

# Gunshot Wounds in the Lower Extremity

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- ▶ **Abstract:** A high number of gunshot injuries occur in the lower extremities, making it likely that the foot and ankle surgeon will encounter these wounds if involved with lower extremity trauma care. An understanding of current thought processes and standards of care in relationship to high and low velocity wounds is imperative for the surgeon to appropriately manage these unique and challenging traumatic injuries. Also important are the legal considerations relating to evidence collection, interaction with law enforcement, and witness testimony. It is the intent of this article to provide the foot and ankle surgeon with standardized guidelines for the treatment of gunshot trauma in the lower extremities, as well as guidelines for appropriate documentation and evidence handling.

**Key words:** Gunshot Wounds, Foot & Ankle Trauma, Gunshot Evidence, Lower Extremity Gunshots

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## Introduction

With more than 65 million handguns in the United States alone, the potential for encountering gunshot wounds is fairly high. Firearms remain the 2<sup>nd</sup> leading cause of injury-related death after automobile accidents, with most gunshot wounds being caused by handguns. The extremities are the most commonly struck areas of the body, occurring in 46% of assaults and 72% of unintentional injuries.[1,2] A high number of gunshot injuries occur in the lower extremities, making it likely that the foot and ankle surgeon will encounter these wounds if involved with lower extremity trauma care. Gunshot wounds in the foot & ankle are frequently accidental or self-inflicted. Due to the many variables surrounding gunshot trauma, an awareness and understanding of gunshot wounds by the foot and ankle specialist is

essential to provide effective care. Also important are the legal considerations relating to evidence collection, interaction with law enforcement, and witness testimony. Following surgical management, the surgeon may be called upon during criminal or civil proceedings, either through witness testimony or expert opinion. It is the intent of this article to provide standardized guidelines for the treatment of gunshot trauma in the lower extremities, as well as guidelines for appropriate documentation and evidence handling.

## Ballistics

Ballistics refers to the physics of the projectile as measured by its mass, velocity, configuration, and shape. These factors affect tissue damage and wound characteristics. The projectile (bullet) transfers its kinetic energy (KE) to the body upon impact. Using the laws of physics,  $KE = \frac{1}{2}mv^2$  [ $m$  = mass (kg)] [ $v$  = velocity (m/s)]. Based on this formula, increase in weight results in only a linear and direct change in the energy (potential damage) inflicted by

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the bullet; whereas an increase in velocity is causative of an exponential increase in the kinetic energy of the bullet. This accounts for the increased wounding power of high-velocity firearms (military-type assault weapons) in comparison to low-velocity (civilian) handguns. [1,3,4] Wound severity is determined by the amount of energy absorbed by the tissues struck, with the degree of energy absorption being determined by bullet velocity, area of tissue exposed to the bullet, and the features of the tissues struck. High-velocity projectiles may cause extensive injury if striking a substantial musculoskeletal structure (i.e. bone, joint, artery), but may inflict less damage if entering and exiting without striking major structures; as compared to a low-velocity projectile striking a major structure.

Yaw equals the deviation of the longitudinal axis of the bullet from its line of flight. Most rifle and handgun barrels are rifled. This causes an increase of axial bullet spin, with a resultant decrease in bullet yaw. At contact, the bullet may tumble or yaw. In such cases the properties of the wound are significantly affected. In cases of bullet tumble or yaw, the greatest amount of tissue destruction occurs when the bullet is 90 degrees to its trajectory (i.e. 90° yaw). [1,4]

Tissue damage is related to the degree to which the tissues absorb the energy of the bullet. Greater slowing of the bullet causes more energy transfer to the tissues, resulting in greater tissue damage. This process of absorption causes both direct and indirect injury. The bullet initiates direct injury via fracture, heat, direct contusion, and laceration. Indirect injury is the area of contusion adjacent to the primary injury tract and from the area of concussion. [1,4,5]

### Wound Types

There are three basic types of gunshot wounds. These types include high-velocity projectile (>2000 ft. /sec.), low velocity projectile (<2000ft. /sec.), and shotgun wounds (numerous projectiles of varying size.) [1,4,6] Entry wounds are generally smaller than exit wounds. Entrance wounds are usually circular or oval in shape and a reddened area (abrasion ring) may be visible surrounding the wound. Furthermore, entrance wounds and the surrounding tissues, may be indicative of firing distance. In contrast, exit wounds are usually larger than the size of the bullet, there is no abrasion ring present, wound shape may

be circular or very irregular, and firing distance is generally indeterminate.

