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ORIGINAL ARTICLE

Incidence and risk factors for deep surgical site infection after open reduction and internal fixation of closed tibial plateau fractures in adults

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This study aimed to investigate the incidence and risk factors of deep surgical site infection (DSSI) during hospitalisation after closed tibial plateau fractures treated with open reduction and internal fixation (ORIF). We performed this retrospective study at a university-affiliated hospital with an advanced trauma centre. The data of adult patients with closed tibial plateau fractures treated with ORIF from January 2012 to February 2017 were extracted from the electronic medical records. Demographics, injury-related and surgery-related variables of DSSI and non-DSSI groups were compared by univariate test. Multivariate logistic analysis models were used to investigate the independent risk factors. In total, 676 patients with complete data met the inclusion criteria and were included, and of them, 17 developed DSSI (2.51%) during hospitalisation. Approximately 60% (9/17) of DSSI was caused by *Staphylococcus aureus*. Compared to the non-DSSI group, DSSI patients had a significantly longer stay in hospital (25.8 vs 15.2 days). Independent risk factors of DSSI identified by multivariate analysis were higher BMI (>26.0) (OR, 1.58; 95% CI, 1.09 to 3.27; $P = 0.032$), prolonged surgical duration (>138 min) (OR, 4.26; 95% CI, 1.54 to 11.19; $P = 0.005$) and current smoking (OR, 3.42; 95% CI, 1.47 to 8.62; $P = 0.01$). A relatively low incidence rate of DSSI (2.51%) was found in this study, and several significant risk factors were identified. Smoking cessation programmes should be implemented immediately after hospitalisation, especially for obesity and morbid obesity patients. Detailed and comprehensive preoperative assessment and a considerate operative plan should be guaranteed to reduce surgical duration.

KEYWORDS
closed tibial plateau fractures, DSSI, incidence, risk factors

1 | INTRODUCTION

Tibial plateau fractures are very common in emergency and orthopaedic departments, accounting for one-third of tibial and fibula fractures in adults.[1] Due to its effect on knee joints, it might impose a catastrophic consequence on patients, if not reduced anatomically. By far, open reduction and internal fixation (ORIF) is currently the most prevalent treatment choice, although arthroscopic and minimal invasive therapies have been reported to have superior results. The most important reason for its prevalence was extensive indications. However,[2–5] excessive soft tissue dissection during surgery further impaired the already damaged soft tissue envelop, along with the concomitant vascular and neurological injuries, inevitably resulting in complications related to incision and bone union.

Among those postoperative complications, deep surgical site infection (DSSI) was the most common one, and the reported incidence was varied (2% to 23.6%) depending on the definitions of infection, study participants, designs of

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the studies and so on. Postoperative DSSI significantly increased the total hospitalisation period of a surgical patient by 7 to 14 days and substantially increased the total costs, compared with non-DSSI.[3,6–8] Furthermore, postoperative persistent pains, prolonged hospital stay and reoperation caused by DSSI might destroy one's confidence of returning to the previous normal life. Therefore, preoperative comprehensive assessment of patients' conditions and identification of related risk factors for DSSI could be a more cost-effective measure to reduce its occurrence.

Only a few studies were conducted to investigate the related risk factors after closed tibial plateau fractures treated with ORIF, and some risk factors were unreported or remained controversial due to under-reporting. High body mass index (BMI) has been reported as a significant risk factor for DSSI after fractures at other sites in the previous literature,[9–12] and is of great predictive value for this complication. However, only one study investigated its effect on DSSI occurrence after tibial plateau fractures, and this study specified the high-energy bicondylar tibial plateau fractures treated with dual plating through 2 incisions.[13] Therefore, the relationship between BMI and DSSI after closed tibial plateau fractures treated by ORIF required studies to investigate.

We hypothesised that higher BMI was associated with a higher incidence rate of DSSI. Therefore, the primary objectives of the study were to[1] identify the independent risk factors associated with DSSI after closed tibial plateau fracture treated with ORIF and[2] to identify the cut-off value if variables were verified as significant predictors.

