Management of Traumatic Foot Wounds

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Abstract

The foot is frequently exposed to direct trauma due to its role in weight-bearing. The soft-tissue wounds that commonly result interfere with ambulation due to complications such as tissue necrosis, scar formation, infection, and deformity. The five most common categories of foot injury are (1) low-velocity blunt trauma, (2) high-velocity blunt trauma, (3) low-velocity penetrating trauma, (4) high-velocity penetrating trauma, and (5) thermal injuries. For major wounds, the treatment is early aggressive debridement, copious irrigation, and skeletal stabilization with early coverage of skin defects. Local and systemic antibiotics are adjunctive to debridement to prevent infection. Prompt recognition and release of compartment syndrome of the foot are extremely important. Close observation is appropriate for wounds that appear minor on initial evaluation.

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The practicing orthopaedist commonly treats a variety of injuries to the foot. These injuries can be due to events as disparate as being in a motor-vehicle wreck and stepping on a nail. The severity of such wounds is highly variable and can be very difficult to assess on initial evaluation. Some of these injuries can be incapacitating or can result in chronic impairment. The initial treatment is important in determining the long-term results.

This review will outline our current recommendations for foot injuries in general and for specific examples of the five types of problems that can be encountered. The five types are (1) low-velocity blunt trauma (e.g., crush injuries), (2) high-velocity blunt trauma (e.g., injuries from motorcycle wrecks), (3) low-velocity penetrating trauma (e.g., nail-puncture wounds), (4) high-velocity penetrating trauma (e.g., lawn mower injuries), and (5) thermal injuries (burns and frostbite). Similar wounds can occur from other mechanisms (e.g., gun shots), but the principles of treatment for each type of wound are generally applicable.

General Principles of Wound Management

The initial evaluation and treatment of wounds to the foot are usually performed by the patient, a family member, or ambulance staff outside the control of the treating orthopaedist. The optimal initial management should include documentation of the site and nature of the wound and application of a clean dressing and an immobilizing splint to the foot and ankle. The environment of the injury (e.g., contamination with barnyard dirt) and an estimate of the quantity of blood loss should also be documented; both may be impossible to determine later. Amputated parts should be preserved in a clean plastic bag and kept cool on ice, with a notation of the time of injury. Even if parts are not replanted, they may serve as a source of skin or other tissue grafts in salvaging the remainder of the foot.

The orthopaedist should assess the extent and severity of the musculoskeletal injury as well as the skin wound. The mechanism of injury may imply more extensive soft-tissue injury than was initially appreciated. Note should be made of the size and location of tissue loss, the condition of surrounding tissue, and specific injuries, such as tendon lacerations and fractures. Gross debridement of foreign bodies should generally be performed and broad-spectrum antibiotics should be administered in the emergency room or at the time of initial evaluation.[1]

Crush Injuries (Low-Velocity Blunt Trauma)

Crush injuries of the foot are often more severe than can be appreciated

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on initial evaluation. The dorsum of the foot is covered by thin skin, minimal subcutaneous tissue and fat, minimally vascular tendons, and minimal muscle. The initial history should identify the energy dissipated by determining the mass, velocity, and shape of the crushing mechanism. The dorsal venous drainage of the foot is usually impaired by crush injuries, and the dependent position of the foot allows marked edema to occur.[2]

Although compartment syndrome has been identified as common in crush injuries of the foot, it continues to be missed or undertreated and can result in severe chronic deformity. It is important to remember that an open wound does not preclude the presence of compartment syndrome.