Gunshot wound management varies based on wound type. Wound severity varies with weapon caliber, projectile type, and firing distance. Close-range, high-velocity gunshot wounds can result in devastating impairment.

Low-velocity gunshot wounds generally result in soft tissue injury limited to course of the bullet and in general do not have an extensive zone of damage around the bullet track. Low-energy wounds can often be managed without extensive reconstruction.



Fig.1 – Low velocity entrance gunshot wound to medial ankle.

In contrast, high-velocity gunshot wounds produce both direct and indirect injuries. Additionally, if the bullet deforms or flattens as it enters, an increase in direct damage can be expected as a result. When bullets fragment or strike articles of clothing the larger area generated also causes more direct trauma to the surrounding tissue, leading to a more rapid transfer of kinetic energy to the tissues in the path of the bullet. Also frequently seen in high-velocity gunshot trauma is cavitation. Significant indirect damage may be produced to surrounding tissues due to cavitation from the high-velocity projectile. This occurs, in part, from the radial dissipation of energy as the projectile travels through the tissue structure. [1,2,4,6]

Cavitation is a consequence of the displacement and expansion of the tissues caused by the bullet, followed by the temporary cavity produced maximally at 2 to 3 ms after the passage of the bullet. This effect may create a cavity

that can be as large as 30 times the size of the bullet. [1,6] A vacuum pressure can be produced after the passage of the bullet, which creates a suction phenomenon. This suction may bring clothing and other foreign matter deep into the wound. Maximum cavitation generally occurs deep within the wound. [1,4] Due to the extensive tissue damage subsequent to the cavitation phenomenon, these wounds often result in amputation within the foot and ankle.

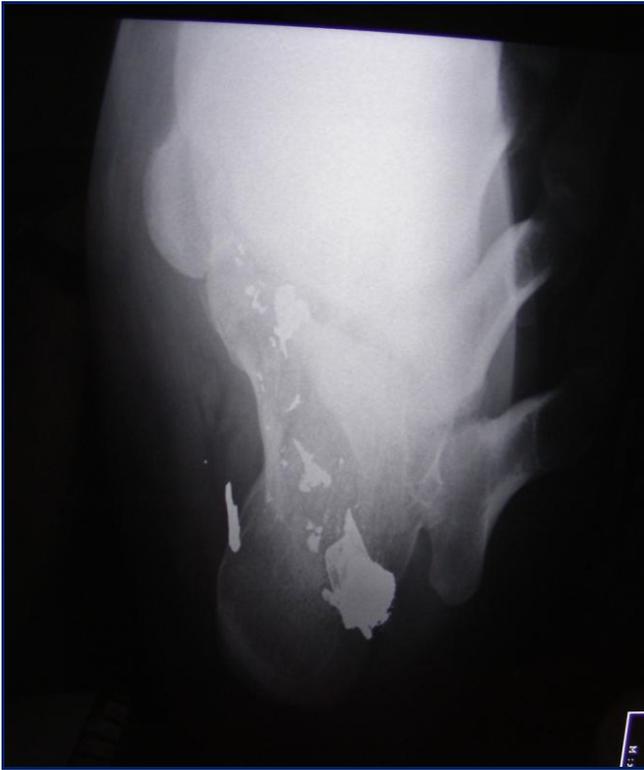


Fig. 2 – Radiograph showing fragmentation with retained projectile along projectile path from medial to lateral in low velocity gunshot injury.

Shotgun wounds have unique characteristics affected by shotgun gauge, pellet mass and size, cylinder type, and firing distance. There is a significant transfer of kinetic energy in these wounds when pellets fail to exit.

