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Prolonged operative time increases infection rate in tibial plateau fractures

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Abstract

Background—Fractures of the tibial plateau present a treatment challenge and are susceptible to both prolonged operative times and high postoperative infection rates. For those fractures treated with open plating, we sought to identify the relationship between surgical site infection and prolonged operative time as well as identify other surgical risk factors.

Methods—We performed a retrospective controlled analysis of 309 consecutive unicondylar and bicondylar tibial plateau fractures treated with open plate osteosynthesis at our institution's level I trauma center during a recent five year period. We recorded operative times, injury characteristics, surgical treatment, and need for operative debridement due to infection. Operative times of infected cases were compared to uncomplicated surgical cases. Multivariable logistic regression analysis was performed to identify independent risk factors for postoperative infection.

Results—Mean operative time in the infection group was 2.8 hours vs. 2.2 hours in the non-infected group (p=0.005). 15 fractures (4.9%) underwent four compartment fasciotomies as part of their treatment, with a significantly higher infection rate than those not undergoing fasciotomy (26.7% vs. 6.8%, p=0.01). Open fracture grade was also significantly related to infection rate (closed fractures: 5.3%, grade 1: 14.3%, grade 2: 40%, grade 3: 50%, p<0.0001). In the bicolumnar fracture group, use of dual-incision medial and lateral plating as compared to single incision lateral locked plating had statistically similar infection rates (13.9% vs. 8.7%, p=0.36). Multivariable logistic regression analysis of the entire study group identified longer operative times (OR 1.78, p=0.013) and open fractures (OR 7.02, p<0.001) as independent predictors of surgical site infection.

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Conclusions—Operative times approaching three hours and open fractures are related to an increased overall risk for surgical site infection after open plating of the tibial plateau. Dual incision approaches with bicolumnar plating do not appear to expose the patient to increased risk compared to single incision approaches.

Keywords

Tibia; plateau; infection; operative time; fasciotomy

Introduction

The optimal treatment paradigm for displaced fracture of the tibial plateau is open reduction internal fixation. Preservation of a healthy soft tissue envelope, restoration of the mechanical axis, and meticulous joint reduction are the primary tenets of care.[1–3] Operative care of high energy plateau fracture requires advanced fracture reduction skills and meticulous soft tissue handling. As such, operative times can be extended.

In the pre-modern era, deep infection rates following open plating of the proximal tibia were reported as high as 80%.[1,4] Modern techniques such as delay of definitive surgery, the use of temporary spanning external fixation, a dual incision approach for bicolumnar fractures, and meticulous soft tissue handling have improved the results of open plating,[5–7] yet complication rates from wound necrosis and infection are still reported in the range of 10–14%.[8] A recent study even identified fracture of the proximal tibia as an independent risk factor for surgical site infection.[9] One variable which may affect the rate of infection and remains poorly investigated is operative time. Specifically, it is unknown how the prolonged operative times necessary to achieve the goals of fracture care affect the incidence of postoperative surgical site infection (SSI). We hypothesize that in open plate osteosynthesis of tibial plateau fractures, prolonged operative times sometimes required for restoration of mechanical axis and joint surface integrity may increase the rate of surgical site infection. In addition, we sought to identify other surgeon-controlled variables which might affect the rate of postoperative surgical site infection.

Methods

Study Design

We performed a retrospective controlled analysis of 309 consecutive tibial plateau fractures treated with open plate osteosynthesis at our institution's level I trauma center during the five69 year period from 2005–2010. Minimum follow-up period from the index procedure was one year. Exclusion criteria included extra-articular fractures, those fractures treated with alternative methods of fracture stabilization other than open plate osteosynthesis, and any patient who had received surgical care at an outside institution. We recorded patient characteristics and comorbidities, injury characteristics, and treatment profiles including operative time (table 1). Lower-energy fractures with Schatzker grades I-IV (N=158) were grouped together in a category labeled "unicondylar," and higher energy fractures with Schatzker grades V and VI (N=151) were grouped together in a category labeled "bicondylar" in order to facilitate statistical analysis along a binary system based on fracture

energy. The major outcome measure in this study, SSI, was defined by postoperative development of deep infection requiring operative debridement as defined by tissue culture or infectious disease consulting opinion. Operative times and other surgeon-controlled variables of infected cases were compared to uncomplicated surgical cases.