Key Messages

- the incidence rate of DSSI after closed tibial plateau fractures treated with ORIF was 2.51% during hospitalisation
- smoking, higher BMI > 26.0 and surgical duration > 138 min were identified as independent risk factors for DSSI occurrence
- smoking cessation programmes should be implemented immediately after hospitalization, especially for obesity and morbid obesity patients; detailed and comprehensive preoperative assessment and considerate operative plan should be guaranteed to reduce surgical duration

2 | MATERIALS AND METHODS

Adult patients (18 years or older) with acute close tibial plateau fractures treated with ORIF at the 6th Hospital of Xinjiang Medical University from January 2012 to February 2017 were included in this study. The exclusion criteria were patients younger than 18 years, pathological fractures, periprosthetic fractures and old fractures (>21 days from initial injury). In total, 676 patients were included.

2.1 | Data collection of variables of interest

Patients' electronic medical records were inquired for variables of interest, which included demographics, injury-related and surgery-related variables. Demographics of patients included gender, age, living places (rural or urban), height and weight and the BMI calculated accordingly (kg/m^2), smoking, alcohol drinking and comorbidities (hypertension, diabetes mellitus and previous history of surgery at any site, allergic history).

Injury-related variables included mechanism (low- or high-energy), side involved, the number of concurrent injuries based on systems involved and fracture type based on the Schatzker classification system. Specifically, low-energy injuries referred to simple falls from standing height, and high-energy injuries referred to the fractures caused by traffic accidents, fall from height, violent collisions, and sporting activity.

Surgery-related variables included surgeon level; preoperative stay (between initial injury and operation); operative duration; intraoperative blood loss; fixation type; preoperative, intraoperative and postoperative intravenous use of antibiotic; postoperative drainage; anaesthesia pattern, surgical months (between June and September or not) and ASA grade (American Society of Anesthesiologists).

2.2 | Definition of DSSI

SSI was defined based on the standard Center for Disease Control (CDC) definitions.[14] DSSI referred to infections involving deep soft tissue, muscle or fascia; persistent wound discharge or dehiscence; and visible abscess or gangrenosum that required surgical debridement and implant exchange or removal. The detailed data on results of causative agent culture and sensitivity were collected and documented.

2.3 | Statistical analysis

Univariate analysis of continuous variables was performed using Mann-Whitney *U*-test or Student *t*-test, depending on the normality status of the variables. For continuous variables with statistical significance ($P < 0.05$), we used receiver operating characteristic curves (ROC curves) to determine the area under the curve (perfect area as 1) and the most useful cut-off point for each variable (ie, the variables were dichotomised). Subsequently, univariate Chi-square or Fisher's exact test was used to preliminarily evaluate the differences of variables between both groups. Finally, all variables were entered into a multivariable logistic regression model to determine independent risk factors for SSI. The Hosmer-Lemeshow test was used to evaluate the goodness-of-fit of the final model and a $P > 0.05$ indicated an acceptable result, and Nagelkerke R^2 was used to quantify the goodness-of-fit. All the tests

TABLE 1 Comparison of continuous variables in patients with and without surgical site infection (SSI)

Variables	Patient without SSI (mean ± SD) (n = 659)	Patient with SSI (mean ± SD) (n = 17)	P
Age (years)	44.4 ± 13.7	46.9 ± 14.8	0.479
Body mass index	25.2 ± 3.4	27.6 ± 2.5	0.003*
Preoperative stay (d)	5.6 ± 4.6	5.7 ± 6.0	0.928
Hospital stay (d)	15.2 ± 8.5	25.8 ± 14.6	<0.001*
Intraoperative blood loss (mL)	229.3 ± 530	586.3 ± 1047	0.016*
Surgical duration (min)	123.5 ± 66.5	174.1 ± 178.2	0.004*

*Statistically significant.

were performed using the SPSS 19.0 software package (SPSS Inc., Chicago, IL).

This study was approved by the Institutional Review Board of the 6th Hospital of Xinjiang Medical University before its commencement.

