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ORIGINAL ARTICLE

The Gustilo–Anderson classification system as predictor of nonunion and infection in open tibia fractures

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Abstract

Purpose We sought to conduct the largest retrospective study to date of open tibia fractures and describe the incidence of complications and evaluate the potential predictive risk factors for complications.

Methods Patients with open tibia fractures treated with reamed intramedullary nail (IMN) across a 10-year period were evaluated. Patient charts were reviewed for demographics, type of open fracture (T), comorbidities, and postoperative complications. A multivariate model was conducted to determine the risk factors for each type of complication.

Results Of the 486 patients with open tibia fractures, 13 % ($n = 64$) had infections, 12 % ($n = 56$) had nonunions, and 1 % ($n = 7$) had amputations. TIII fractures had much higher rates of each complication than TI and TII fractures. Fracture type was the only significant risk factor for both nonunion and infection.

Conclusion Our study found that the Gustilo grade of open tibia fracture is by far the greatest predictor of nonunion and infection.

Keywords Orthopedics · Infection · Tibia fractures

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Introduction

Tibia shaft fractures, the most common form of orthopedic injury, account for approximately 77,000 hospitalizations and 569,000 hospital days per year [1]. Open injuries, which are more likely to occur along the tibia than with any other long bone, are particularly difficult to treat due to minimal soft tissue coverage and poor blood supply along the tibial shaft [2, 3]. Because of this, the rates of infection and nonunion remain high for open tibial shaft fractures [2, 4, 5].

As we move toward a value-based system of health care in which readmissions for complications will no longer be reimbursed, orthopedic surgeons will need to be able to identify high-risk patients early to prevent the need for reoperations. Although patient characteristics such as comorbidities and smoking status have been identified as risk factors for complications among tibia fractures, it is unknown which factors are the most important to consider for open injuries [6–9]. In fact, most large studies on tibia fractures treated by intramedullary nailing (IMN) have consisted primarily of closed injuries [10–13]. While the SPRINT investigators found several risk factors for adverse events in the largest study to date on tibia fractures, only a third of their patients ($n = 400$) had open wounds and those with highly severe open injuries were excluded [10]. Although Gaebler et al. conducted a smaller study that included 202 open fractures, they included the Gustilo–Anderson type of open injury in their analysis. However, type IIIc fractures were not further divided into subtypes based on the severity of injury [11].

To our knowledge, only a few studies exist that have investigated patients with exclusively open tibia injuries. All of these studies were limited due to very small sample sizes that contained only a few high-grade open fractures [14–20]. Currently, no large-scale investigation of risk factors for postoperative complications among open tibia fractures has been conducted. Therefore, the purpose of our study was to conduct a large-scale multivariate analysis of all open tibia fractures treated by IMN at a level I trauma center across a 10-year period. In doing so, we were able to determine which patient characteristics and clinical factors are most predictive of infection, nonunion, and amputation for open tibial shaft fractures.

Materials and methods

Following IRB approval, patients were identified for our study by querying the institutional database at a major level I trauma center using the Current Procedural Terminology Code (CPT) 27759 for open treatment of a tibial shaft fracture treated by intramedullary nailing and CPT codes 11010, 11011, and 11012 for irrigation and debridement of an open fracture. Medical records were reviewed for patient characteristics including age at surgery, gender, ASA class, and race/ethnicity. The Gustilo–Anderson type of open fracture was also identified by reviewing each operative note. Patients who were identified to have closed tibia fractures or were less than 16 years of age were excluded from further analysis. For adult patients with open tibia fractures, the presence of comorbidities including AIDS/HIV, alcohol abuse, blood loss anemia, coagulopathy, cardiac arrhythmias, congestive heart failure, chronic pulmonary disease, rheumatoid arthritis/collagen vascular disease, diabetes, depression, deficiency anemia, drug abuse, fluid and electrolyte disorders, hypertension, liver disease, lymphoma, metastatic cancer, obesity, other neurological disorders, paralysis, pulmonary circulation disorders, peptic ulcer disease (excluding bleeding), psychoses, peripheral vascular disorder, renal failure, solid tumor without metastasis, hypothyroidism, valvular disease, and weight loss were recorded.

Postoperative medical records were reviewed for the incidence of complications. These include wound infection, nonunion, and amputation. The number of reoperations required to treat each of these complications was calculated for each patient. The number of postoperative clinic visits was also recorded. Radiographs of the tibia fracture were reviewed for each patient to determine the distance from the plafond for each fracture in centimeters.