Furthermore, close range shotgun wounds may result in tissue damage, which is comparable in nature to high-energy projectile wounds. [1,2,7]

With shotgun wounds, a high incidence of compartment syndrome has been reported. Based on current literature, the surgeon may consider prophylactic fasciotomy in the presence of significant tissue damage due to this concern. [8,9] Due to the ballistic nature of shotgun firearms and variability of projectile types, it is important to note as shotgun firing distance increases, there is a rapid decrease in wounding potential. This will most likely dictate acute

treatment or the necessity for aggressive prophylactic modalities such as fasciotomy.

### Initial Assessment and Treatment

Current practitioners are well aware of the importance of comprehensive history and physical examination in order to provide quality patient care. The initial history and physical exam is critical for the acute care of gunshot injuries, not only for preservation of life and limb, but for evidentiary documentation and possible civil or criminal court proceedings. Pertinent history includes position at time of injury, gun type, projectile type and caliber, and firing distance. Initial physical examination should include inspection of clothing, wound inspection (of entrance and exit sites), establishment of the degree of tissue loss, and vascular and neurologic assessment. In the acute care setting it is vital that the need for either vascular or neurologic specialty intervention be assessed and initiated quickly if required.

Initial Treatment must include stabilization of the patient's vital signs, along with treatment for shock and potential fluid loss. Copious wound irrigation with normal saline should be initiated, followed by the application of a sterile dressing. Topical antibacterial agents may be added if desired. Splinting of the extremity should be performed as necessary for stabilization and tetanus prophylaxis should be initiated. [3,4,10,11]

### Wound Classification

There are different classification systems in use at the present time with application to gunshot trauma. Two such classifications are the Ordog and the Gustillo-Anderson classification systems. The Ordog Classification is widely accepted for use in civilian bullet injuries. This system grades injuries from 0 – 8 based on type. Using this system, Type 0 - no physical injury to the extremity, Type 1 - contusion only, Type 2 – abrasions, Type 3 – blast injuries, Type 4 – blast & penetration injuries, Type 5 – one penetration injury, Type 6 - complete perforating injury, and Type 7 - combined penetration and embolization. [12] Relating to open fractures, and also referenced frequently in relationship to gunshot wounds, is the Gustillo and Anderson Classification. This classification uses six types relating to wound size and cleanliness, along with structural exposure and tissue loss.

Type I – wound less than 1cm, minimal soft tissue injury, clean in nature; Type II – wound greater than 1cm, moderate soft tissue injury, no large flaps or avulsion; Type III – High energy, extensive soft tissue damage or loss; Type IIIa – adequate bone coverage despite soft tissue injury; Type IIIb – osseous exposure, soft tissue loss, and periosteal stripping; and Type IIIc – associated arterial injury with repair required. [2]

### Wound and Fracture Care

Fractures that result from gunshot wounds should be considered to be open fractures. Using the Gustillo-Anderson system, low-velocity gunshot wounds less than 8 hours old may be classified as Type I open injuries. Gunshot wounds open for greater than 8 hours should be considered Type II open injuries. [1,2]

The hallmark of Type I low-velocity gunshot trauma is surface debridement and cleansing, along with application of a sterile dressing. Type I stable fractures, in the presence of a normal neurovascular exam, generally require only a splint, cast, or brace for stabilization. Unstable Type I fractures may require additional stabilization (i.e. internal, external, or hybrid fixation). [1,2,13]

Low-velocity Type II wounds are generally treated with delayed closure. Initial debridement and wound excision may be performed with a plan for delayed closure in approximately 5 days following. The wound may be closed when no evidence of infection exists and tissue is viable. Of note, IV antibiotics have been deemed the most important factor in reducing infection rate, specifically in Type II or higher wounds. [10,14] While internal or external fixation may be employed for stabilization, external fixation is favored for initial management of unstable Type II or Type III fractures. This allows for adequate wound care, vascular reconstruction, and wound coverage. After wound stabilization and coverage has been achieved, definitive fracture treatment may be fixated by internal or external means. [15,16,17]

Due to the significant trauma created by high-velocity gunshot wounds, more attention is demanded in comparison to low-velocity wounds. Acute treatment protocols for high-velocity projectile wounds stress wound decompression, debridement of devitalized tissues, adequate wound drainage, avoidance of wound closure, and internal or external fixation. [1,15]



Fig. 3a – High velocity entrance wound to lateral lower extremity, exhibiting relatively circular characteristics. (top) Fig. 3b – Exit wound to lateral leg with significant tissue loss. (bottom)

