Gunshot Wounds to the Foot and Ankle: Review of Cases from a Level-1 Trauma Center

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ABSTRACT

Background: Gunshot injuries frequently involve the foot and ankle. The standard of care for treatment of gunshot injuries to the foot and ankle is not clear. To better understand these injuries, we completed a retrospective review of foot and ankle gunshot injuries at a level-1 trauma center seen as orthopaedic consults over a 2-year period.

Methods: Orthopaedic consults for foot and ankle gunshot injuries from June 1st, 2018, through May 31st, 2020, were reviewed. Patient characteristics, zone of injury, mechanism of injury, associated injuries, treatment, follow-up, and outcomes were recorded.

Results: Forty-eight foot and ankle gunshot injuries were identified, encompassing 16.0% of all gunshot consults in that period. Most patients were men and, on average, 30 years old. Most injuries were due to altercations and self-inflicted injuries. Most injuries were distal to the tarsometatarsal joint (zone one). There were three arterial injuries, five nerve injuries, and one tendon laceration. Three infections occurred, and 18 patients did not follow-up after their initial consultation. Most patients (68.8%) were treated as outpatients with a dose of intravenous antibiotics, bedside irrigation and debridement, and immobilization followed by a short course of oral antibiotics.

Conclusion: In this series, most gunshot injuries to the foot and ankle occurred in men approximately 30 years of age owing to altercations. Most were treated nonoperatively with a 6.0% rate of infection. From our review, nonoperative treatment was found to be successful in the majority of gunshot injuries to the foot and ankle.

Keywords: Foot, Ankle, Wounds, Injuries

INTRODUCTION

Injuries due to gunshot wounds are common in the United States. In 2017, there were 39,773 firearm-related deaths, with 12.2 firearm-related deaths occurring per 100,000 population.[1] Although gunshot injuries are common in the United States, there is a paucity of literature about firearm injuries to the foot or ankle. Using data from the Firearm Injury Surveillance Study, Cosco and King[2] reviewed the epidemiology of self-inflicted gunshot injuries to the foot in the United States from 1993 to 2010. They found that these 667 incidents represented 1.0% of the reported gunshots. In this study, 90.0% of the patients were male, and 52.0% were between ages 15 and 34 years. Husain et al[3] published a retrospective case series evaluating 27 civilian patients over 8 years with low-velocity gunshot injuries to the foot and ankle. Most injuries in their series were distal to the midtarsal joint, and 96.3% of injuries involved fractures. They reported that 37.0% of these patients underwent fracture surgery, and one patient later developed osteomyelitis.

Several unique features of the foot and ankle may impact gunshot injuries. There is minimal soft tissue coverage of the bones. Owing to this minimal coverage, injury from lower velocity guns may lead to more frequent fractures and difficulties with wound healing. There are multiple bones and joints in the foot, making intra-articular fractures more likely. More than 80.0% of gunshots to the foot and ankle have been found to cause fractures.[4] Shoe and sock material can be forced into the wound by the projectile, which has been found to increase the risk of developing pseudomonas osteomyelitis.[5,6] Infection rates after gunshot injuries to the foot specifically are higher than in other locations.[7,8] Foot mobility, weight bearing, and the ability to comfortably wear shoes may also be negatively impacted by the gunshot injury. Given the lack of literature evaluating foot and ankle gunshot injuries, we sought to understand better our experience with the presentation and treatment of these injuries. We hypothesized that most foot and ankle gunshot injuries at our institution were treated nonoperatively with bedside irrigation and debridement, immobilization, and antibiotics. A retrospective review of all patients who had an orthopaedic surgery consultation at a level-1 trauma center was completed over a 2-year period.

