweight, 24 to 27.9; obesity, 28 to 31.9; and morbid obesity ≥ 32.

Fracture-related variables included injury type (closed, open), concurrent fracture sites (single fracture, multiple fractures), affected side and injury mechanism. Injury mechanisms were divided into two categories: low-energy (fall from a standing height) and high-energy (traffic accidents, falling accidents from high places, human violence and others).

Operation-related variables included history of previous operation at any site, preoperative stay, postoperative stay, intraoperative blood loss (< 400 and ≥ 400 mL), operation duration (< 120, 120 to 180, and > 180 minutes), anaesthetic type (local, combined spinal-epidural, and general), internal fixator use (plate or no plate), intraoperative drainage use, incision cleanliness (I, clean; II, potentially contaminated; and III, contaminated), and the American Society of Anesthesiologists (ASA, I-II and III-IV) classification system [9]. Preoperative stay was defined as the time period from the first injury to ORIF, which was separated into two groups: 1, < 7 days and 2, ≥ 7 days.

Laboratory-related variables were assessed within 24 hours preoperatively and were conventionally divided into normal (reference range), above normal, and below normal. These biochemistry indices
involved white blood cell (WBC) counts, and neutrophil granulocyte (NEUT), lymphocyte (LYM), monocyte (MON), eosinophil granulocyte (EOS), basophilic granulocyte (BAS), red blood cell (RBC), blood platelet (PLT), blood glucose (GLU), serum total protein (TP), albumin (ALB), globulin (GLOB), and albumin/globulin (A/G).

Statistical analysis

Statistical analyses were conducted with SPSS version 25.0 (IBM Corp., Armonk, NY, USA). The continuous variables were showed as the median, mean ± standard deviation (SD), and range. The distributions of all data were evaluated for normality using the Shapiro-Wilk test. A Whitney U test or t test was performed to compare continuous variables between SSI and non-SSI groups according to the homogeneity of variance test and normality test. For the continuous variables with statistical significance ($p < 0.05$), receiver operating characteristic (ROC) analyses were carried out to detect the optimum cut-off value. Subsequently, Pearson chi-square or Fisher’s exact test was utilized to indicate the intercorrelation between each categorical variable and the infection risk. Predictors found to be significant ($p < 0.05$) in the single factor analysis were entered into stepwise multiple logistic regression analyses (backward LR) to screen the adjusted factors. The odds ratio (OR) and 95% confidence interval (95% CI) were conducted to evaluate the correlation magnitude between factors and SSI risk. Normally a $p < 0.05$ was considered statistically significant. The Hosmer-Lemeshow test was carried out to assess the goodness of fit for the final model.

Results

The selection of the participants

Fig. 1 showed the flow chart for the selection of study participants. During the investigation, a total of 461 patients suffering from distal femoral fractures were treated by ORIF in our institution. Of them, 47 patients were less than 18 years old; 19 had pathological fractures (including bone or joint tumor, or soft tissue tumor)5 had old fractures and 2 incomplete data. A total of 388 patients treated by ORIF were included in this study, and 24 were lost (6.2%) to follow-up. Finally, the remaining 364 patients with complete data were included in the analysis. For the 364 patients, the average age was 53.7±17.0 years, and the average BMI was 25.6±4.1 kg/m$^2$. The cohort included 193 males and 171 females, with 215 left-side and 149 right-side fractures.

Frequency of causative bacteria

Table 1 demonstrated the frequency of causative bacterial. In total, there were 22 SSIs: 9 superficial SSIs and 13 deep SSIs. The total incidence of SSIs was 6.0% (22/364), with superficial SSIs accounting for
2.4% (9/364) and deep SSIs accounting for 3.6% (13/364). The earliest diagnosis of SSI was on the second day after ORIF, while the latest was on the 106th day, with a median time of 14 days. The majority of SSIs (81.8% 18/22) occurred during the hospital stay. Swabs from the wounds of 8 superficial SSIs and 11 deep SSIs were cultured for bacterial species. Of 22 patients with SSIs, 19 (86.4%, 19/22) were successfully tested for causative bacteria. *Staphylococcus aureus* (*methicillin-resistant Staphylococcus aureus* in 2 cases) was the most common pathogenic bacteria (36.8% 7/19), followed by mixed bacteria (31.6% 6/19), *Escherichia coli* (21.1% 4/19), *Enterobacter cloacae* (21.1% 4/19), *Acinetobacter baumannii* (15.8% 3/19), *Pseudomonas aeruginosa* (15.8% 3/19), and others (Table 1).