Shotgun wounds require a treatment approach similar to those used in high-velocity projectile wounds. These principles include sharp & early debridement, possible extensive fasciotomy, pulse lavage, external or internal fixation, arteriography and neurologic assessment, delayed wound closure, negative pressure wound therapy (NPWT), and advanced reconstructive procedures. [3,9,18,19] Both high-velocity projectile and shotgun wounds have potential for significant contamination, along with an increased risk of clostridium infection. These should not be primarily closed in order to decrease the risk of gas gangrene. [3,4,17,20]

In the presence of severe tissue loss, regardless of gunshot type, vascular injury should be assessed. Vascular injury can be via direct or indirect injury (i.e. projectile contact or

cavitation). Arteriography may be used to evaluate injury extent. Duplex Doppler ultrasound is also a viable option for vascular evaluation, as some literature has indicated ultrasound to be as sensitive as angiography with 95% sensitivity and 99% specificity reported. [4,16,17] Neurological injury should also be assessed in these cases and may also occur via direct or indirect forces. Most neurological injuries are found to be compressive (neuropraxia) and usually recover without exploration or repair. Direct nerve injury (neurotmesis) has been linked to poor outcomes and has been associated with a permanent loss of nerve function. [1,21]

### Legal Considerations

By nature, gunshot wounds have a high potential for evaluation by law enforcement. The possibility of criminal prosecution or civil litigation is extremely high. The appropriate assessment of the circumstances surrounding the wound, patient interview, evidence handling, and medical documentation may prove paramount in facilitating accountability, either by the patient or other offending party if present. The surgeon will likely be in a position to not only handle evidence directly, but may be called upon to provide expert opinion or provide witness testimony in court proceedings.

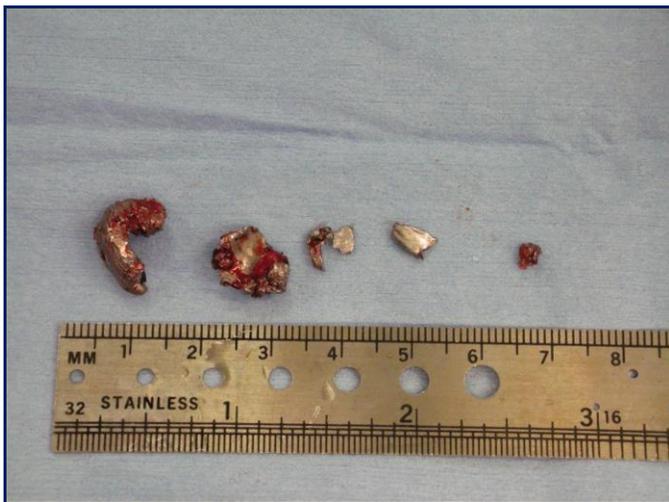


Fig. 4 – Recovered projectile showing significant deformity and fragmentation. (Note measurement for evidentiary documentation.)

It is of the utmost importance that the surgeon has at least a basic understanding of proper evidentiary technique and evidence handling. If questions exist regarding evidentiary requirements, investigators should be consulted prior to collection if possible. Pre and post-debridement

photographs should be taken. If removing clothing, do not cut clothing through bullet holes. Bullet fragments, shotgun wadding, pellets, and clothing articles should be photographed, documented, and collected. An appropriate chain of custody must be maintained until such time as the evidence is turned over to investigators. Documentation should include a complete description of powder burns, abrasions and tattooing, affected clothing, entry and exit wounds, bullet disposition, and treatment.

### Discussion

Gunshot wounds present a unique challenge for the Foot and Ankle Surgeon. Initial assessment and treatment may range from the very simple to the extremely complex. Due to the highly variable nature and uniqueness of each wound, along with the many combinations of firearms and projectiles, a stepwise approach will assist with not only acute management, but during the weeks and months following the event. Low-velocity wounds can frequently be managed without extensive reconstruction; however, high-velocity and shotgun wounds frequently require a multidisciplinary approach. Advanced Trauma Life Support (ATLS) guidelines should be followed, wounds should be evaluated on a case by case basis, and fractures that result from gunshot wounds should be treated as open fractures. [1,16] While low-velocity Gustillo-Anderson Type I stable wounds may often be closed primarily, delayed closure is indicated in low-velocity Type 2 wounds, along with high-velocity and shotgun wounds. [1,4,11,21] Neurovascular assessment is critical upon initial examination, along with appropriate referral as indicated. Additionally, the surgeon should possess a basic understanding of evidence handling and documentation, from the time of initial interview through the peri-operative period.