3 | RESULTS

3.1 | Characteristics of the study sample

Overall, the data of 676 patients with closed tibial plateau fractures treated with ORIF were collected. Of them, 465 were males and 211 were females; the mean age was 44.6 years, and 140 patients had at least 1 concurrent fracture at other sites (20.7%). The mean total hospital stay was 15.4 days, and the mean preoperative stay (between initial and operation) was 5.6 days. According to the Schatzker classification system for tibial plateau fractures, the respective corresponding figure for type I, II, III, IV, V, and VI was 94, 102, 99, 142, 57, and 186, respectively; 266 tibial plateau fractures were caused by high-energy trauma.

3.2 | Characteristics of SSI

During hospitalisation, 17 patients (2.51%) had a DSSI. Of them, 3 patients were treated with local wound care and intravenous antibiotics and healed uneventfully, and 14 patients required at least 1 debridement in the operating theatre due to necrotic tissue in the wound, continuous wound drainage or sepsis. The earliest diagnosis of SSI occurred on the 2nd day post-operation and the latest on the 37th day, with a median time of 9 days. *Staphylococcus aureus* was the most common causative pathogen (9, 58.8%), followed by *Staphylococcus epidermidis* (4, 23.5%), multi-bacterium (3, 17.6%), and Pseudomonas aeruginosa (1, 5.9%). Hardware removal was performed in 1 case because of persistent positive culture causing implant loosening.

There were no significant differences between DSSI and non-DSSI groups in term of age (46.9 vs 44.4 years, $P = 0.479$) and preoperative stay (5.7 vs 5.6 days, $P = 0.928$). However, a significant difference was observed for variables including BMI (27.6 vs 25.2 kg/m^2), intraoperative blood loss (586.3 vs 229.3 mL) and surgical duration (174.1 vs 123.5 min) between both groups. DSSI patients had a prolonged mean of 10.6 days of hospitalisation, compared to the non-DSSI group (25.8 vs 15.2 days, $P < 0.001$). Detailed results aere presented in Table 1.

3.3 | Univariate and multivariate analyses

According to the analytical results for continuous variables, we used ROC curves to determine the area under the curve and the most useful cut-off point for each predictor variable, and detailed results are presented in Table 2. The cut-off values for BMI, intraoperative blood loss and surgical duration were 26.0 kg/m^2, 290 mL and 138 min, respectively. Based on these cut-off values, we dichotomise them.

Results of the univariate analysis are summarised in Table 3. The significant variables included BMI (>26.0), current smoking, more severe fracture type (Schatzker V, VI), surgical duration (>138 min) and Intraoperative blood loss (>290 mL). Other variables were not associated with the incidence of DSSI (Table 3). All the variables were entered into the multivariate logistic regression model to determine the independent significant ones. The results showed that BMI >26.0 kg/m^2 (OR, 1.58), current smoking (OR, 3.42) and prolonged surgical duration > 138 min (OR, 4.26) remained significant and were independent risk factors for the occurrence of SSI (Table 4).

The results of Hosmer-Lemeshow test demonstrated the good fitness of the final model, with $P = 0.935$, and Nagelkerke R^2 was 0.144.

4 | DISCUSSION

DSSI is a serious complication after tibial plateau fractures, causing implant removal, malunion and even reoperation, which imposes individual, family and social burdens.[6,15] Several studies were conducted to investigate the incidence and risk factors for SSI, including superficial and DSSI.[3,13,16,17] Researchers dichotomized some clinical continuous variables based on their own clinical experience, which we thought was

TABLE 2 The detailed results of the ROC curve

Variable	Cut-off value	Area under the curve (95 CI)	Sensitivity	Specificity	P
BMI (kg/m^2)	26.0	0.742 (0.650 to 0.833)	0.765	0.620	0.003
Intraoperative blood loss (mL)	290	0.688 (0.543 to 0.814)	0.563	0.730	0.016
Surgical duration (min)	138	0.707 (0.582 to 0.832)	0.688	0.680	0.004

TABLE 3 Univariate analysis of factors associated with deep surgical site infection (DSSI) after operation