### Continuous variables and the optimum cut-off value

Table 2 demonstrated a comparison of the results of eight continuous variables between the SSI and non-SSI groups. There were no significant differences between the groups in terms of age (54.0 vs 49.7 years), BMI (25.6 vs 26.1 kg/m²), preoperative stay (7.7 vs 7.0 days), operation duration (177.0 vs 194.6 minutes) or intraoperative blood loss (606.7 vs 629.6 mL). However, a significant difference was observed for the variables of postoperative stay (15.5 vs 45.5 days, *p* < 0.001), ALB level (34.0 vs 30.5 g/L, *p* = 0.017) and A/G level (1.5 vs 1.2, *p* < 0.001) between the two groups. Table 3 showed that ROC analysis was performed to identify the area under the curve and the optimum cut-off value for each statistically significant variable listed above. The cut-off values for ALB and A/G levels were 30.3 g/L and 1.35, respectively. Based on these cut-off values, we dichotomised the variables.

### Univariate analysis of the variables

Table 4 depicted the univariate analysis of the variables of interest. Of the 35 predictive variables listed, 10 factors were demonstrated to correlate with SSI; these factors included location, smoking status, alcohol consumption, open fracture, injury mechanism, concurrent fracture sites, incision cleanliness, drain use, ALB level and A/G level. Hence, these 10 factors were included in the multiple logistic regression model. In addition, other common variables, involving surgical duration, diabetes mellitus, hypertension, cardiovascular diseases and BMI, were also enrolled in the final models.

### Multiple logistic regression analysis

Table 5 indicated the final results of the multiple logistic regression analysis. Open fracture (OR = 7.3; 95% CI, 2.0-26.7; *p* = 0.003), drain use (OR = 4.1; 95% CI, 1.1-15.5; *p* = 0.037) and incision cleanliness (OR = 3.5; 95% CI, 1.6-7.7; *p* = 0.002) were identified as the adjusted risk factors associated with SSIs, while A/G level ≥1.35 (OR = 0.2; 95% CI, 0.1-1.0; *p* = 0.042) appeared as an independent protective factor of SSIs. The results of the Hosmer-Lemeshow test demonstrated adequate fitness (χ² = 5.2; *p* = 0.735).
**Discussion**

Our present study of 364 patients indicated that the total incidence of SSI after ORIF for DFFs was 6.0% at the one-year follow-up, which is consistent with a retrospective multicentre analysis of 724 patients with a two-years follow-up [15]. After adjusting for confounding variables, open fracture, drain use, incision cleanliness and A/G level were demonstrated to be significantly associated with SSIs. We also confirmed that *S. aureus* was the most frequently isolated pathogen of SSIs; patients with an SSI had a significantly longer postoperative stay than those without an SSI (45.5 vs 15.5 days).

Open fracture is a well-recognized risk factor for SSIs after orthopaedic surgeries [16]. In the present study, the odds ratio of open fracture was 7.3 in multivariate analysis models. The prevalence of SSI after open DFFs treated by ORIF in our study was 19.8% (17/86), which was in the range from 10.4% to 20.0% according to previous studies on lower limbs [6,12,15]. However, Lu and his colleague reported that the prevalence of SSI after open intra-articular fractures of the distal femur treated by ORIF decreased to 10.4%, which was approximately equal to half of the prevalence of our current study (19.8%) [15]. The potential cause for this was the exclusion of femoral supracondylar fractures. In his study, all enrolled patients were sustained an intraarticular fracture, such as femoral intercondylar fractures, and the blood supply around the intercondylar region was more abundant than that around the supracondylar region. The higher the blood supply is, the lower the infection rate. In addition, open fractures accounted for 9.4% (68/724) in his study, while the proportion of open fractures was 23.6% (86/364) in our study. Regarding open fractures with severe soft-tissue trauma, delaying ORIF might have a positive influence on preventing SSI. Damage control orthopaedics (DCO) facilitates the recovery of soft tissue, which provides sufficient union for fractures [17]. We were unable to identify the effect of delayed ORIF owing to the small sample size of open fractures. Furthermore, surgeons should attach great importance to open fractures; early intravenous antibiotics and thorough surgical debridement should be routinely performed.