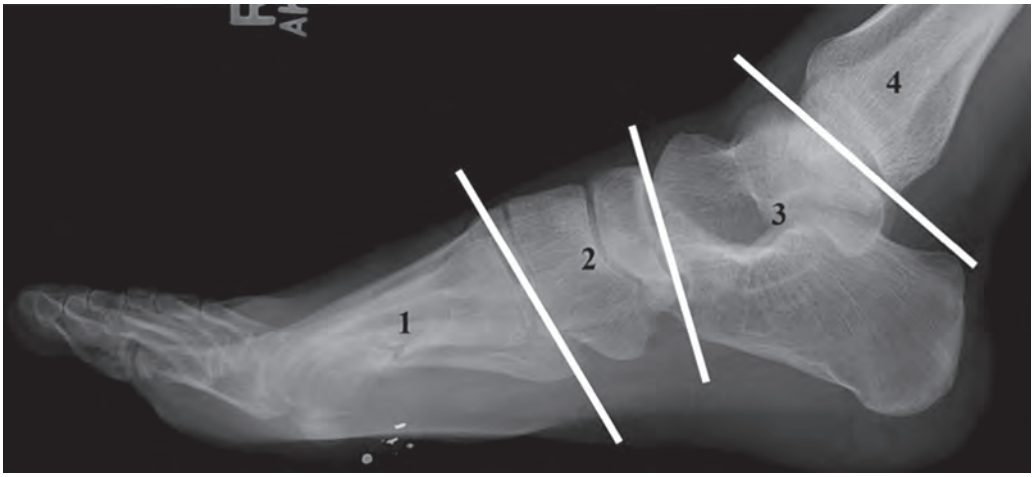

Figure 1. *Lateral radiographic view of the zones of injury. 1: distal to the tarsometatarsal joint, including the metatarsals and phalanges. This radiograph shows an example of a zone one injury. Two: between the transverse tarsal joint and the tarsometatarsal joint, including the cuneiforms, navicular, and cuboid. Three: hindfoot with the talus and calcaneus. Four: ankle joint and proximal, including the distal tibia and distal fibula.*

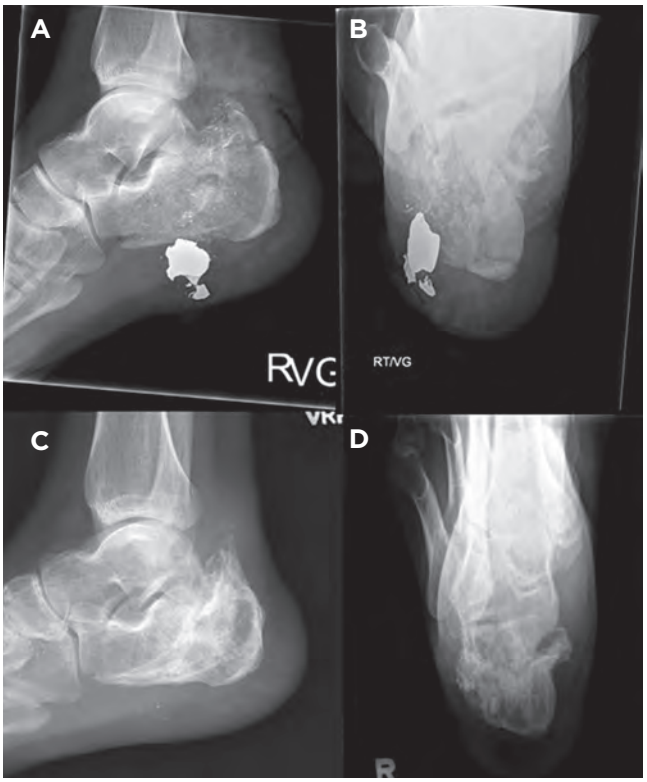

Figure 2. *A and C) Lateral and B and D) Harris/axial radiographic views of zone three calcaneus fracture gunshot injury. C and D) represent radiographs at 6-months follow-up. The bullet fragment had been removed.*

METHODS

After obtaining Institutional Review Board approval (HSC #20-410), we reviewed the daily orthopaedic consult list from June 1st, 2018, to May 31st, 2020. This list contains the identifying information of every patient whom the orthopaedic on-call service was asked to see in consultation at our institution. The consults were requested from the emergency department, urgent care, or other inpatient services. Patients diagnosed with gunshot injuries were noted, and their charts and radiographs were reviewed to determine which patients had been shot in the foot or ankle. A chart and radiographic review of patients shot in the foot or ankle was performed for this study.

Chart Review

The electronic chart was reviewed for patients who had sustained a gunshot to the foot or ankle. Age, sex, and side of injury were noted. We recorded the mechanism of injury, the presence of other injuries, screening of alcohol and drugs if applicable, and the length of orthopaedic follow-up. The type of treatment and complications developed were also reviewed. Prisoners, patients who were pregnant, children under 18 years, and cognitively impaired patients were excluded.

Radiographic Review

We reviewed radiographs to determine the location of the injury and which bones, if any, were fractured. The location of the injury was divided into four zones (Figure 1). Zone one was distal to the tarsometatarsal joint and included the metatarsals and phalanges. Zone two was between the transverse tarsal joint and the tarsometatarsal joint. This zone included the cuneiforms, navicular, and cuboid. Zone three was the hindfoot with the talus and calcaneus (Figure 2). Zone four was above the ankle joint, including the distal tibia and distal fibula.