Variables	Number (%) of patients without DSSI (n = 659)	Number (%) of patients with DSSI (n = 17)	P
Gender (males)	453 (68.7)	12 (70.5)	0.871
Occupation (peasant)	496 (75.2)	14 (82.3)	0.506
Body mass index (>26.0)	242 (36.7)	12 (70.5)	0.004*
Current smoking	68 (10.3)	5 (29.4)	0.019*
Drinking alcohol	274 (41.6)	7 (41.1)	0.974*
High-energy injury	257 (38.9)	9 (52.9)	0.251
Fracture type (Schatzker V, VI)	227 (34.4)	10 (58.8)	0.038*
Multiple injuries	135 (20.4)	5 (29.4)	0.370
Diabetes mellitus	19 (2.8)	1 (5.8)	0.404
Hypertension	83 (12.5)	2 (11.7)	0.919
Previous operation in any site	169 (25.6)	3 (17.6)	0.459
History of allergy	43 (6.5)	1 (5.8)	0.916
American Society of Anesthesiologists (≥3)	55 (8.3)	5 (29.4)	0.459
Surgeon level (archiater and vice archiater)	562 (85.2)	13 (76.4)	0.314
Surgical performance between June and September	248 (37.6)	7 (41.1)	0.766
Preoperative antibiotics use	92 (13.9)	4 (23.5)	0.272
Intraoperative antibiotics use	482 (73.1)	13 (76.4)	0.760
Postoperative antibiotics use	456 (69.1)	12 (70.5)	0.775
Anaesthesia			0.737
General	59 (8.9)	2 (11.7)	
Regional	582 (88.3)	15 (88.2)	
Combination	18 (2.7)	0 (0)	
Two incisions (vs one)	112 (17.0)	5 (29.4)	0.182
Plate and screws (vs screws only)	612 (92.9)	17 (100)	0.623
Two plates implanted	166 (25.2)	5 (29.4)	0.693
Surgical duration (>138 min)	212 (32.1)	11 (64.7)	0.009*
Intraoperative blood loss >290 mL	178 (27)	10 (58.8)	0.007*
Intraoperative transfusion	166 (25.1)	5 (29.4)	0.693
Drainage use	362 (54.9)	10 (58.8)	0.750

*Statistically significant.

TABLE 4 Independent risk factors associated with deep surgical site infection (DSSI) after closed tibial plateau fractures treated with open reduction and internal fixation (ORIF)

Variables	Exp (B)	95% CI (lower limit)	95% CI (upper limit)	P
Body mass index	1.58	1.09	3.27	0.032
Smoking	3.42	1.47	8.62	0.01
Prolonged surgical time (>138 min)	4.26	1.54	11.19	0.005

imprecise. In addition, open tibial plateau fracture itself was identified as the strongest independent risk factor for SSI, which might weaken the contributing effects of other potential risk factors. In this study, we used ROC curves to identify the cut-off values of continuous variables and identified several, more-precise independent risk factors for DSSI after closed plateau fractures treated with ORIF. The DSSI incidence rate was 2.51% for DSSI during hospitalisation, and higher BMI (>26 kg/m^2), current smoking status and prolonged surgical duration (>138 min) were identified as independent predictors of DSSI.

Very few studies were conducted to investigate the incidence and risk factors of DSSI after closed tibial plateau fractures treated with ORIF. In this study, we excluded patients with open tibial plateau fractures and only selected DSSIs as the case group and others as the control group; 2.51% of the patients developed DSSI during hospitalisation, which was in the range of the reported data in literature.[2,16–18] Morris et al conducted a retrospective study of 302 adult patients undergoing operative fixation of bicondylar fractures (AO/OTA 41-C) and observed a high incidence of DSSI requiring reoperation (43 cases, 14.2%).[18] In a retrospective study evaluating complications after the operative fixation of bicondylar (OTA/AO 41-C) tibial plateau fractures using dual plates through 2 incisions, 33 of 140 (23.6%) patients developed DSSI.[13] The reported high incidences was not difficult to understand because interacting factors of high-energy injuries, open injuries, bicondylar

fractures and even more invasive surgery (dual plates, 2 incisions) inevitably produce the strongest synthetic effect on DSSI occurrence, let alone the other comorbidities. On the other hand, researchers reported moderate incidence rates of 2.1% to 6.0%[3,16,19] in studies where such conditions were restricted. In our opinion, it was inappropriate to directly compare the incidence rates of DSSI between these studies because of existing heterogeneity among patients, different study designs and varied applied implants. However, through these indirect comparisons, we could obtain more comprehensive and thorough knowledge about this topic.