Drains are used extensively in orthopaedics with the purpose of reducing the postoperative seroma. However, the criteria for using drains are not clear; patients often complain of anxious and pain from drainages, and drainage sites may retain a potential infection source. Some studies indicate that drain use plays a critical role in developing SSI after surgery [18,19], which is in accordance with our results that an independent factor of drain use increased probability of SSI by 4.1 times (95% CI, 1.1-15.5). Theoretically, drain use can increase the risk of infection. Bacteria, especially skin microbiome, spread along the drainage tube and have been identified from the tips of drainage tubes even as early as 48 hours post-operatively [20]. Pennington et al. reported that long-term surgical drain retention was correlated with the risk of deep SSI after operations for degenerative spinal diseases [21]. Therefore, we suggest that no or short-term drain use may reduce the risk of SSI and further shorten the length of hospitalization.

It is well known that dirty surgical incisions have prolonged adverse impacts on wound closure. In the present investigation, we evaluated incision cleanliness during the operation. Then, we concluded a similar result that the risk of SSI increased by 3.5 (95% CI, 1.6-7.7) times with every increase in the grade
of incision cleanliness. In a retrospective case-control study that included 2617 cases of ankle fractures treated by ORIF, the OR of SSI was 1.8 (95% CI, 1.1-3.2) with grade II-IV incision cleanliness, which is also in agreement with other reports of orthopaedic procedures [13,22]. In clinical practice, medical staff examine surgical incisions and worry about infection in the early days after surgery. However, patient-directed active surgical incision self-monitoring may help to further SSI reduction [23]. Hence, this finding would be a significant advance for SSI management that integrates reliable patients’ surgical incision surveillance into the clinical workflow.

The higher A/G level instead of ALB level was a significant independent protective factor for SSI after adult DFFs treated by ORIF, which was first reported in the present study, although a lower ALB level had been reported as a risk factor for SSIs after traumatic and elective orthopaedic surgeries [16]. Moreover, we further found that patients with A/G levels ≥ 1.35 had a 77.0% decreased possibility of SSI when compared to those with A/G levels < 1.35. In the clinic, the A/G level (protein quotient) is the weight ratio of albumin to globulin, which is normal range from 1.2 to 2.4. The A/G maintains a lower level in protein deficiency or metabolic abnormalities. We proposed that the A/G level was more comprehensive and meaningful for predicting SSI risk than the ALB level. Both ALB and GLOB are necessary to maintain nutrition and immune balance for wound healing. On the one hand, ALB transports essential electrolyte and amino acids to improve the wound healing. On the other hand, GLOB, especially immunoglobulin, has indispensable and favourable anti-infection effects as well as lowers the high risk of postsurgical infection in the intensive care unit (ICU) [24]. Undoubtedly, the preoperative active supplementation of nutrition to maintain an appropriate level of serum A/G plays a significant beneficial role in the decrease of SSIs and other postoperative complications. Therefore, we recommend that all inpatients, especially those with serum A/G levels <1.35, are supposed to regularly supplement with protein-rich products in the perioperative period.

The present study had three highlights: first, it was a prospective study with a one-year follow-up; second, ROC analysis was performed to detect a highly sensitive cut-off value for statistically significant continuous variables; and third, to our knowledge, it was first study to report that an A/G level ≥ 1.35 is an independent protective factor for SSI after adult DFFs treated by ORIF. However, the study was not without limitations. The interference of ORIF performed by multiple trauma surgeons was not excluded. In addition, some variables that potentially influence the development of SSI were not included, such as the internal fixation material (titanium or stainless) and surgical incision length.

