


Risk Factors of Surgical Site Infection After Adult Closed Tibial Plateau Fractures Treated by Open Reduction and Internal Fixation

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Background: Surgical site infection (SSI) after surgery can cause serious sequelae in patients with tibial plateau fractures. This study aims to report the incidence and characteristics of SSI and to investigate the risk factors of SSI in adult patients with closed tibial plateau fracture, especially the relationship between SSI and preoperative hypoalbuminemia.

Methods: We retrospectively reviewed the records of adult patients with closed tibial plateau fracture who were treated at our institution from January 2016 to December 2022. From the medical records, demographic data, surgical data, preoperative results of laboratory examination and postoperative complications extracted. Univariable and multivariable analyses were performed to determine the association between risk factors and SSI after surgery.

Results: In total, 460 patients met inclusion criteria, and 23 patients were diagnosed with SSI, the postoperative infection rate was 5%, with eleven cases (2.4%) were deep SSI and twelve cases (2.6%) were superficial SSI. According to the univariable analysis, current smoking, alcoholism, fracture type (IV-VI), osteofascial compartment syndrome, operative time ≥ 3 hours, intraoperative blood loss ≥ 400 mL, double incisions, more plates, preoperative hypoalbuminemia were investigated to the significant risk factors for SSI. According to the multivariable analysis, fracture type and hypoalbuminemia were independently risk factors for SSI.

Conclusion: Fracture type and preoperative hypoalbuminemia could be predictors of SSI in adult patients with closed tibial plateau fractures. Shorten operation time, reduce intraoperative blood loss, stop smoking and drinking and correct hypoalbuminemia could reduce the risk of postoperative infection.

Keywords: risk factors, surgery, infection, tibial plateau fracture, hypoalbuminemia

Introduction

Tibial plateau fractures are common injuries in the orthopaedic department, and surgical treatment is recommended to the patients who could achieve good knee joint function.¹ The aim of surgical management of tibial plateau fractures is to reduce the articular surface, restore mechanical alignment, provide stable fixation that permits an early range of motion of the knee.^{2,3} Due to compromised surrounding soft tissue of the fracture site and the metal device implantation of foreign body, there is potential risk of surgical site infection (SSI).

The reported incidence of surgical site infection following open reduction and internal fixation of tibial plateau fractures ranges from 2 to 11% and higher than the overall rate seen in all orthopedic surgical procedures (1–3%).^{3–7} SSI increases the morbidity and mortality of patients, but also increases the associated healthcare costs. Patients with SSI require prolonged treatment and even removal of internal fixation devices. It is important to identify risk factors for

postoperative infection following open reduction and internal fixation of tibial plateau fractures. There are many previous studies to detect risk factors of postoperative infection, suggesting that a variety of factors are related to postoperative infection, including open fracture, smoking status, fracture type (Schatzker types IV–VI), presence of compartment syndrome, open fasciotomy wounds, more severe tissue damage, prolonged surgical time, incision approach, temporary external fixation and longer intensive care unit (ICU) stay.^{3,5,7–9}

Previous studies have shown that preoperative hypoalbuminemia (serum albumin <3.5 mg/dL) is associated with SSI after orthopedic surgeries, such as knee or hip joint arthroplasty,^{10,11} revision total knee arthroplasty,¹² spinal fusion surgery of lumbar fusion,^{13–16} but no article has reported whether it is associated with SSI of tibial plateau fractures. Therefore, we designed this retrospective study and aimed to describe the incidence and characteristics of SSI during 1-year follow up and to investigate the risk factors of SSI in patients with closed tibial plateau fracture, especially the relationship between SSI and hypoalbuminemia.

Patients and Methods

Permission for this study was obtained from the Medical Ethics Committee of Shandong Provincial Hospital Affiliated to Shandong First Medical University (NO.2018–242).

Study Design

We retrospectively analyzed all patients with closed tibial plateau fracture who were treated at our institution from January 2016 to December 2022. All patients aged older than 18 years old with closed tibial plateau fractures treated by open reduction and internal fixation (ORIF) were included. The patients which younger than 18 years, inveterate fractures (from initial injury to surgery more than three weeks), pathological fracture were excluded. All patients must be followed up for more than one year.