Table 1. *Demographic information for patients with foot and ankle gunshot wounds*

Sex	40 Male	8 Female
Laterality	23 Left	25 Right
Mean Age (years)	29.75	--
Age Range (years)	16 to 80	--

Table 2. Number of fractures and soft-tissue only injuries in respective zones of injury

Zone of Injury	Fracture	No Fracture
1	19	1
2	0	0
3	8	2
4	8	2
1, 2	2	0
2, 3	1	0
3, 4	2	1
1, 2, 3	0	1
1, 2, 4	1	0

Table 3. Summary of fractured bones, mechanism of injury, toxicology screen results, and nerve/tendon/vessel injuries

Bones Fractured	Number of Injuries
Tibia	6
Fibula	7
Talus	7
Calcaneus	9
One or more tarsals	6
One or more metatarsals	14
One or more phalanges	8
Mechanism of Injury	
Self-inflicted	14
Altercations	19
Unknown	13
"Looking at gun and went off"	1
Bullet through wall	1
Toxicology Screen	**Substances**
Not tested	19
Negative	8
ETOH	8
Amphetamine	7
Opioids	6
Benzodiazepines	4
Cannabinoids	7
Structures Injured	
None	39
Artery	3
Vein	1
Nerve injury	5
Tendon	1

ETOH, Alcohol

RESULTS

We reviewed a total of 309 orthopaedic consultations involving gunshot injuries. Forty-eight of these were foot- or ankle-related injuries, accounting for 16.0% of gunshot injuries. There were 48 foot and/or ankle gunshot injuries identified. Demographic information is listed in Table 1.

Of the 48 patients, 14.6% sustained only soft-tissue injuries, and 85.4% had bony involvement (Table 2). Zone one was most commonly affected (41.7%). All but one zone four injuries involved the ankle joint or syndesmosis. All but one of the bony injuries within zone four were intra-articular or within the syndesmosis. The one exception was an isolated fibula fracture, which occurred 4 cm above the ankle joint. The bones most affected were metatarsals (29.2%), followed by the calcaneus (18.8%) (Table 3). Non-foot and ankle injuries also occurred in seven patients, and one of these patients was shot in the spinal canal.

The mechanism of injury was most often altercations (39.6%), followed by self-inflicted injuries (29.2%) (Table 3). In the chart review, we were unable to distinguish between intentional and accidental self-inflicted injuries. In 13 patients, the mechanism was unknown or not recorded. Twenty-nine of the 48 patients were tested for alcohol or drugs. One or more of these substances were found in 21 patients (72.4%). Three patients were noted to have been wearing shoes or socks at the time of injury. Most patient charts did not note whether bullet(s) went through shoes or socks. Fifteen of the 48 patients were admitted to the hospital (31.3%), primarily due to other injuries. The remaining 33 patients were treated as outpatients.

Eighteen patients did not show up for their orthopaedic follow-up after the initial consultation. Of these patients, 11 patients were not tested for drugs and alcohol or tested negative, and the remaining seven patients tested positive for one or more substances. Of the remaining 30 patients, the average follow-up length was 102.7 days (±151.4). There were three infections, two patients with residual nerve pain and one patient with a symptomatic foreign body that was later removed. There was one extensor hallucis longus rupture, one anterior tibial artery injury, one dorsalis pedis artery injury, one superficial femoral artery injury, and one femoral vein injury. Nerve injuries included two deep peroneal nerve neuropraxias, one tibial nerve neuropraxia, one patient with second and third toe numbness presumed to be digital nerve neuropraxias, and one patient with clinical allodynia with signs of neuritis in the foot.

Ten patients had operative procedures to the foot and ankle, five inpatients and five outpatients. The reasons for operative treatment are listed in Table 4. Two patients presented to the emergency department after their wounds had healed. The remaining 36 patients presented with open wounds and were treated

Table 4. *Summary of foot and ankle gunshot injuries treated operatively*

Operative Procedures	Inpatient/ Outpatient	Number
I&D	Inpatient	2
I&D, external fixation	Inpatient	1
I&D, removal of foreign bodies, ORIF	Inpatient	1
I&D, removal of foreign bodies	Outpatient	3
I&D, removal of foreign bodies	Inpatient	1
EHL repair	Outpatient	1
I&D, removal of bony prominences	Outpatient	1

I&D, irrigation and debridement; ORIF, open reduction internal fixation; EHL, extensor hallucis longus

with bedside irrigation, debridement, antibiotics, and immobilization. Bedside irrigation and debridement were performed with two liters of normal sterile saline directly into the wound(s). If the wound was small, it was dressed with petroleum gauze or xeroform and allowed to granulate in. If the wound was large, it was loosely sutured with nylon or prolene. Intravenous cefazolin was most commonly given initially, followed by 5 to 14 days of oral cephalexin antibiotics. Ciprofloxacin was given to three patients per provider choice.