**Conclusion**

In summary, the overall incidence of SSIs after adult DFFs treated by ORIF was 6.0% (22/364), with an incidence of superficial SSIs of 2.4% (9/364) and of deep SSIs of 3.6% (13/364). Open fracture, drain use, and incision cleanliness were identified as adjusted risk factors for SSIs after DFFs. An A/G level ≥ 1.35 was an adjusted protective factor for SSIs. We recommend that an early assessment of nutritional status and adequate protein intake were introduced during hospitalization and judicious use of drains was conducted for reducing the risk of post-operative SSI.
Abbreviations

DFFs: distal femur fractures; SSI: surgical site infection; ORIF: open reduction and internal fixation; ROC: Receiver operating characteristic; A/G: albumin/globulin; BMI: body mass index.

Declarations

Ethics approval and consent to participate

This study was approved by the Committee on Ethics and the Institutional Review Board of the Third Hospital of Hebei Medical University (NO 2014-015-1). All the participants had written the informed consent before the study.

Consent to publish

Written informed consent for publication was obtained from all patients.

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors’ contributions
YZZ designed the study; JZZ and KZ searched relevant studies; JYL and HYM analysed and interpreted the data; YBZ and JZZ wrote the manuscript and YZZ approved the final version of the manuscript.

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### Tables

#### Table 1 Frequency of causative bacteria

| Bacteria                                   | Frequency |
|--------------------------------------------|-----------|
| **Single-bacteria causing SSI**             |           |
| *Staphylococcus aureus*                    | 2         |
| *Pseudomonas aeruginosa*                   | 2         |
| *Enterobacter cloacae*                     | 3         |
| *Escherichia coli*                         | 3         |
| *Acinetobacter baumannii*                  | 2         |
| *Coagulase negative staphylococcus*        | 1         |
| *Enterococcus faecalis*                    | 1         |
| **Mixed-bacteria causing SSI**              |           |
| *Staphylococcus aureus + Staphylococcus epidermidis* | 1 |
| *Staphylococcus aureus + Enterococcus faecalis* | 1 |
| *Staphylococcus aureus + Klebsiella pneumoniae pneumoniae* | 1 |
| *Enterobacter cloacae + methicillin-resistant Staphylococcus aureus (MRSA)* | 1 |
| *Escherichia coli + methicillin-resistant Staphylococcus aureus (MRSA)* | 1 |
| *Escherichia coli + Acinetobacter baumannii + Enterobacter cloacae + Pseudomonas aeruginosa* | 1 |

_Abbreviation: SSI surgical site infection._
### Table 2 Comparison of continuous variables in patients with and without SSI

| Variables                  | Patient without SSI (median, mean ± SD) (n=342) | Patient with SSI (median, mean ± SD) (n=22) | p value |
|----------------------------|-----------------------------------------------|---------------------------------------------|---------|
| Age (years)                | 55,54.0±17.1                                  | 48,49.7±14.6                                | 0.186   |
| BMI (kg/m²)                | 24.9,25.6±4.2                                 | 27,26.1±4.0                                 | 0.454a  |
| Preoperative stay (days)   | 6,7.7±5.0                                     | 5.7.0±7.1                                   | 0.184b  |
| Operation duration (minutes)| 163,177.0±76.4                               | 180,194.6±71.6                              | 0.136b  |
| Intraoperative blood loss (ml)| 400,606.7±522.2                          | 550,629.6±329.4                              | 0.151b  |
| Postoperative stay (days)  | 11,15.5±28.1                                  | 36,45.5±28.1                                | <0.001b |
| ALB(g/L)                   | 33.6,34.0±5.6                                 | 30.1,30.5±6.3                               | 0.017a  |
| A/G                        | 1.4,1.5±0.4                                   | 1.1,1.2±0.3                                 | <0.001a |

*Abbreviation: SSI surgical site infection, BMI body mass index, ALB albumin, A/G albumin/globulin.*

*a* Student t test;

