Combat Foot and Ankle Trauma

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Injury to the lower extremity is common in the current conflicts, often severely affecting the foot and ankle. Secondary to continued surgical advances, many lower extremities are able to undergo limb salvage procedures. However, scoring systems still do not reliably predict which patient will be best served with an amputation or limb salvage. Because of this, limb salvage should be attempted whenever possible, awaiting definitive treatment at a later time. Treatment begins at the time and location of injury with aggressive debridement, with reduction and external fixation of fractures when possible. Serial debridements are often necessary until the traumatic wounds are ready for coverage or closure. Forefoot injuries are treated with varying techniques depending on the location of the injury. Amputation of toes and/or flap coverage is often necessary secondary to tenuous soft tissues. Midfoot injury patterns are complex, possibly requiring arthrodesis, antibiotic spacers, soft tissue coverage, and thin-wire ring external fixation. Hindfoot or calcaneal injuries are often the most difficult to treat, requiring extraordinary efforts to salvage a viable limb. Early reduction of the remaining fragments and percutaneous fixation are often followed by arthrodesis of the subtalar joint. Fractures of the calcaneus requiring free soft tissue coverage frequently lead to amputation. Blast injuries to the lower extremity are severe injuries. They are frequently associated with fractures to multiple levels. Early elective amputation at the level V treatment center is frequently performed. When limb salvage is performed, basic principles must be followed to optimize treatment. (Journal of Surgical Orthopaedic Advances 19(1):70–76, 2010)

Key words: amputation, ankle, calcaneus, foot, fracture, metatarsal, talus

Since the onset of combat in Iraq and Afghanistan there have been more than 16,000 casualties that have been unable to return to duty due to their injuries. Reports on the characteristics of the combat injured from this current conflict have indicated that up to 53% of combat casualties have sustained a lower extremity injury (1–6). The magnitude and severity of the foot and ankle blast injuries from this conflict are profound. The orthopaedic surgical care for the severely injured lower extremity is unique and must be approached in a methodical yet individualized manner to ensure the optimal outcome. In this review, a few unique aspects of the care of the combat blast-injured foot and ankle are discussed.

Limb Salvage Versus Amputation

Significant progress has been made in the orthopaedic, plastic, and vascular surgical fields, making the salvage of even severely mutilated limbs possible. In the combat setting, early consideration of limb salvage versus amputation occurs soon after the initial blast injury in field hospitals. Unfortunately, scoring systems designed to aid trauma surgeons in the difficult task of deciding limb salvage versus amputation have routinely failed to prove valid or reliable in the literature (7, 8). As such, the only clear, yet still debatable, indications for amputation are anatomic transection of the tibial nerve and or an irreparable vascular injury with an ischemic distal extremity (9).

Despite the lack of an objective and reliable scoring system to predict the outcome following limb salvage or amputation, the following principles may prove useful to the combat surgeon making this difficult decision. The first principle when dealing with the combat-wounded patient is that early limb salvage should almost always be attempted as long as the salvage effort does not negatively affect the patient's overall health. This approach allows the time necessary for an experienced team of multidisciplinary reconstructive surgeons to understand the extent of an injury and make well informed recommendations. This also allows a patient and his or her family the ability to conceptualize the injury and potential treatments as well as learn the risks and benefits of limb salvage or amputation. Finally, it may allow for preservation of amputation length by maintaining maximal soft tissue and bone length until the time of definitive treatment.

It is important to recognize the increased lower extremity amputation rate in the presence of multilevel

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The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Army, Department of Defense, or the United States Government.

Received for publication September 22, 2009; accepted for publication October 7, 2009.

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1548-825X/10/1901-0070$22.00/0

segmental foot and ankle injuries. In addition, the combination of foot/ankle fractures with an ipsilateral open tibia fracture leads to increased risk of amputation (10, 11). In patients presenting with these multilevel ipsilateral open fractures, early consideration should be given to amputation after arrival at the definitive military treatment facility. Finally, it is imperative to remember that an amputation should not be considered as a failure of treatment but as a reconstructive procedure that is performed in attempts to provide for an improved functional outcome for the specific patient.