Data Collection

We collected the following data for each patient: gender, age, cause of injury, underlying disease (diabetes, hypertension, coronary heart disease, autoimmune disease), fracture type, body mass index (BMI), number of associated organ injuries, current smoker (yes or no), alcoholism (yes or no), time from injury to operation, osteofascial compartment syndrome (yes or no), anaesthesia types, intraoperative blood loss, surgical incisions, number of plates, bone graft (autogenous bone graft, allogenic bone graft or no graft), length of stay. The preoperative results of laboratory examination were also collected from the document. The variables included White blood cell (WBC), red blood cell (RBC), haemoglobin (HG), blood platelet (PLT), albumin (ALB) and globulin (GLB).

Definition of SSI and Related Variables

Based on the CDC definition of SSI, due to the implants are required for the treatment of fractures, the infection involves deep soft tissues (such as fascial and muscle layers) occurs within one year could be defined deep SSI. Additionally, it must meet at least one of the following: persistent wound discharge or dehiscence; incision has fever, local pain or tenderness which spontaneously dehisces or requires surgical debridement; an abscess in deep incision; direct examination, histopathologic or radiologic examination confirmed deep infection. The infection involves only skin or subcutaneous tissue which occurs within 30 days after operation could be defined superficial infection. In addition, it must meet at least one of the following: purulent drainage from the superficial incision; organisms isolated from the superficial incision; superficial incision has at least one of the infection signs (pain, tenderness, localized swelling, redness or heat) and deliberately opened by surgeon. It is necessary to collect wound swabs and send them for pathogen culture and sensitivity testing for both deep and superficial SSI.

We used the Schatzker system to classify the fracture, in brief, it was classified six types according to the position of fracture. Additionally, type I–III was considered as low-energy injury and type IV–VI was considered as high-energy injury. Alcohol consumption in excess of 13 units per week was identified as alcoholism. Body mass index (BMI) was calculated as weight divided by the square of height and was grouped according to the Chinese reference criteria: underweight, <18.5; normal, 18.5–23.9; overweight, 24–27.9; obesity, 28–31.9; morbid obesity, 32 and more.

Statistical Analysis

Statistical analysis was performed with SPSS Statistics for Windows, Version 12.0 (SPSS Inc., Chicago, IL, USA). The Shapiro–Wilk test was first used to determine whether the measurement data were normally distributed. The mean and standard deviation (SD) were calculated for continuous and discrete variables. All categorical variables were presented as the number of patients and were analyzed using χ^2 test or the Fisher exact test. Binary logistic regression analysis was used to identify the risk variables. A two-sided significance value of 0.05 was used for all statistical tests.

Results

During the study period, a total of 460 patients met inclusion criteria and 23 patients were diagnosed with SSI, the postoperative infection rate was 5%. 172 females and 265 males in non-SSI group, 10 females and 13 males in SSI group. The average age was 45.8 ± 14.4 and 45.4 ± 13.3 respectively. In both groups, the left was the predominant injury side. In non-SSI group, the most cause of injury was fall, however, the most cause of injury was traffic injury in SSI group. Most patients did not have concurrent injuries, the ratio was 84.9% in non-SSI group and 78.3% in SSI group. Gender, age, predominant injury side, cause of injury, concurrent injuries, and the underlying diseases including diabetes, hypertension, coronary heart disease, autoimmune disease was no significant difference between two groups. Thirty-five patients (8%) in non-SSI group and 5 patients (21.7%) in SSI group were current smokers, 17 patients (3.9%) in non-SSI group and 3 patients (13%) in SSI group were alcoholism, the ratio was higher in SSI group and the statistical difference was significant. Most patients in non-SSI group had normal BMI, however, higher BMI in SSI group, there was a statistical difference.