Initial descriptive statistics were computed to determine the distribution of patient and clinical characteristics for our patient population. A multivariable logistic regression model was constructed to examine which patient characteristics were associated with complications due to nonunion, infections, and amputations. Age, gender, ASA class, race (white versus non-white), the sum of all identified comorbidities, and fracture grade were controlled for in our analysis to predict the risk of amputation. ASA score was recoded as a binary variable combining patients with scores of ASA 1–2 and those with scores of 3 or greater. Two models were used to predict the incidence of infection and nonunion. In the primary model, fracture grade was categorized as less than or greater than 3. In our secondary analysis, type II, type IIIa, type IIIb, and type IIIc fractures were kept as separate categories and compared to those with type I. In our model to predict nonunion, the distance from the plafond was also included as a continuous variable. Statistical significance was set at $p = 0.05$.

Results

551 patients who had IMN of a tibia shaft fracture were identified through our CPT code search. Of these, 65 patients who were found to either have a closed tibia fracture, who were under 16 years of age, or who had incomplete radiographs, were excluded from further analysis.

Demographics for the 486 patients included in the analysis are provided in Table 1. 67 % of patients were between the ages of 21–50 years and 78 % were male. 13 % ($n = 63$) of fractures were type I, 42 % ($n = 202$) were type II, and 46 % ($n = 221$) were type III. The majority of the type III fractures were type IIIa (63 %, $n = 140$) or type IIIb (33 %, $n = 73$) injuries. The overall complication rate of all fracture types was 35.0 % ($n = 170$). 13 % of patients had infections and 12 % had nonunion. 4 % of patients had hardware pain or prominence that required surgical removal of the implant and 1 % required amputation (Table 1).

Table 2 provides further analysis of patients who developed complications by the type of open injury. The vast majority of patients who had complications had type III fractures. The percentage of patients who developed each type of complication also increased among type III fractures based on the degree of soft tissue injury. 14 % ($n = 19$) of type IIIa fractures had infection, 11 % ($n = 26$) had nonunion, and 1 % ($n = 1$) required amputation. In contrast, 30 % ($n = 22$) of type IIIb fractures developed infection, 26 % ($n = 19$) had nonunion, and 7 % ($n = 5$) required amputation. Type IIIc fractures had the highest proportion of patients who developed complications: 62 % ($n = 5$) of patients developed infection, 25 % ($n = 2$) had nonunion, and 12 % ($n = 1$) required amputation.

The results of our primary multivariate logistic regression model found that patient age, race, gender, and the number of comorbidities were not found to be significant risk factors for nonunion and infection. Based on the results of our primary model, we conducted a secondary

Table 1 Patient characteristics

	n	%
Age		
16–20	78	16
21–30	141	29
31–40	91	19
41–50	91	19
51–60	57	12
61–70	21	4
71–80	3	1
81–90	4	1
Average (SD)	486	36 (15)
Gender		
Male	364	78
Female	102	22
ASA class		
1	49	9
2	244	52
3	132	28
4	45	10
5	1	0
Race		
White	340	78
Non-white	128	28
Average # of comorbidities (SD)	1.0 (1.4)	
Number of clinic visits	6.0 (5.5)	
Fracture grade		
I	63	13
II	202	42
IIIa	140	29
IIIb	73	15
IIIc	8	2
Complications		
Infection	64	13
Nonunion	56	12
Amputation	7	1
Average number of reoperations (SD)		
Infection	1.5 (1.4)	
Nonunion	1.2 (0.4)	

Table 2 Complications by grade

Grade	Infection		Nonunion		Amputation	
	n	%	*n*	%	*n*	%
I	1	2	4	6	0	0
II	17	8	15	7	0	0
IIIa	19	14	16	11	1	1
IIIb	22	30	19	26	5	7
IIIc	5	62	2	25	1	12

multivariate analysis for nonunion and infection controlling for the same factors, but differentiating by the three types of type III fractures. In this model, type IIIb fractures were shown to be 4.91 times as likely to develop nonunion when compared to patients with type I fractures, demonstrating a significant increase (OR 4.91, 95 % CI 1.55–15.50, $p = 0.007$). The odds of developing a nonunion were 1.73 times as likely for type IIIa fractures (OR 1.73, 95 % CI 0.55–5.47, $p = 0.352$) and 4.60 more likely with type IIIc fractures (OR 4.60, 95 % CI 0.69–30.66, $p = 0.114$), although neither of these reached statistical significance. None of the other risk factors including age, gender, ASA class, race, and number of comorbidities were shown to be significant (Table 3). Univariate analysis on smoking found it not to be a significant risk factor for developing a complication with an odds ratio of 0.84 (95 % CI 0.55–1.29).