Initial Care

Aggressive management of the open fractures and soft tissue wounds begins in theater. Serial irrigation and debridement procedures are performed throughout the evacuation chain. Early external fixation of open ankle or distal tibia fracture is usually indicated to stabilize the fractures and prevent secondary soft tissue compromise. With isolated foot trauma, well padded splinting is frequently performed. If the fracture pattern is amenable, external fixation is provided in an attempt to avoid further soft tissue injury, while still allowing for easy wound access and surveillance.

Despite attempts to prevent secondary injury, heel pressure ulcers do occur and present a significant challenge once patients have arrived at definitive treatment facilities. These occur due to a combination of factors, likely to include decreased tissue perfusion from large or small vessel injuries, sensory deficits (either from nerve injury, nerve blocks, or epidurals provided for pain control), and prolonged evacuation time. Acknowledgment of the frequency of this complication as well as continued surveillance throughout the evacuation chain is necessary to decrease the incidence of this occurrence. Unloading of the heel should be a constant goal of the physicians and nurses caring for the injured patients. In the presence of an external fixator, the liberal use of a “kickstand” adequately unloads the heel and should be constructed (12, 13).

Serial irrigation and debridement every 48–72 hours has become the accepted wound management protocol at most military treatment facilities. Large bone or soft tissue defects are frequently filled with antibiotic-impregnated cement spacers or beads in order to help control local wound bacterial levels and to decrease the dead space. Negative pressure wound therapy (V.A.C. Therapy, KCI Licensing, Inc., San Antonio, TX) is used in most wounds between operative procedures. After the wound appears stable and the patient shows no systemic signs of an infection, then delayed primary closure, skin grafting, or vascularized soft tissue flap coverage is performed. This frequently occurs several days to weeks after the initial injury. At this time, a transition from the temporary monoplanar external fixator to a ring external fixator or other definitive fracture treatment is performed. Once wound closure has been successful and infection has been avoided, then consideration for delayed bone grafting of bone defects can begin. This usually occurs 6–12 weeks following the initial injury.

Specific Injury Patterns

Forefoot Injuries

Forefoot injuries are usually associated with distal soft tissue loss and the soft tissue injury at this level usually determines the treatment. In most instances, the degree of toe injury is severe enough that partial or complete toe amputation is usually indicated. Amputation of the third and fourth toes usually can be performed relatively simply with good outcomes. The amputation of the first, second, and fifth toes is slightly more complex. With amputation of the fifth toe, a prominent metatarsal head results and the lateral condyle of the metatarsal should be removed in order to taper the foot and prevent a painful prominence on the lateral side of the foot. With removal of the second toe, there is a loss of lateral support to the great toe and this can cause a severe hallux valgus deformity. In this situation, a ray amputation through the proximal metaphysis of the second toe should be performed. The resulting gap between the first and third toes usually approximates itself and the hallux valgus deformity is avoided (14).

The great toe is unique and more problematic than other forefoot injuries. The great toe is important during the push phase of the gait cycle and its loss may severely disrupt normal gait. In the situation where a great toe injury is present, the soft tissue injury will again likely dictate treatment options. If the soft tissues allow for forefoot salvage, a delayed reconstruction of the great toe should be considered. Early bone grafting is not recommended in the combat wounded, but can usually be safely performed 4–6 weeks after definitive soft tissue coverage is obtained. An antibiotic-impregnated polymethyl methacrylate (PMMA) spacer can be inserted to maintain soft tissues at length prior to reconstruction. Various methods, including vascularized and nonvascularized autograft with metatarsophalangeal fusion as well as allograft bone, have all been used for first toe reconstruction (15, 16).

Metatarsal bone loss is also frequently seen and the management differs with regards to the medial and lateral columns. In the mobile lateral column of the foot, a patient may do well with a partial foot amputation and a lateral shoe filler. A partial foot amputation in the presence of severely comminuted or segmental loss of the lateral column in this situation will often allow for the soft tissue coverage of a large dorsal foot wound. The medial column of the foot should, however, be reconstructed because it is more vital to the normal gait pattern. Both autograft and allograft structural and/or cancellous grafting have all been utilized (17). In bone defects greater than 1 cm, a structural graft is usually utilized. A benefit of the vascularized graft is a quicker time to incorporation and remodeling (18) (Fig. 1).

