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Outcomes of tibia shaft fractures caused by low energy gunshot wounds

Charles A. Su, Mai P. Nguyen, Jeffrey A. O'Donnell, Heather A. Vallier*

Study performed at Department of Orthopaedic Surgery, MetroHealth Medical Center Affiliated with Case Western Reserve University, United States

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ABSTRACT

Background: The purpose of this project was to compare the rates of infections, nonunions, malunions, and secondary operations in tibia fractures resultant from low energy GSWs versus those seen in open and closed tibia fractures resultant from blunt trauma. A secondary objective was to assess the utility of using the traditional Gustilo-Anderson classification system for open fractures to describe fractures secondary to low energy GSW.
Methods: A retrospective review of 327 patients with tibia shaft fractures was conducted at our level I trauma center. Patients underwent a variety of interventions depending on their injury. Standard fixation techniques were utilized. Outcome measures include: mechanism of injury, rates of superficial and deep infection, nonunion, malunion, and secondary operations.
Results: Deep infection after low energy GSW tibia fractures was uncommon and seen in only 2.3% of patients. Rates of infection after low energy GSWs were similar to low and high energy closed tibia fractures resultant from blunt trauma, but significantly less than that seen in open type II (25%, $p < 0.05$), type IIIA (19.5%, $p < 0.05$), and type IIIB fractures (47%, $p < 0.01$). There were no nonunions following GSW fractures, versus 3.7% after closed tibia fractures from blunt trauma ($p = 0.2$). Nonunions were more common after open fractures from blunt trauma (11%, $p < 0.05$) versus GSWs. Differences in infection and nonunion were associated with more secondary operations (18%, $p < 0.01$) in the open tibia fracture group compared with GSWs (2.3%) and closed fractures (7.9% $p = 0.19$).
Conclusions: While GSWs are traditionally thought of as open injuries, low energy GSW tibia fractures had a low rate of infection and no nonunions, and resulted in a reoperation rate similar to closed blunt tibia shaft fractures and significantly lower than open tibia fractures.

Introduction

The United States leads all high income nations in GSW mortality [1]. Approximately 88 deaths occur every day due to a firearm injury [2]. Injuries from GSWs are also associated with tremendous costs. Between 2006 and 2010 firearm related injuries resulted in an estimated 385,769 emergency department visits, 141,914 hospital admissions and cost $88.6 billion in the United States [3]. The economic burden of GSWs extends far beyond medical treatment with valuations of single year productivity loses secondary to GSWs estimated at greater than $35 billion dollars and total lifetime costs of fatal and nonfatal GSW injuries of $44 billion and $1.4 billion dollars, respectively [4,5]

Extremity involvement secondary to GSW is common. [5,6] Despite their frequency, the classification of GSWs remains poorly defined. While ballistic fractures have traditionally been categorized as low or high-velocity injuries, distinguishing the energy transferred may instead be a more important factor encapsulating the projectile's physical characteristics, kinetic energy, and the injury of the tissues. [7]. Moreover, though GSWs are typically thought of as open injuries, literature regarding the risks of infection associated with ballistic fractures is limited, and treatment standards for debridement and antibiotics remain controversial, particularly with the most common, lower energy injuries [6,8] Seminal work on the subject of open fractures by Gustilo and Anderson mentions ballistic fractures within the group of open injuries, referring to either close-range gunshot injuries with wadding or high velocity injury. They do not make specific mention of the more common low energy injuries [9,10,12].

The purpose of this project was to compare the rates of infections, nonunions, malunions, and secondary operations in tibia fractures resultant from low energy GSWs versus those seen

* Corresponding author at: Department of Orthopaedic Surgery, 2500 MetroHealth Drive, Cleveland, OH 44109, United States.
E-mail address: hvallier@metrohealth.org (H.A. Vallier).

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in open and closed tibia fractures resultant from blunt trauma. A secondary objective was to assess the utility of using the traditional Gustilo-Anderson classification system for open fractures to describe fractures secondary to low energy GSW. We hypothesized that tibia shaft fractures from low energy GSW would have lower rates of infection and nonunion versus open fractures secondary to high energy blunt trauma.

Methods

Institutional Review Board approval was obtained for the study. Three hundred thirty-eight skeletally mature trauma patients with tibia shaft fractures (AO/OTA 42) [11], presenting from 2010 to 2014 at a Level I trauma center were reviewed. A minimum of 90-day follow-up was available for 327 patients. Medical records were reviewed for demographic information, mechanism of injury, treatment modality, and complications including superficial and deep infections, nonunion, malunion, and reoperations were documented. High energy injuries included those resulting from motor vehicle collisions (MVCs), pedestrian vs auto injuries, crush injuries, cycling injuries, and falls from a height. Low energy injuries included falls from a stand, altercations, and sports-related injuries. Open fractures were classified into the categories as previously described by Gustilo and Anderson (Table 1) [10,12]. Exclusion criteria included less than 90 days of follow-up and high velocity GSWs or shotgun injuries.