For infection, a fracture type of IIIa, IIIb, or IIIc was shown to be the only significant risk factors. Type IIIa fractures were 9.27 times likely (OR 9.27, 95 % CI 1.05–4.33, $p = 0.033$), type IIIb fractures 25 times likely (OR 25.44, 95 % CI 3.28–197.22, $p < 0.002$), and type IIIc 108 (OR 108.9, 95 % CI 9.18–1293.0, $p < 0.001$) times likely to develop an infection when compared to type I fractures. Age, gender, ASA class, race, and the number of comorbidities were not statistically significant risk factors for infection (Table 3). The overall complication rates were 0.079 (95 % CI of 0.011–0.145) for grade I, 0.158 with (95 % CI of 0.105–0.207) for grade II, and 0.376 (95 % CI of 0.309–0.439) for grade III.

Discussion

In this study, we conducted a large-scale analysis of risk factors for open tibia shaft fractures treated by IMN. After controlling for patient demographics and comorbidities, we found that the Gustilo–Anderson type of open injury was by far the greatest predictor of infection and nonunion.

Although the best form of surgical treatment for open tibia fractures has been contested throughout the decades, there is now consensus that IMN is associated with better postoperative outcomes and is currently the preferred form of treatment for this injury among orthopedists [18, 21–29]. Because of this, other recent large-scale investigations of outcomes following tibia shaft fractures have also focused on those treated by intramedullary nailing (IMN) [13]. In one study of 467 tibia fractures treated by IMN, Gaebler et al. found that while nonunion only occurred in midshaft and distal fractures, there were no significant differences in the overall rate of nonunion based on the location of the fracture [11]. Similarly, we found that the distance from

Table 3 Secondary multivariable logistic regression models for risk factors for nonunion and infection

Risk factor	Nonunion			Infection		
	OR	95 % CI	*p*	OR	95 % CI	*p*
Age	1.01	(0.99–1.03)	0.435	0.99	(0.98–1.02)	0.920
Male gender	1.47	(0.66–3.26)	0.341	1.46	(0.70–3.46)	0.250
Race (nonwhite versus white)	0.57	(0.31–1.06)	0.075	1.18	(0.61–2.29)	0.622
Number of comorbidities	0.93	(0.73–1.19)	0.563	0.99	(0.79–1.26)	0.993
ASA class >3	0.97	(0.51–1.87)	0.934	0.79	(0.43–1.48)	0.466
Gustilo type II[a]	1.08	(0.34–3.42)	0.896	5.414	(0.71–41.78)	0.105
Gustilo type IIIa[a]	1.73	(0.55–5.47)	0.352	**9.269**	**(1.05–4.33)**	**0.033**
Gustilo type IIIb[a]	**4.91**	**(1.55–15.50)**	**0.007**	**25.44**	**(3.28–197.22)**	**0.002**
Gustilo type IIIc[a]	**4.60**	**(0.69–30.66)**	**0.114**	**108.9**	**(9.18–1293.0)**	**<0.001**

Odds ratio (OR) and 95 % confidence intervals (CI) for the risk factors included in our secondary model in which type III fractures were broken down into subtypes. Risk factors that were found to be significant are included in bold

[a] Gustilo–Anderson type I fractures used as a reference category

the plafond had no significant association with the rates of nonunion.

While Gaebler et al. also reported that Gustilo–Anderson type III open fractures are significantly more likely to develop a deep wound infection and nonunion than type II, type I, and closed fractures, only 202 of their fractures were open [11]. Most likely as a result of this relatively lower sample size, type III open injuries were not further distinguished by IIIa–IIIc, which greatly limited the applicability of their results to open injuries. While the original Gustilo grading system did not include type III subtypes of open fractures, it was eventually incorporated into the system after Gustilo et al. analyzed a cohort of 75 type III open fractures and determined that the current designation was too inclusive and could not accurately predict the incidence of complications [30]. His findings were corroborated in our multivariate analysis of 221 type III open fractures, in which we found that extensive soft tissue injury loss (type IIIb) or arterial injury (type IIIc) increases the odds of infection or nonunion by a much greater magnitude compared to those with adequate soft tissue coverage of the bone (type IIIa).