Midfoot Injuries

Blast injuries that affect the midfoot often result in highly complex injury patterns with severe contamination and soft tissue compromise. In addition to the traumatic wounds, they are frequently complicated by fasciotomy incisions that provide additional difficulty achieving soft tissue coverage. Myerson has previously outlined the important concepts for midfoot reconstruction as well as the risk factors for treatment failure. He described the importance of identifying the full extent of the injury as well as the goal of obtaining an open reduction to restore normal anatomy. The risk factors for failure of treatment include residual postoperative metatarsal angulation or Lisfranc-type injuries with step-off greater than 2 mm (19, 20).

For these reasons, open reduction and internal fixation or primary arthrodesis is the standard treatment for severe tarsometatarsal joint fracture dislocations in a civilian setting. Due to the severe contamination of war wounds as well as the inability to provide early coverage to the blast-induced wounds, the previously discussed staged approach to the soft tissue management and wound closure followed by conversion to ring external fixators has become common among military orthopaedic surgeons worldwide (21–25) (Fig. 2).

The use of the ring external fixator has a number of advantages over standard open reduction and internal fixation techniques. The avoidance of additional surgical insult to the soft tissues and the absence of hardware

FIGURE 1 (**A** and **B**) Medial column injury with comminuted segmental defect of the first metatarsal with an overlying soft tissue defect. External fixation applied to maintain medial column length. (**C**) Soft tissue coverage with fasciocutaneous flap and temporary Integra Bilayer Matrix Wound Dressing. (**D**) Final radiograph showing union of the first metatarsal fracture. (**E**) Final gross appearance of foot after split-thickness skin grafting over Integra and a small portion of the fasciocutaneous flap.

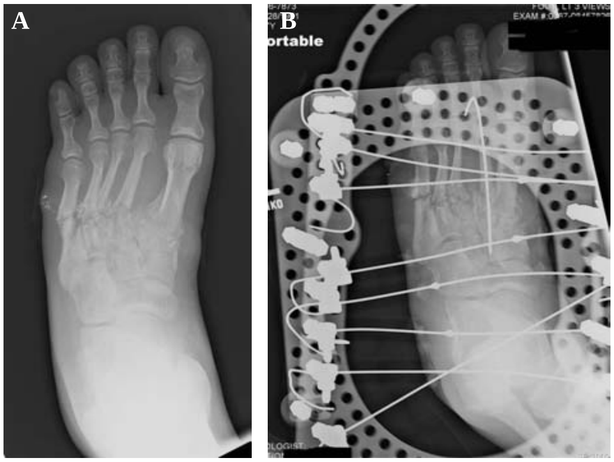

FIGURE 2 (**A**) Open comminuted tarsometatarsal joint fracture dislocation. (**B**) Radiograph after a closed reduction and percutaneous pinning as well as placement of a ring external smooth wire fixator.

placed within the bacterially colonized wounds are benefits of this treatment. Additionally the use of the ring fixator allows for a near-anatomic reduction of the midfoot complex, while allowing for immediate ankle range of motion and early weightbearing.

Injuries more proximal in the foot sometimes lead to medial or lateral column shortening and may result in abnormal foot alignment. Significant shortening to the medial or, more commonly, the lateral column frequently needs to be addressed. A similar approach using ring external fixation can be used with these injuries; however, a monolateral external fixation system will often suffice to hold the column out to length. Antibiotic-impregnated PMMA spacers are usually used with delayed bone grafting of segmental defects in order to restore both medial and lateral column length (Fig. 3).

Hindfoot Injuries

Open Calcaneus Fractures

The open calcaneus fracture is a daunting injury associated with devastating potential complications. The restoration of normal hindfoot function can prove difficult with closed calcaneal fracture management and is explicitly more complicated in the presence of traumatic lacerations or soft tissue loss. Sanders reviewed open calcaneus fractures and suggested that Gustillo type I and type II fractures associated with medial wounds could safely be treated with open reduction and internal fixation. He concluded, however, that type II and type III fractures with wounds in other locations should not be treated acutely with internal fixation because of high rates of osteomyelitis and frequent subsequent amputations (26).