Based on Schatzker system, 160 patients (36.6%) in non-SSI group and 18 patients (78.3%) in SSI group were type IV-IV fractures, there was a statistical difference. Most of the patients underwent surgery within a week, with no statistically significant difference. Four patients (0.9%) in non-SSI group and 2 patients (8.7%) in SSI group were diagnosed with osteofascial compartment syndrome, the ratio in SSI group was significant higher, all of whom underwent emergency open decompression. Only two patients had vascular injury, and they eventually developed infection, which was statistically significant between the two groups. In the SSI group, 78.3% of patients had an operation time of more than 3 hours, and 17.4% had an intraoperative blood loss of more than 400 mL, both of which were significantly higher than that of non-SSI group. However, there was no significant difference in the proportion of intraoperative blood transfusions. Double incisions were used in 56.5% of patients undergoing open reduction and internal fixation in SSI group, it was higher than non-SSI group. Meanwhile, in the SSI group, more patients with fracture were fixed with more than 2 plates. About 64.3% patients in non-SSI group and 69.6% in SSI group were received bone grafts, including autografts and allografts, there was no statistical difference between the two groups. The average length of stay was 12.8 ± 6.0 and 43.4 ± 28.2 respectively, the length of hospitalization in SSI group was significantly longer than that in non-SSI group.

The preoperative results of laboratory examination were also collected, the value was divided into normal (a range), above normal and below normal. The values of White blood cell (WBC), red blood cell (RBC), haemoglobin (HG), blood platelet (PLT) and globulin (GLB) in most patients were in the normal range, there was no significant difference between two groups. However, the proportion of hypoalbuminemia in SSI group was higher than non-SSI group, there was statistical difference between the two groups.

Characteristics of SSI

Twenty-three patients (5%) were diagnosed SSI, eleven cases (2.4%) were deep SSI and twelve cases (2.6%) were superficial SSI. Eight cases of deep SSI and two superficial SSI were cultured for bacterial species: four were caused by *Staphylococcus aureus*, two by *Enterococcus faecium*, one by *Streptococcus salivarius*, one by *Serratia marcescens*, one by *Enterobacter cloacae* and one by *Pseudomonas aeruginosa*. The average time for postoperative infection was 38 days, the earliest diagnosis of SSI occurred at 5 days after surgery, whereas the latest presentation was at 300 days. Nineteen patients developed SSI within one month, and the remaining four patients developed infection after one month, at 33 days, 90 days, 240 days, and 300 days, respectively. Sixteen SSIs developed during hospital stays, and seven developed

after discharge from hospital. All patients were treated with additional intravenous antibiotics, and if there was a sensitivity result, the sensitive antibiotic was selected based on the result. Twenty patients underwent at least one debridement with a mean of 1.85 debridements (range 1–4), four of the patients had the plates removed early. Three patients underwent dressing of the wound and finally achieved infection control.

Univariate and Multivariate Analysis

In the univariate analysis, current smoking, alcoholism, fracture type (IV–VI), osteofascial compartment syndrome, operative time ≥ 3 hours, intraoperative blood loss ≥ 400 mL, double incisions, more plates, preoperative hypoalbuminemia were investigated to the significant risk factors for SSI. Other factors, including demographical information, underlying diseases and other variables from laboratory examination were not associated factors with SSI occurrence. The detailed information is presented in Tables 1 and 3. In the multivariate model, we found that fracture type (OR 0.286; 95% CI 0.085–0.958; $p = 0.042$) and preoperative hypoalbuminemia (OR 7.439; 95% CI 2.286–24.212; $p = 0.001$) were independently associated with SSI.

Table 1 Demographic Data

Variables	Patients Without SSI (n=437)	Patients with SSI (n=23)	p
Age	45.8±14.4	45.4±13.3	0.96
Gender			0.69
Male	265	13	
Female	172	10	
Injury side			0.117
Left	231	16	
Right	206	7	
Cause of injury			0.051
Fall	184	3	
Fall from height	33	3	
Traffic accident	124	10	
Electric bicycle accident	96	7	
Associated injuries			0.307
None	371	18	
1	35	1	
2	17	2	
≥ 3	14	2	
Underlying disease			
Hypertension	55	2	0.581
Coronary heart disease	23	0	0.259
Diabetes mellitus	34	4	0.103
Autoimmune disease	1	0	0.818
Current smoking			0.023
Yes	35	5	
No	402	18	
Alcoholism			0.036
Yes	17	3	
No	420	20	
Body mass index			0.010
<18.5	25	0	
18.5–23.9	296	6	
24–27.9	61	7	
28–31.9	45	8	
>32	10	2	

Abbreviation: SSI, means Surgical site infection.