Displaced fractures were treated with provisional closed reduction and splinting in the emergency department. Non-displaced fractures were also splinted, but were converted to casting within several days depending on the amount of associated swelling. Patients with open fractures received intravenous antibiotics upon presentation to the emergency department, consisting of cefazolin and gentamicin. Those with penicillin allergy received clindamycin instead of cephalosporins. Blunt open fractures were treated urgently with surgical debridement in the operating room, followed by reduction and fixation of the fracture. Other displaced fractures were offered surgical reduction and stabilization for their injuries, and were treated at the discretion of the attending surgeon with conventional techniques including reamed intramedullary nailing or plate fixation (Fig. 1). Intravenous antibiotics were administered postoperatively for 24 h for closed fractures and ballistic fractures and for 48 h for open fractures. Open wounds associated with types I, II, and IIIA fractures were closed primarily. Patients with type IIIB fractures underwent serial debridement in the operating room every approximately 48 h until soft tissue coverage was achieved via rotational or free tissue transfer (mean 5.2 days, range 3 to 13 days). Negative pressure dressings were utilized for open wounds awaiting soft tissue coverage. All patients with open type IIIC fractures underwent primary amputation and were excluded from further analysis.

Superficial infection was defined as infection superficial to fascia, treated with local wound care and/or oral antibiotics. Deep infection was defined as infection deep to fascia requiring surgical debridement. Nonunion was defined as painful fracture with inadequate healing of the fracture 6 months after injury and requiring revision surgery to achieve union. Malunion was defined as more than 5° of angular or rotational malposition or of more than 1 centimeter of shortening. Secondary procedures were recorded.

Data were evaluated with two-tailed student *t*-tests and Fisher exact tests where appropriate. Mann-Whitney *U* test was used for non-parametric data. Statistical significance was set at $\alpha = 0.05$.

Results

Patient and injury characteristics

327 patients with tibia fractures had adequate clinical and radiographic follow up, including 225 men and 102 women with mean age 40.4 years. Of these, 284 patients had tibia fractures from blunt trauma, which included 164 closed fractures (81 low energy, 83 high energy) and 120 open fractures (Table 1). Other musculoskeletal injuries occurred in 12 patients (14.8%) with closed low energy tibia shaft fractures and in 48 (57.8%) with closed high energy fractures. One hundred and twenty patients sustained open tibia fractures: 7 type I, 16 type II, 82 type IIIA, 15 type IIIB, and 4 type IIIC. Sixty (50%) had multiple fractures. Fracture classification as described by the AO/OTA classification is also included in Table 1 [11].

Forty-three patients sustained tibia shaft fractures from low energy GSW (13.0%). Twenty one (48.8%) had multiple fractures. Compared to tibia shaft fractures from blunt trauma, patients who sustained GSW were more likely to be male (95.3% vs 70.4%,

Table 1
Patient and injury characteristics.

	Age	Gender (M)	AO/OTA classification*	Multiple Fractures
Closed fracture (n = 164)	41.8	113 (69%)		60 (37%)
Low energy (n = 81)	41.1	46 (57%)	A:29, B:51, C:1	12 (15%)
Low energy fall (64)	44.4	33 (52%)		9 (14%)
Altercation (7)	45.9	6 (86%)		3 (43%)
Sports (5)	27.6	4 (80%)		0
Cycling (5)	30.6	4 (80%)		0
High energy (n = 83)	41.4	57 (69%)	A:2, B:59, C:22	48 (58%)
MVC (57)	42.6	37 (65%)		33 (58%)
Pedestrian (18)	47.9	10 (56%)		13 (72%)
Crush (6)	37.3	6 (100%)		2 (33%)
High energy fall (2)	36.0	2 (100%)		0
Open fracture (n = 120)	42.1	87 (73%)	A:8, B:89, C:23	60 (50%)
Type I (7)	35.0	3 (43%)		5 (71%)
Type II (16)	46.1	9 (56%)		2 (13%)
Type IIIA (82)	41.2	61 (74%)		36 (44%)
Type IIIB (15)	47.0	10 (67%)		15 (100%)
Type IIIC (4)	38.0	4 (100%)		2 (50%)
GSW (n = 43)	30.1	41 (95%)	A:0, B:12, C:31	21 (49%)

* AO/OTA fracture classification in included. All are fractures of the tibia shaft (42) with designations of A: simple, B: wedge, and C: complex as shown for each of the four groups described in the table.

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