*b* Mann-Whitney U test

### Table 3 The detailed results of the ROC curve

| Variable | Cut-off value | Area under the curve (95 CI) | Sensitivity | Specificity | p value |
|----------|---------------|------------------------------|-------------|-------------|---------|
| ALB(g/L) | 30.3          | 65.2%(52.9%-77.4%)           | 73.0%       | 59.1%       | 0.017   |
| A/G      | 1.35          | 71.8%(62.0%-81.6%)           | 56.3%       | 81.9%       | 0.001   |

*Abbreviation: ROC receiver operating characteristic, ALB albumin, A/G albumin/globulin.*
### Table 4: Univariate analysis of variables of interest

| Variables                                         | Number (%) of patients without SSI (n = 342) | Number (%) of patients with SSI (n = 22) | p value  |
|---------------------------------------------------|---------------------------------------------|-----------------------------------------|----------|
| **Gender (males)**                                | 177 (51.8)                                  | 16 (72.7)                                | 0.056    |
| **Age**                                           |                                             |                                         | 0.192    |
| 18-45                                             | 103 (30.1)                                  | 8 (36.4)                                 |          |
| 46-59                                             | 96 (28.1)                                   | 9 (40.9)                                 |          |
| ≥60                                               | 143 (41.8)                                  | 5 (22.7)                                 |          |
| **Location (rural)**                              | 242 (70.8)                                  | 20 (90.9)                                | 0.041*   |
| **Obesity (BMI ≥ 28)**                            | 61 (17.8)                                   | 9 (40.9)                                 | 0.084    |
| **Diabetes mellitus**                             | 81 (23.7)                                   | 5 (22.7)                                 | 0.918    |
| **Hypertension**                                  | 89 (26.0)                                   | 6 (27.3)                                 | 0.897    |
| **Cardiovascular diseases**                       | 52 (15.2)                                   | 2 (10.5)                                 | 0.578    |
| **History of previous operation at any site**     | 110 (32.2)                                  | 5 (22.7)                                 | 0.356    |
| **Smoking**                                       | 42 (12.3)                                   | 8 (36.4)                                 | 0.004*   |
| **Alcohol consumption**                           | 49 (14.3)                                   | 9 (40.9)                                 | 0.003*   |
| **Open fracture**                                 | 69 (20.2)                                   | 17 (77.3)                                | <0.001*  |
| **Mechanism (high energy)**                       | 212 (62.0)                                  | 20 (90.9)                                | 0.006*   |
| **Side (left)**                                   | 201 (58.8)                                  | 14 (63.6)                                | 0.653    |
| **Concurrent fractures (≥ 2 sites)**              | 158 (44.2)                                  | 18 (81.8)                                | 0.001*   |
| **Preoperative stay (≥ 7 days)**                  | 165 (48.2)                                  | 11 (50.0)                                | 0.873    |
| **Incision cleanliness**                          |                                             |                                         | <0.001*  |
| I                                                 | 322 (94.2)                                  | 11 (50.0)                                |          |
| II                                                | 14 (4.1)                                    | 4 (18.2)                                 |          |
| III                                               | 6 (1.8)                                     | 7 (31.8)                                 |          |
| **ASA**                                           |                                             |                                         | 0.133    |
| I-II                                              | 225 (65.8)                                  | 11 (50.0)                                |          |
| III-V                                             | 117 (34.2)                                  | 11 (50.0)                                |          |
| **Anesthesia type**                               |                                             |                                         | 0.497    |
| **Local anesthesia**                              | 14 (4.1)                                    | 2 (9.1)                                  |          |