Operative Protocols

Our cohort was cared for by a heterogeneous population of 5–6 attending surgeons whose protocols can be generalized in several ways. All 309 cases presented initially to our institution for definitive care without outside surgical intervention. After initial trauma survey and radiographic and clinical evaluation, each patient was medically optimized for operative intervention. For patients with excessive swelling who displayed clinical signs of acute compartment syndrome, urgent operative four-compartment fasciotomy with external fixation was used for preservation of the soft tissues and to obtain tissue equilibrium until definitive fracture stabilization. The diagnosis of compartment syndrome was in nearly all cases a clinical one and compartment measurements were inconsistently available. For those who did not have acute compartment syndrome, immediate external fixation or splinting is used depending on soft tissue traumatization, swelling, injury energy and mechanism, neurologic and circulatory exam, and knee joint congruity. Definitive open plating was performed at the discretion of the attending surgeon when the swelling decreased and soft tissue equilibrium was achieved. The goals of each surgeon in this series were to use meticulous soft tissue handling utilizing full thickness fascio-cutaneous flaps, and to perform anatomic restoration of the mechnical axis, joint line, and condylar width. Fracture reduction was accomplished using standard AO techniques for split patterns (Schatzker I, IV). For depression-type fractures (Schatker II, III) we typically use an “open book” or corticotomy technique to gain visualization of the depressed fragments prior to elevating them into an antomic position followed by bone grafting as necessary. For higher energy variants (Schatker V, VI), we typically use a combination of the above techniques as dictated by fracture personality. Open plating was performed with a variety of implants but the overwhelming majority consisted of modern proximal tibia periarticular plating systems. Minimally invasive plating techniques were rarely used. For bicondylar variants, lateral locking vs. dual column, dual incision plating techniques were used at the attending surgeon’s discretion. Care was taken to identify posteromedial fragments which were stabilized with posteromedial plating. In all cases, preoperative antibiotics were administered just prior to skin incision, were re-dosed if the operative duration was longer than 4 hours, and for closed fractures were discontinued within 24 hours postoperatively in accordance with our institution’s participation in the Surgical Care Improvement Project. All attending surgeons typically close wounds over a drain, except for those wounds which have fasciotomy incisions, where a VAC (Kinetics Concepts, Inc, San Antonia, TX) dressing is applied until delayed closure or skin grafting.

Statistical Analysis

In order to examine differences between patients who experienced SSI and those who did not, bivariate analysis was performed for all variables using two-tailed Student’s t-test and non-parametric tests for continuous data and two-tailed chi-squared tests for categorical data. Using those variables where we detected a statistically significant difference between

infected and non-infected cases, we performed multivariable logistic regression analysis to identify independent risk factors for postoperative infection.

Results

A total of 309 tibial plateau fractures (158 unicondylar, 151 bicondylar) were analyzed. We found an overall postoperative surgical site infection rate of 7.8%. When comparing the infected group to the non-infected group in univariate analysis (table 1), there was no significant difference with regard to patient-related factors such as age (47.9 years vs. 47.8 years, p=0.97), sex (79.2% male vs. 58.9% male, p=0.05), incidence of diabetes mellitus (20.8% vs. 9.5%, p=0.08), and use of tobacco products at the time of injury (45.8% vs. 30.5%, p=0.12).

Conversely, multiple injury-related factors were significantly related to increased rates of SSI in univariate analysis. Gustillo open fracture grade demonstrated a highly significant linear-by-linear correlation to rate of SSI (SSI in closed fractures: 5.3%, grade 1: 14.3%, grade 2: 40%, grade 3: 50%, $p<0.0001$). Likewise, presence of compartment syndrome requiring four-compartment fasciotomies of the leg (total study group incidence = 4.9%) had a higher rate of SSI following the open plating procedure than in cases not complicated by compartment syndrome (26.7% vs. 6.8%, p=0.01). Schatzker grade of the initial fracture (simplified in this analysis to unicondylar vs. bicondylar variants) was not significantly related to rate of SSI (5.7% vs. 9.9%, p=0.16).