Table 2 Surgical-Related Data

Variables	Patients Without SSI (n=437)	Patients with SSI (n=23)	p
Fracture type			<0.05
I-III	277	5	
IV-VI	160	18	
Time from injury to operation			0.216
<7 days	351	15	
7-14 days	75	7	
>14 days	11	1	
Osteofascial compartment syndrome			0.001
Presence	4	2	
Absence	433	21	
Anaesthesia types			0.111
General	270	18	
Intraspinal	167	5	
Operative time			<0.05
<3 hours	295	5	
≥3 hours	142	18	
Intraoperative blood loss (mL)			<0.05
<400 mL	425	19	
≥400 mL	12	4	
Intraoperative transfusion			0.225
Presence	16	2	
Absence	421	21	
Surgical incision			0.001
Single incision	336	10	
Double incisions	101	13	
Number of plates			0.001
1	325	10	
2	97	12	
3	15	1	
Bone graft			0.801
Autogenous bone	46	2	
Allogeneic bone	235	14	
None graft	156	7	
Length of stay (days)	12.8±6.0	43.4±28.2	<0.05

Table 3 Preoperative Results of Laboratory Examination

Variables	Patients Without SSI (n=437)	Patients with SSI (n=23)	p
White blood cell ($10^9/L$)			0.182
< 3.5	3	1	
3.5–9.5	320	16	
> 9.5	114	6	
Red blood cell ($10^{12}/L$)			0.768
< 4.3	296	17	
4.3–5.8	137	6	
> 5.8	4	0	

(Continued)

Table 3 (Continued).

Variables	Patients Without SSI (n=437)	Patients with SSI (n=23)	p
Blood platelet (10 ⁹ /L)			0.057
< 125	15	3	
125-350	384	19	
> 350	38	1	
Hemoglobin (g/L)			0.159
< 130	275	19	
130-175	161	4	
> 175	1	0	
Albumin (g/L)			<0.05
<35	80	13	
≥35	357	10	
Globulin (g/L)			0.350
<20	16	0	
≥20	421	23	

Discussion

Tibial plateau fracture is a complex intra-articular fracture. Although surgical instruments, surgical approaches and treatment concepts have been improved in recent years, complications are still common, and the most common complication is SSI.^{3,4} The SSI rate of tibial plateau fracture is higher than other fractures after open reduction and internal fixation.³⁻⁷ Once infected, it means longer hospital stays, more operations, higher medical costs, and may ultimately impair the function of the knee joint. It not only causes a huge economic burden to patients, but also brings a heavy burden to individuals, families and society.⁵ How to avoid SSI and find out the risk factors related to SSI has always been a hot spot. Many factors including demographic-related, injury-related and surgical-related were reported in previous studies.^{3,5,7-9} Open fracture, for example, is a well-accepted risk factor for deep infection due to more extensive soft-tissue injury and frank contamination of the wound with skin and ambient flora.¹⁷ Therefore, we excluded these patients who suffered open fracture and tried to get risk factors of SSI in patients with closed tibial plateau fracture. Additionally, previous studies were characterized by higher energy mechanisms, such as bicondylar fractures, accompanied by osteofascial compartment syndrome, etc. The difference is with them, all types of fractures were included in our study, which ultimately led to the above conclusions.

Momaya AM studied 532 patients and found that types Schatzker IV-VI was a risk factor of SSI after open reduction and internal fixation.¹⁸ Similarly, our data show that types Schatzker IV-VI, double incisions, more plates are risk factors of SSI after surgery, and fracture type was an independent risk factor. Types Schatzker IV-VI fractures are caused by high energy and are comminuted, it usually associated persistent swelling, severe soft tissue injury even ungloned injuries. In addition, it usually requires double incisions, and the fractures are fixed with more plates, which means extensive soft tissue dissection and damage to blood supply. It could aggravate the already serious soft tissue injury and increase risk of SSI after surgery. Therefore, in our experience, it is crucial that the soft tissue is properly recovered before surgery.