| **Combined spinal-epidural**                      | 147 (43.0)                                  | 8 (36.4)                                 |          |
| **General**                                       | 181 (52.9)                                  | 12 (54.5)                                |          |
| **Drainage use**                                  | 174 (50.9)                                  | 16 (72.7)                                | 0.047*   |
| **Plate use (vs without plate)**                  | 263 (76.9)                                  | 19 (86.4)                                | 0.303    |
| **Intraoperative blood loss**                     | 161 (47.1)                                  | 13 (59.1)                                | 0.274    |
| **≥ 400 mL**                                      |                                             |                                         | 0.312    |
| **Surgical duration**                             |                                             |                                         | 0.420    |
| <120 minutes                                      | 56 (16.4)                                   | 2 (9.1)                                  |          |
| 120-180 minutes                                   | 181 (52.9)                                  | 10 (45.5)                                |          |
| >180                                              | 105 (30.7)                                  | 10 (45.5)                                |          |
| **WBC (10⁹/L)**                                   |                                             |                                         | 0.476    |
| References (4-10)                                 | 198 (57.9)                                  | 10 (45.5)                                |          |
| >10                                               | 140 (40.9)                                  | 12 (54.5)                                |          |
| **NEUT (10⁹/L)**                                  |                                             |                                         | 0.812    |
| References (1.8-6.3)                              | 135 (39.5)                                  | 7 (31.8)                                 |          |
| >6.3                                              | 207 (60.5)                                  | 15 (68.2)                                |          |
| **LYM (10⁹/L)**                                   |                                             |                                         |          |
| References (1.1-3.2)                              | 195 (57.0)                                  | 14 (63.6)                                |          |
<1.1
MON (10⁹/L) 146(42.7) 8(36.4) 0.818
References (0.1-0.6) 117(39.5) 7(31.8)
>0.6 225(65.8) 15(68.2) 0.829
EOS (10⁹/L) 248(72.5) 17(77.3) 0.408
References (0.02-0.52) 313(91.5) 19(86.4)
<0.02 91(26.6) 5(22.7) 0.076
BAS (10⁹/L) 29(8.5) 3(14.0) 0.209
References (0-0.06) 313(91.5) 19(86.4)
>0.06 244(68.7) 19(86.4)
RBC (10¹²/L) 206(60.2) 9(40.9) 0.630
References (125-300) 116(33.9) 11(50.0)
<125 20(5.8) 2(9.1) 0.005*
>300 264(77.2) 16(72.7)
TP (<65 g/L) 71(20.8) 2(9.1) 0.294
ALB (<30 g/L) 150(44.0) 18(81.8) 0.001*
GLOB (<20 g/L) 192(56.0) 4(18.2)
A/G 151(44.2) 9(40.9) 0.766
<1.35 116(33.9) 11(50.0)
≥1.35 20(5.8) 2(9.1) 0.042
GLU (mmol/L) 191(55.8) 13(51.9)
References (3.9-6.1) 151(44.2) 9(40.9) 0.003
>6.1 192(56.0) 4(18.2)
Abbreviation: SSI surgical site infection, BMI body mass index, ASA American Society of Anesthesiologists, WBC white blood cell, NEUT neutrophile, LYM lymphocyte, MON monocyte, EOS eosinophils, BAS basophilic, PLT platelet, TP total protein, ALB albumin, GLOB globulin, A/G albumin/globulin, RBC red blood cell, reference range(10¹²/L): females 3.5-5.0; males 4.0-5.5.

* indicates significant variable at p < 0.05.

Table 5  Multivariate analysis of factors associated with SSI after ORIF

| Variables                  | Odds ratio | 95% CI       | p value |
|----------------------------|------------|--------------|---------|
| Open injury                | 7.3        | 2.0-26.7     | 0.003   |
| Drainage use               | 4.1        | 1.1-15.5     | 0.037   |
| Incision cleanliness       | 3.5        | 1.6-7.7      | 0.002   |
| A/G≥1.35                   | 0.2        | 0.1-1.0      | 0.042   |

Abbreviation: SSI surgical site infection, ORIF open reduction and internal fixation, CI confidence interval, A/G albumin/globulin.

Figures
Figure 1

The flow chart for the selection of study participants.

Patients with distal femoral fractures were treated by ORIF from October 2014 to December 2018 (n=461)

Exclusion criteria (n=73): Age < 18 (n=47) Pathologic fractures (n=19) Old fractures (n=5) Incomplete data (n=2)

Included for the data extraction (n=388)

Less than 12 months of follow-up (n=24)

342 patients without SSI

22 patients with SSI