Treatment-related factors were also analyzed in univariate analysis to determine their effect on SSI. For the total study cohort, operative time was significantly longer in the infected group than in the non-infected group (2.8 hours vs. 2.2 hours, p=0.01). For bicondylar fractures only, mean operative time in the infected group was 3.2 hours vs. 2.5 hours in the non-infected group (p=0.05). For unicondylar fractures only, the infected group had longer operative times but the difference was not significant (2.2 vs. 1.9 hours, p=0.25). The use of external fixation was associated with a higher infection rate than in those fractures without external fixation (10.9% vs. 3.7%, p=0.02), but external fixation was also correlated with longer operative times and open fractures, both of which were associated with higher infection rates (Pearson correlation=0.28 and 0.14, $p<0.01$ and $p<0.05$, respectively). The average time from injury to index operation for the entire series was 4.2 days. The delay in time from injury to index operation did not appear to be different between infected and non-infected groups (5.0 vs 4.1 days, p=0.15). For those patients who had external fixation placed on the day of injury followed by a time interval before open plating, the time from injury to open plating was not statistically different between the infected group and non-infected groups (6.4 days vs. 7.3 days, p=0.46). Finally, for bicolumnar fractures only, the use of a dual incision approach (anterolateral and posteromedial) with dualcolumn plating had no increase in the rate of infection when compared to a single anterolateral incision with lateral locked plating only (13.9% vs. 8.7%, p=0.35).

In order to control for confounding effects between variables, multivariable logistic regression modeling was performed using those variables found to be statistically significant in univariate analysis (table 2). These included operative time, open fracture grade,

compartment syndrome requiring fasciotomies, and use of external fixation. In this analysis, longer operative times (OR 1.78, p=0.01) and open fractures (OR 7.02, p<0.001) were found to be independent predictors of infection. Compartment syndrome requiring fasciotomies (OR 2.88, p=0.14) and use of external fixation (OR 1.83, p=0.27) were not significant independent predictors of SSI.

Discussion

An ideal analysis of the cause of postoperative infection would necessarily consider innumerable variables. For example, events leading to a surgical site infection might involve factors involving patient characteristics, operating room environment, operative site preparation and draping, antibiotic administration, surgical technique, and postoperative care. While it is impossible to be exhaustive in examining every variable which might effect the rate of SSI, this study focuses on a broad array of patient and injury-related variables, and specifically seeks to examine treatment variables over which the surgeon has reasonable control.

We found that longer operative times are an important predictor of postoperative surgical site infection in fractures of the tibial plateau. The odds ratio we report effectively says that for every extra hour of operative time, the risk of a postoperative SSI increases approximately 78%. We theorize that prolonged operative time is probably a marker of technical difficulty, more extensive soft tissue stripping, and extended exposure of the wound, all of which likely lead to higher rates of postoperative SSI. The concept of prolonged operative time affecting the postoperative SSI rate has been poorly studied in the orthopedic trauma literature but is consistent with findings in other surgical disciplines, especially total joint arthroplasty.[10–17] Peersman's data suggest that prolonged operative times in primary and revision knee and hip arthroplasty procedures have a significant and independent effect on postoperative infection rates. The difference in absolute operative times between the non-infected group and the infected group for all joint replacements in his study was 33 minutes (93 minutes in the non-infected group vs. 127 minutes in the infected group), compared to 36 minutes of absolute difference in our study. There are countless variables which affect operative time, including but not limited to preoperative planning, surgeon experience, surgeon fatigue, operating room staff experience, equipment availability, soft tissue characteristics, patient habitus, and fracture difficulty. Some of these variables are able to be manipulated and others are not; surgeons should be aware of the effect of operative time on surgical site infection and optimize their workflow accordingly.