It is well known that smoking plays an important role in the development of many diseases, it is also known to have a negative effect on surgical outcomes. Smoking can impair the oxygen distribution of soft tissues, further affect the soft tissue blood supply, and reduce immune system sensitivity. It has been shown that smoking could result in not only SSI, but also impairing healing of skin, bone, and soft tissues, even result in nonunion, delayed unions.^{17,19} The Lower Extremity Assessment Project Study Group showed that current smokers were more than twice as likely to develop an infection and 3.7 times as likely to develop osteomyelitis at the site of a limb threatening open tibial fracture.²⁰ Morris BJ studied 302 patients which were identified as bicondylar tibial plateau fractures and treated by open reduction and internal fixation, and concluded smoking was the only patient modifiable predictor of deep infection after surgery.⁸ In a multicenter, single-blinded, randomized, controlled clinical trial, Näsell H indicated that a smoking cessation

intervention program during the first six weeks after acute fracture surgery decreases the risk of postoperative complications.¹⁹ It is critical to recognize the complications of smoking and the benefit of smoking cessation, therefore, surgeons should encourage patients to cease smoking as early as possible.

Preoperative alcohol consumption increases the general morbidity and SSI after surgery,^{21,22} which is thought to be due to the acute immunosuppressive effects of ethanol.²³ Olsen LL retrospectively reviewed 1043 patients and found that alcohol overuse are independent risk factors for the development of infection following surgery for a fracture of the ankle.²⁴ Chan G also retrospective reviewed 175 patients identified excessive alcohol consumption as the only independent risk factor for postoperative infection in patients with all types of tibial plateau fracture treated with operative fixation.²⁵ In this study, we found alcoholism was a risk factor for postoperative infection after tibial plateau fracture surgery, but it was not an independent risk factor. Therefore, stopping the use of alcohol after surgery is conducive to reducing the occurrence of complications.

Osteofascial compartment syndrome is one of the serious complications of fracture. The increase of compartment contents or the decrease of volume caused by various risk factors may cause the disturbance of microcirculation in the affected compartment, resulting in insufficient perfusion of the wound tissue, and then tissue necrosis. There are conflicting data in the literature regarding the risk of SSI after tibial plateau fracture with ipsilateral compartment syndrome. Several studies have shown no increased risk of SSI with compartment syndrome,^{9,26} but a common limitation of these studies is the small sample size. Blair JA et al retrospectively reviewed 184 patients and concluded that compartment syndrome is associated with a significant increase in infection.²⁷ Dubina AG et al conducted a retrospective cohort study and concluded that tibial plateau fractures with ipsilateral compartment syndrome have a significant increase in rates of SSI compared with those without compartment syndrome.²⁸ In this study, we also came to a similar conclusion that osteofascial compartment syndrome is a higher risk for postoperative infection of tibial plateau fracture, but it is not an independent risk factor.

It is reported that obesity contributed to infection risk in patients after orthopaedic surgery. Malinzak RA considered that obesity is an overwhelming risk factor for SSI after total joint arthroplasty.²⁹ Choong et al also reported that BMI greater than 30 lead to elevated infection risk in hip patients.³⁰ In our study, we found that higher BMI in SSI group than non-SSI group, higher BMI was a risk factor of SSI in patients treated by ORIF. In higher BMI patients, obesity leads to impaired healing and the creation of a dead space because wound difficult to close adequately and the process of fat necrosis, which leads to problems with local wound healing, resulting in SSI finally.^{31,32} Obesity is associated with increased surgical time, which further increases the risk of infection.²⁹ Although diabetes was not a risk factor in our study, it has been shown in other studies to be a risk factor for postoperative infection. Diabetes predisposes patients to SSI because it prevents adequate use of glucose for energy and glycosylation of hemoglobin and adequate oxygen delivery due to microvascular and macrovascular diseases, ultimately making ischemic tissues more susceptible to infection.³² Since diabetes is common in obese patients, it is necessary for surgeons to remind obese patients to monitor blood glucose.