The SPRINT investigators studied 400 open injuries within a larger cohort of 1227 tibia shaft fractures treated with IMN [10]. They found several factors that were predictive of overall adverse outcomes after IMN of the tibia, such as reamed vs unreamed nails in smokers with open tibia fractures [10]. However, the Gustilo–Anderson type of open injury was not considered in their model, and patients with type IIIc fractures were excluded from their study altogether. In comparison, we found that when the Gustilo–Anderson type of open fracture is included in a multivariate model along with other patient demographics and comorbidities, it remains by far the greatest prognostic indicator of infection and nonunion among open tibia shaft fractures.

A few other small-scale studies have analyzed adverse outcomes among open tibia fractures. When Khatod et al. performed a univariate analysis among 103 patients with open tibia fractures, they found an infection rate of 22.6 %, with 8.7 % for type 1, 10.9 % for type II, 23.5 % for type IIIa, 66.7 % for type IIIb, and 62.5 % for type IIIC ($p < 0.0001$) [15]. In Harley et al.'s study of 202 open long bone fractures, over a quarter of which were tibia fractures, a higher Gustilo grade significantly increased the risk of both nonunion (5 % for type I versus 37 % for type III) and infection (2 % for type I versus 22 % for type III) [16]. In contrast, Enninghorst et al. determined that Gustilo grade was not a significant risk factor for infection and patient outcomes, when other factors, such as timely debridement, were considered [17].

Although all of these studies included the Gustilo classification system in their analysis of adverse events for open fractures, the depth of the investigation was limited due to small sizes. For example, none of these studies had considered the confounding effects of patient comorbidities. However, substantial evidence exists that individual factors including diabetes, blood loss, and drug and alcohol abuse can influence outcomes for patients with tibia shaft fractures [6, 9, 31–33]. In our study, we were able to consider the effects of 29 comorbidities. In doing so, we found that the number of comorbidities a patient had prior to injury had no effect on complication rates when the Gustilo grade of injury was considered. Additionally, all of these studies included patients that were treated by external fixation and plate and screw in addition to nailing. However, it is well established in the literature that complication rates vary widely based on the type of procedure performed and can partially explain our relatively lower complication rates than those found in the previously mentioned studies [34–36].

Our study was limited by a variety of factors. Because of our retrospective design, we were unable to control for the treatment protocols for our patients, and other confounding factors may have biased our results. Although a strength of our study was our large cohort, we were still limited statistically in the number of variables we could include in our model. Because of this, we were unable to consider the individual effects of each of the 29 comorbidities we analyzed and instead adopted a method in which we added the number of comorbidities present for each patient. Additionally, although we included several variables in our analysis, other variables, such as the material of the nail, mechanism of injury, and severity measure, were not included in our analysis. If possible, a large, prospective, observational study of open tibia fractures including all known risk factors could be used to perform a more comprehensive multivariate analysis to confirm our findings.

Overall, in this study, we found that the degree of soft tissue injury as defined by the Gustilo–Anderson classification system is the single most important risk factor in determining the incidence of postoperative infection and nonunion for open tibia fractures. Due to the high prevalence of open tibia fractures among patients that sustain traumatic injuries, it will be essential to identify high-risk patients early to predict the financial costs due to readmissions and reoperations in a bundled payment system of reimbursement. While previous studies have suggested that risk stratification of patients may be complex and involve a variety of patient, clinical, and surgical factors, our results indicate that the type of open fracture should be the main factor to be considered to stratify risk and predict patient outcome.

Compliance with ethical standards

This study was performed in accordance with the relevant regulations of the US Health Insurance Portability and Accountability Act (HIPPA) and the ethical standards of the 1964 Declaration of Helsinki. The protocol was approved by the Vanderbilt Institution Review Board.

Conflict of interest Author William Obremskey has previously been consulted for biometrics, provided expert testimony in legal matters, was committee chair of the OTA and SEFC, and has a grant from the Department of Defense. Rachel V. Thakore, Elvis L. Francois, Paul S. Whiting, Michael A. Siuta, Michael A. Benvenuti, Anne K. Smith, Basem Attum, Samuel K. Nwosu, and Manish K. Sethi declare that they have no conflict of interest.

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Copyrighted material/consent forms This study used no previously copyrighted materials or signed patient consent forms. This study was retrospective in nature.

IRB approval This study has approval from the Vanderbilt IRB.

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