DISCUSSION

This study is a retrospective chart and radiographic review of 48 foot and/or ankle gunshot injuries identified by orthopaedic surgery consultations at a level-1 trauma center. The patients represent 16.0% of all orthopaedic consults involving gunshot injuries seen in consultation over 2 years. Our review covers more patients than the 2016 study by Husein et al,[3] who reviewed foot and ankle gunshot injuries over 8 years. Similar to their review, most injuries were distal to the midtarsal joint, with most patients being male. In their series, 70.0% of patients underwent operative irrigation and debridement within 1 hour of presentation. Only 31.3% of the patients in our study were admitted to the hospital, and most admissions were for injuries other than the foot and ankle. Indications for admission for isolated gunshot wounds to the foot or ankle included vascular injury or skin compromise requiring immediate open reduction. Most of our patients did not require internal or external fixation of their fractures.

In a review of lower-extremity gunshot injuries, including the foot and ankle at a level-1 trauma center in Jamaica by Abghari et al,[9] there were 148 gunshot injuries over 2 years. The Abghari et al study found that these patients had worse functional scores at final follow-up than the general population.

The velocity of the gunshot was rarely recorded on our patient charts. Most patients with low-velocity gunshot injuries can be treated as outpatients with surgical indications as appropriate.[10,11] Many high-energy injuries require formal operative debridement with fracture fixation and wound coverage techniques if considerable soft-tissue damage occurs.[12]

Many of the patients in our series tested positive for illicit substances or alcohol. Alcohol misuse has been shown to be associated with firearm violence and risk behaviors.[12] Controlled substances have also been associated with gun violence, interpersonal violence, and suicide.[13]

Three of our patients (6.3%) had arterial injuries, one to the dorsalis pedis, one to the tibialis anterior, and one to the superficial femoral artery owing to a separate gunshot injury to the thigh. Only one of these patients required a revascularization procedure. It has been reported that in the lower extremities, gunshot injuries more frequently lead to arterial injury than in the upper extremities.[14] Sadjadi et al[15] recommends obtaining ankle brachial indices (ABIs) on all hemodynamically stable patients with lower-extremity gunshot injuries. If initial ABIs are over 0.9, patients can be safely discharged home with 100.0% positive predictive value and 98.0% negative predictive value in their study.[15] In our series of patients, ABIs were not routinely recorded. Since most gunshot injuries in our series were distal to the ankle, ABIs may not always be necessary. They should be considered in more proximal injuries.

Various studies have supported the use of antibiotics in lower-extremity gunshot injuries to prevent infection.[16-22] We had three infections in our series, all bony injuries without neurovascular or other considerable injuries. All three patients received intravenous cefazolin in the emergency department and bedside irrigation and debridement. One patient was brought to the operating room for formal irrigation and debridement and required two further operative irrigation and debridements with wound vacuum placement for methicillin-sensitive *Staphylococcus aureus* infection with wound dehiscence. His wound eventually granulated in after he completed his intravenous and oral antibiotic regiment. Another patient informed us that he was treated at an outside hospital for methicillin-resistant *Staphylococcus aureus* infection with intravenous antibiotics. The third patient had some early signs of superficial cellulitis at their 2-week follow-up, in which oral cephalexin was prescribed. The patient did not return to clinic. Most of our patients were treated with at least one dose of intravenous antibiotics with gram-positive coverage. They were discharged on 5 to 14 days of oral gram-positive antibiotic coverage. A few patients were also discharged with ciprofloxacin to cover gram-negative organisms. Standardized procedures to recommend only gram-positive coverage under most circumstances may be indicated in the treatment of gunshot injuries to the foot and ankle.

Limitations of this retrospective review include its retrospective nature, possible errors in charting, and lack of significant follow-up. If the orthopaedic service

was not consulted, which can happen when there is no fracture or concern for neurovascular or tendon injury, they were not included in the study. We believe that our list captures most patients with this injury, but we may have missed some soft-tissue-only injuries. Many patients did not follow-up in the outpatient clinic, and there was a large range of follow-up length for patients that did come back. We were limited by data available in patient records.

Presented here is the largest case series to our knowledge of foot and ankle gunshot injuries, associated injuries, treatment, and outcomes. Most patients were treated with bedside irrigation and debridement, a dose of intravenous antibiotics, immobilized in a splint or hard-soled shoe, and discharged on oral antibiotics with gram-positive coverage. Of the patients that followed up, most of them did well with excellent clinical outcomes.

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