Previous studies have shown that preoperative lower serum albumin is associated with infection after orthopaedic surgery. Bohl DD surveyed 4310 patients who had undergone posterior lumbar fusion and concluded that patients with preoperative hypoalbuminemia had a higher risk for occurrence of SSI, increased length of stay and readmission.¹³ Moldovan F retrospectively reviewed 77 consecutive patients undergoing revision total hip arthroplasty (rTHA) and found that serum biomarkers were associated with the diagnosis of periprosthetic joint infection, but the specificity was relatively low.¹⁶ In addition, in comparison to patients with normal albumin concentration, patients with hypoalbuminemia had a higher risk for SSI after total joint arthroplasty.¹³ Kamath AF did a retrospective study which included 4,551 patients undergoing revision total knee arthroplasty and found patients in the low serum albumin group were statistically more likely to develop deep SSI.¹² However, the potential link between lower serum albumin and poor postoperative outcomes including SSI has been not understudied when patients with tibial plateau fractures treated open reduction and internal fixation. In this study, our group has demonstrated that low serum albumin is an independent predictor of SSI after surgical treatment of tibial plateau fractures. Lower serum albumin may prompt patients to SSI because it could impair wound healing and prolong inflammation through several mechanisms. Firstly, lower serum albumin may diminish fiber blast proliferation, impair collagen synthesis and delay wound healing. Secondly, it also may decrease

lymphocyte count which lead to impair the ability of immune system to fight infection.³¹ Kamath AF also emphasized that with more complex surgery, the influence of low serum albumin appears greater.¹² This was also demonstrated in our study, where most patients with SSI had high-energy injuries, high degree of fracture comminution, and long operation time.

In this study, we found that longer operative time and more intraoperative blood loss are predictors of postoperative SSI after the open reduction and internal fixation of tibia plateau fractures. Colman M performed a retrospective controlled analysis of 309 consecutive patients with tibia plateau fractures and concluded that longer operative times were an independent risk factor of postoperative SSI.⁴ The authors also said that for each additional hour of operative time, the risk of SSI increased nearly 78%.⁴ Additionally, longer operative time is also a risk factor for postoperative SSI in other orthopedic surgeries. Peersman G retrospectively analyzed 6489 knee replacements and figured out that longer operative time increases the infection risk after surgery. It also reported that if the surgery took longer than 2.5 hours, the risk of infection was increased significantly.³³ Colman M speculates that the longer operative time may be a sign of technical difficulty, more extensive soft tissue stripping, and extended wound exposure, all of which may lead to a higher incidence of postoperative SSI.⁴ In this study, we came to the same conclusion. In SSI group, eighteen patients were operated more than 3 hours, all of them were high-energy injuries and complex fracture types. However, there are numerous variables which include fracture type, soft tissue injury characteristics, surgeon experience and so on could affect the operative time. Some of these variables can be manipulated, some cannot. We should be aware of the impact of operative time on SSI and optimize their workflow accordingly.

The current study has some limitations. First, our study was retrospective rather than prospective. A few patients with SSI were included in the study because of the low morbidity. Future multicenter, large sample randomized controlled trials are needed to assess the risk factors of SSI after adult closed tibial plateau fractures treated by open reduction and internal fixation.

Conclusion

In summary, we observed 23 cases (5%) of SSI in 460 tibial plateau fractures, with eleven cases (2.4%) were deep SSI and twelve cases (2.6%) were superficial SSI. Infected patients were associated with prolonged hospital stay (43.4 days versus 12.8 days), compared to non-infected patients. Current smoking, alcoholism, fracture type (IV-VI), osteofascial compartment syndrome, operative time ≥ 3 hours, intraoperative blood loss ≥ 400 mL, double incisions, more plates, preoperative hypoalbuminemia were investigated to the significant risk factors for SSI. Fracture type and preoperative hypoalbuminemia were independently associated with SSI after tibial plateau fractures. Meanwhile, we recommend that patients stop smoking and drinking and correct hypoalbuminemia to reduce the risk of postoperative infection. Timely diagnosis and management of compartment syndrome are also essential.

Data Sharing Statement

Please contact author for data requests.

Ethics Approval and Consent to Participate

The experimental protocol was established according to the ethical guidelines of the Declaration of Helsinki and was approved by the Human Ethics Committee of Shandong Provincial Hospital Affiliated to Shandong First Medical University (NO.2018-242). All the patients were informed of the purpose of this study and signed the informed consent form.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests.

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