Previously, most researchers dichotomised the potentially significant continuous variables based on their clinical experience or subjective assumption and thereby obtained cut-off values. We thought it was inappropriate because optimised sensitivity and specificity for 1 variable could not be available. In this study, we used ROC curves to obtain more precise cut-off values of significant variables. Finally, prolonged surgical duration (>138 min), BMI (>26.0) and current smoking status were identified as independent risk factors of DSSI after tibial plateau fractures. Identification of these cut-off values could be of reference value in counselling patients and relatives regarding their increased risk of DSSI, aiding surgeons in making more advisable treatment strategies and helping nurses implement timely preventive measures (smoking cessation).

Although BMI could not be modified by a great degree during hospitalisation, early implementation of smoking cessation programmes, improving surgical skills and utilising optimal surgical protocol to decrease surgical time showed clinical significance in the of DSSI occurrence. In this study, smoking increased the risk of DSSI up to 3.42 times in multivariate logistic analysis models ($P = 0.01$). Even temporary smoking could significantly cause negative effects of peripheral blood and oxygen distribution, resulting in adverse complications after surgical fractures. Similarly, prolonged surgical duration > 138 min increased the risk of DSSI up to 4.26 times, which was consistent with that reported by Colman et al.[2] In that study included closed and open tibial plateau fractures, the risk odds of DSSI increased 1.78 times when surgical time approached 3 h.[2] Similarly, Matthew et al retrospectively studied 309 patients who underwent open plate osteosynthesis over a 5-year period.[2] They confirmed that operative time approaching 3 h significantly increased the overall risk for SSI following ORIF, and every extra hour of intraoperative duration increased the risk of postoperative SSI by 78%. Therefore, we suggested that patients with a tibial plateau fracture should be encouraged to quit tobacco immediately after hospitalisation. For those with higher BMI, especially obesity and morbid obesity and poorer physical conditions, a detailed and comprehensive preoperative assessment and considerate operative plan should be guaranteed. In addition, a high-level experienced surgeon and advanced fixation concepts and techniques were of significance in reducing surgical duration to decrease the occurrence of DSSI.

Several limitations have to be mentioned in this single-centre study. First, the retrospective nature of this study inherited a selective bias. The quality of the data depended on the accuracy and completeness of patients' electronic medical records, which might be affected to a certain extent. Second, patient-specific variables such as smoking status, alcohol drinking and medical comorbidities mainly relied on the patient's self-report, and some of them might not be willing to inform us of these bad addictions and chose to conceal information. Third, patients who underwent ORIF for closed tibial plateau fractures and developed DSSI during the hospitalisation were defined as the case group in this study; those patients who might develop DSSIs after discharge from our hospital were excluded. Therefore, we might underestimate the overall DSSI rate. In addition, our hospital was the tertiary referral centre, and the patients admitted were likely presenting with more severe injuries requiring integrated treatment, which was not representative of the overall treatment level for this injury.

In conclusion, our study confirmed 17 cases (2.51%) of DSSI after 676 closed tibial plateau fractures treated with ORIF, and 3 independent risk factors for DSSI were identified. The greatest strength of this study was to identify the cut-off values of BMI and surgical duration using ROC curves. Prolonged surgical duration (>138 min), higher BMI (>26.0 kg/m^2) and current smoking status increased the OR of DSSI after closed tibial plateau fracture treated with ORIF by 4.26, 1.58, and 3.42 times, respectively. Therefore, we suggest that patients with tibial plateau fractures should be encouraged to quit tobacco immediately after hospitalisation, especially obesity and morbid obesity patients. Detailed and comprehensive preoperative assessment and considerate operative plan should be guaranteed to reduce surgical duration.

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CONFLICT OF INTEREST

All the authors declare that they have no conflict of interest with any organisation that sponsored the research.

AUTHORS' CONTRIBUTIONS

Z.S. designed the study; Q.M. and A.A. abstracted and documented the data and searched related literature; G.W., C.W. and L.Y. analysed and interpreted the data; Q.M. and

A.A. wrote the manuscript; and Z.S. approved the final version of the manuscript.

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