FIGURE 3 (**A**) Lateral column injury with comminuted fractures of the base of the fifth metatarsal and the cuboid. External fixation in place to maintain lateral column length. (**B**) Three-dimensional CT depiction of lateral column injury. (**C**) Oblique radiograph of healed fractures. (**D**) Lateral radiograph of healed fractures.

Blast-induced open calcaneus fractures are even more destructive injuries. They are frequently complicated by fractures to both extremities with associated nerve and vascular injuries. An "outside in" mechanism of soft tissue damage predominates and the bone comminution is frequently so severe that the subtalar joint surface is often determined to be nonreconstructable. A staged protocol for these open calcaneus fractures is mandatory in order to ensure the optimal outcome.

In the early treatment of these fractures, the soft tissue status may dictate consideration for early amputation. Anecdotally, we have noted that most patients who undergo flap reconstruction for an open calcaneus fracture end up with a delayed elective amputation due to poor functional outcome or chronic infection. We thus strongly consider amputation in the presence of an open calcaneus fracture that will require flap coverage. If salvage is chosen, the patient should understand the potential risks and benefits as well as the predicted potential outcome with limb salvage.

The initial stages of management include aggressive standard open wartime fracture management. Upon arrival at the definitive treatment facility or previously along the evacuation route, a minimally invasive percutaneous reduction and pinning technique is often performed to restore a more anatomic alignment of the calcaneus. Following this, serial irrigations and debridements and negative pressure wound therapy are utilized until wound coverage is achieved either by delayed primary closure, skin grafting, or flap coverage.

Once stable soft tissue coverage is achieved, delayed consideration for open reduction and internal fixation is given using a lateral approach to the calcaneus. At the time of surgery, a primary subtalar arthrodesis is performed if comminution or articular bone loss precludes an anatomic reconstruction of the subtalar joint. Specific wound characteristics are the primary concern when planning this procedure and, if wound location will not allow an open approach, a planned osteotomy and subtalar fusion are usually performed at a later date.

Talus Fractures

Open talus fractures may be initially stabilized with the use of smooth Kirschner wires upon arrival to the definitive treatment facility if the soft tissue wounds preclude early open reduction and internal fixation. They are then usually treated with open reduction and internal fixation when the soft tissue is amenable.

Talar neck bone loss can be accommodated by open reduction and plating techniques that maintain overall length and alignment of the talar neck. Significant osteochondral bone loss in the tibiotalar or the subtalar joints can present a serious challenge. Subtalar or tibiocalcaneal fusions may be the only treatment option in this situation. Fortunately, the isolated talus fracture with substantial bone loss is a rare injury and in most instances is accompanied by multiple ipsilateral fractures and soft tissue loss that frequently make amputation the optimal treatment.

Despite the severity and rarity of significant talar bone loss, limb salvage may sometimes be possible. In the civilian literature, tibiocalcaneal fusion has been performed with the use of the Ilizarov frame for cases of severe talar avascular necrosis or chronic osteomyelitis. The use of the Ilizarov frame allows for concomitant limb lengthening, which decreases the limb discrepancy that frequently accomplishes a tibiocalcaneal fusion (27, 28) (Fig. 4).

Soft Tissue Coverage

The soft tissue envelope about the foot and ankle is tenuous with minimal subcutaneous fat. The neurovascular and tendinous structures are superficial and are often left exposed following a traumatic injury. It is not uncommon to have difficulty primarily closing traumatic wounds in this location. Fasciocutaneous, muscle, and free flaps are