### References

1. Holmes, G. Gunshot Wounds of the Foot. CLINICAL ORTHOPAEDICS AND RELATED RESEARCH. Number 408, pp. 86–91 (2003).
2. Gustillo & Anderson. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones. J Bone Joint Surg. 58A:453–458, 1976.

3. Marinović et al., Gunshot injury of the foot: treatment and procedures--a role of negative pressure wound therapy. *Coll Antropol*. 2013 Apr;37 Suppl 1:265-9.
4. Bluman et al., War Wounds of the Foot and Ankle: Causes, Characteristics, and Initial Management. *Foot Ankle Clin N Am* 15 (2010) 1–21 doi:10.1016/j.fcl.2009.11.004.
5. Haag, L., The Forensic Aspects of Contemporary Disintegrating Rifle Bullets. *Am J Forensic Med Pathol & Volume* 34, Number 1, March 2013
6. Yildiz et al., High-Velocity Gunshot Wounds of the Tibial Plafond Managed With Ilizarov External Fixation: A Report of 13 Cases. *Journal of Orthopaedic Trauma*. Vol. 17, No. 6, pp. 421–429 (2003).
7. Haag, L. Range of Fire Determination From the Pseudostippling of Skin by Shotgun Buffer Material. *Am J Forensic Med Pathol & Volume* 34, Number 1, March 2013.
8. Grossman et al. Gunshot wounds below the popliteal fossa: A contemporary review. *The American Surgeon*; Apr 1999; 65, 4; *ProQuest Nursing & Allied Health Source* pg. 360.
9. Hoekstra et al. The management of large soft-tissue defects following close range shotgun injury. *J Trauma* 30:1489-1493, 1990.
10. Simpson et al., Antibiotic Therapy in Gunshot Wounds. *CLINICAL ORTHOPAEDICS AND RELATED RESEARCH* Number 408, pp. 82–85 (2003)
11. Weinstein et al., Low velocity gunshot wounds result in significant contamination regardless of ballistic characteristics. *Am J Orthop (Belle Mead NJ)*. 2014 Jan;43(1):E14-8.
12. Ordog et al. Extremity gunshot wounds Part 1. Identification and treatment of patients at high risk of vascular injury. *J Trauma* 1994;36:358-68.
13. Marcus et al. Low velocity gunshot wounds to the extremities. *J Trauma* 20:1061–1064, 1980.
14. Arunkumar et al., Management challenges in a short-range low-velocity gunshot injury. *Ann Maxillofac Surg*. 2012 Jul-Dec; 2(2): 200–203.
15. Bek et al., Ankle arthrodesis using an Ilizarov external fixator in patients wounded by landmines and gunshots. *Foot Ankle Int*. 2008 Feb;29(2):178-84.
16. Hampton OD: The indications for debridement of gunshot bullet wounds of the extremities in civilian practice. *J Trauma* 1:368–372, 1961.
17. Sadjadi et al., Expedited Treatment of Lower Extremity Gunshot Wounds. *J Am Coll Surg* 2009;209:740–745. © 2009.
18. Liu et al., Two different flaps for reconstruction of gunshot wounds to the foot and ankle in a child. *Journal of Pediatric Surgery* (2012) 47, E13–E17.
19. Hartl WH, Klammer HL: Gunshot and blast injuries to the extremities. *Acta Chir Scand* 154:495–499,1988.
20. Wang et al. [Surgical treatment of shotgun injuries of the sciatic nerve]. *Zhonghua Wai Ke Za Zhi*. 2004 Jan 22;42(2):81-3.
21. Seery et al., Effects of Metal Fragments on Nerve Healing in Extremity Injuries Using a Rat Peroneal Nerve Model. *J Am Coll Surg*. Vol. 209, No. 2, August 2009.