Open fracture 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. It is therefore not surprising that in our study this variable was found to be an independent predictor of postoperative SSI. Its presence should continue to alert the treating surgeon of a heightened risk profile. Although the presence of compartment syndrome requiring fasciotomies was significantly related to higher rates of SSI in univariate analysis, we found only a trend towards independent predictor status in our multivariable analysis. However, recent evidence has reaffirmed the overall increased infection risk of fasciotomy wounds

surrounding tibial plateau fractures regardless of the timing of definitive fracture fixation,[18] and our data support this assertion, if not conclusively.

Counterintuitively, our analysis did not identify Shatzker grade itself as an independent predictor of infection. Despite this, we continue to believe that energy of injury does in fact play an important role in the development of infection after surgery. One explanation for this discrepancy is that what matters most in predicting SSI is not necessarily the bony fracture characteristics but rather the status of the soft tissues and the manner in which the surgeon handles them when treating that injury.

Other variables were also found not to influence the rate of postoperative SSI. Patient related factors such as smoking and diabetes mellitus only showed a trend towards significance in univariate analysis and thus were not included in the multivariable model. It is possible that in a larger study with more infection events these variables could be shown more definitively to contribute to higher rates of SSI. In addition, it does not appear that using a dual-incision as opposed to single-incision approach in bicolumnar fractures contributes to increased infection rates. This is consistent with recent reports that low infection rates can be achieved with a dual incision approach.[19] In fact, use of a dual incision approach is especially important in fracture patterns involving a posteromedial fragment, which may not be adequately stabilized with lateral locked plating alone.[20] Furthermore, recent evidence suggests that attempts at minimally invasive techniques may be unwise.[21] In Phisitkul's series of 37 complex intra-articular fractures of the tibial plateau treated with single incision locked plating, the authors observed an unexpectedly high deep infection rate of 22%. They noted that despite a single small incision, the higher infection rate might be explained either by a bulkier implant which sits off the anterior tibia or by technical difficulties with minimally invasive fracture reduction.

In summary, operative times approaching three hours and open fractures are independent predictors of postoperative surgical site infection. Treatment of complex intra-articular fractures of the tibial plateau should prioritize an expeditious restoration of the mechanical axis and articular surface with meticulous soft tissue handling. It is not acceptable to achieve shorter operative times through hurried soft tissue handling or suboptimal fracture reduction. However, using a staged approach to avoid prolonged wound exposure, working with an experienced support staff, and focusing on other operating room efficiencies may be helpful in reducing operative times.

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Table 1

Results of univariate analysis of risk factors for surgical site infection following open plating. Unless otherwise specified, statistical analysis comprised of Chi Squared test or Student's t-test.

Risk Factor		N=24 Infected Group	N=285 Non-infected group	p value
Age (mean in years)		47.9	47.8	0.97
Sex (male incidence)		79.2%	58.9%	0.05
Diabetes mellitus (incidence)		20.8%	9.5%	0.08
Tobacco use (incidence)		45.8%	30.5%	0.12
Presence of compartment syndrome and four-compartment fasciotomies (incidence)		16.70%	3.90%	0.01
Schatzker grade (bicondylar incidence)		62.50%	47.70%	0.16
Open fracture grade				<0.0001*
	Closed	62.5%	94.4%	
	1	4.2%	2.1%	
	2	16.7%	2.1%	
	3	16.7%	1.4%	
Time from injury to definitive plating (days)		5.0	4.1	0.15**
Use of external fixation		79.2%	54.4%	0.02
Time from external fixation to definitive plating (days; external fixator group only, N=174)		6.4	7.3	0.46
Operative time (hours)		2.8	2.2	0.005**
Incidence of dual incision approach (bicondylar group only, N=151)		33.3%	22.8%	0.36

* Linear by linear correlation;

** non-parametric test

Table 2

Results of mulivariate logistic regression model derived from significant risk factors in univariate analysis.

Risk Factor	p value	Odds Ratio (OR)	95% Confidence interval of OR
Operative Time (hours)	0.01	1.78	1.12 to 2.80
Open vs. Closed Fracture	<0.01	7.02	2.52 to 19.6
Presence of compartment syndrome and four-compartment fasciotomies	0.14	2.88	0.71 to 11.7
Use of external fixation	0.27	1.83	0.62 to 5.43