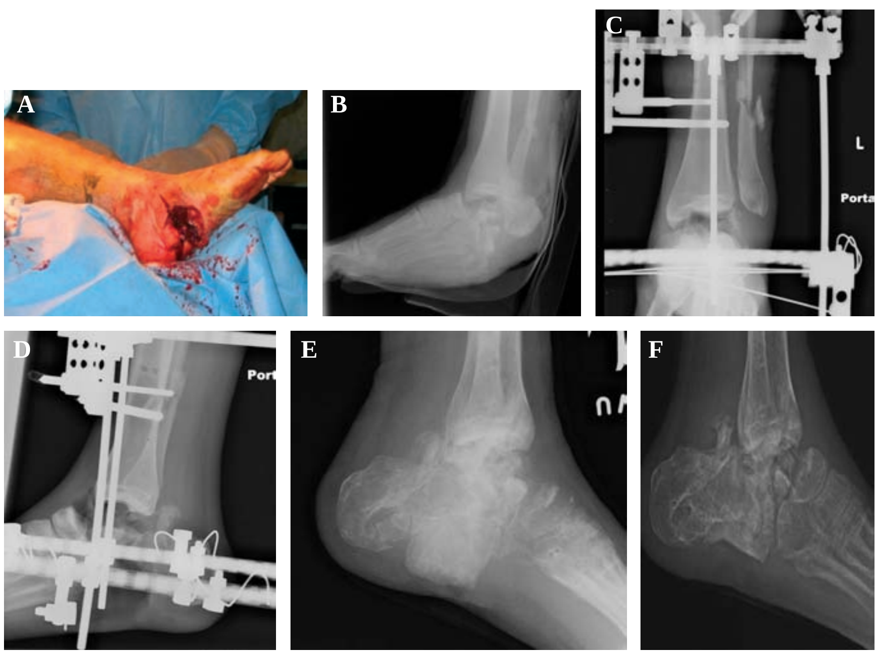

FIGURE 4 (**A**) Open comminuted calcaneus fracture, associated with ipsilateral talus fracture with severe bone loss. (**B**) Lateral radiograph depicting comminuted calcaneus, fibula, and talus fractures with severe bone loss. (**C**) AP radiograph with spanning ring external fixator maintaining length. Lengthening of the fibula was performed using half-pins and threaded rods. Autograft was harvested from the patient's left femur using the Reamer Irrigator Aspirator System (Synthes). Allograft, reamings, and bone morphogenic protein were utilized in attempted tibiocalcaneal fusion. (**D**) Lateral radiograph showing maintenance of limb length. (**E**) Patient went on to a pseudoarthrosis of the attempted tibiocalcaneal fusion. Lateral radiograph demonstrating active plantarflexion and prominent calcaneal exostosis. (**F**) Lateral radiograph after calcaneal exostectomy.

frequently necessary to cover vital tendinous, neurovascular, or bony structures. Classic teaching has described that flap coverage provided outside of the first 7 days following injury has been associated with increased infection rates and higher rates of flap failure (29, 30). Despite this historic tenet, Kumar et al. (31, 32), in his review of combat wounds that underwent flap reconstruction in the subacute time period (7 days to 3 months), supported the concept that delayed flap coverage can be safely achieved with good success. Limited civilian literature has also supported the safety of performing flap coverage during this time period (33, 34). In Kumar's analysis of lower extremity open fractures requiring flap reconstruction, the most commonly used flaps to the foot and ankle included free rectus abdominus, free anterolateral thigh, and pedicled dorsalis pedis flaps (32).

Skin substitutes, such as Integra Bilayer Matrix Wound Dressing (Integra Life Sciences, Plainsboro, NJ), have also been commonly used in wounds about the foot and ankle. Following incorporation of the dermal analog, a split-thickness skin autograft is performed, significantly limiting donor site morbidity. Helgeson et al. reported successful results in achieving soft tissue coverage over exposed tendon or bone in war-injured patients 83% of the time using Integra. In the successful cases, more sophisticated flap coverage was avoided, thus decreasing resources as well as avoiding any potential donor site morbidity (35) (Fig. 1).

Conclusion

Blast injuries to the lower extremity are severe injuries. They are frequently associated with fractures to multiple levels, including the foot, ankle, and the leg. Due to this frequent multilevel injury often associated with significant soft tissue damage, early elective amputation at the level V treatment center is frequently performed. When limb salvage is attempted, it is imperative to follow the basic tenets and principles discussed previously in an attempt to avoid infection and salvage optimal limb use. Future research is needed to determine which injury patterns should undergo early amputation and which can be salvaged with good outcomes.

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