Clinical signs of compartment syndrome in the foot include pain that is out of proportion to the injury, especially during active or passive toe extension. Other signs include swelling and tautness of the skin. Sensory changes or diminished pulses should alert the physician to the possibility of compartment syndrome; however, these findings may be absent in the acute setting and may develop only later.[3]

Pressure monitoring is especially useful because the clinical signs of compartment syndrome in the foot are not as specific as those in other anatomic sites. Pressure monitoring should be performed when there is a high risk of compartment syndrome or when the patient has a head injury or impaired mentation and cannot cooperate in accurate clinical examination. Open fasciotomy with release of the muscular compartments of the foot is indicated when the pressure is greater than 30 mm Hg. Hypotension may decrease the tolerance of the tissues to increased compartment pressure and thus lower the threshold for fasciotomy.[4]

When compartment syndrome has not developed but is a risk, close observation is essential, and repeat pressure measurement may be required. Tight circumferential dressings and excessive elevation should be avoided. If symptoms of compartment syndrome are strongly present but the intracompartmental pressure measurement is below 30 mm Hg, the surgeon should nevertheless proceed with fasciotomy.

Nine compartments have been described in the foot. If global compartment syndrome is suspected, we prefer to decompress the foot through the three incisions shown in Figure 1. A medial longitudinal incision is created along the inferior border of the first metatarsal and is extended proximally. This allows access to the medial compartment, which is decompressed. Following this, the abductor hallucis muscle is retracted inferiorly to gain access to the central foot compartments and the lateral compartment. Two dorsal longitudinal incisions are created over the second and fourth metatarsals. Dissection medially and laterally is performed to decompress the interosseous compartments. Care must be taken to avoid undermining of the skin or creation of a narrow skin bridge between these incisions. Fracture fixation may be performed through the fasciotomy incisions, which are then closed or skin-grafted on a delayed basis.[5]

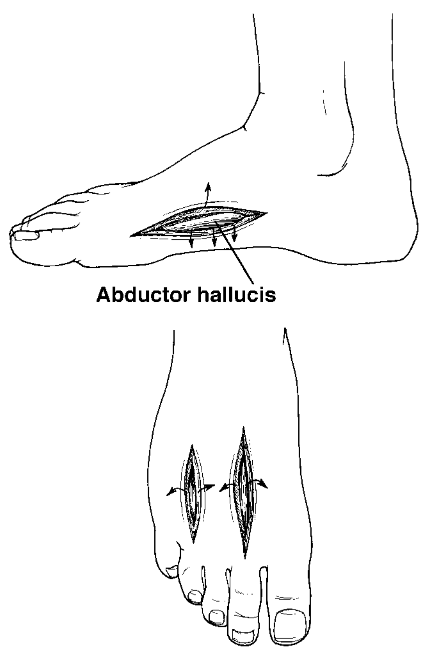

Fig. 1 Three-incision fasciotomy of the foot for release of pressure from compartment syndrome and prevention of tissue death.

The initial evaluation should also identify specific structures that have been injured. Radiographs of the foot should always be obtained. Stress views may be useful in demonstrating ligamentous injuries. Tendon repair and fracture stabilization with specific attention to joint surfaces will facilitate soft-tissue care.

Primary treatment of the crush wound should include a bulky compressive dressing with cast padding and elevation of the foot slightly above the level of the heart on pillows or a Bohler frame. The dressing should be wrapped from the toes proximally to the knee, and the foot and ankle should be immobilized. If the severity of the injury is moderate, severe, or indeterminate, hospitalization is recommended for 48 hours for close monitoring and enforced elevation. The length of hospitalization depends on the severity of the injury and the amount of tissue injury that becomes apparent over the course of 5 days.

Full-thickness eschar should be debrided and grafted once demarcation has occurred to speed eventual healing and return of function. Vascular injury to the forefoot may lead to toe loss, but amputation and reconstructive surgery in general should be delayed until there is clear demarcation and initial recovery of surrounding tissues. Posttraumatic stiffness, deformity, and arthritis may also occur but are best treated by reconstructive procedures after 6 months of recovery.[6]

Injuries From Motor-Vehicle Accidents (High-Velocity Blunt Trauma)

Another common mechanism of injury is motor-vehicle trauma, especially that due to motorcycle accidents in which the foot is crushed between the motorcycle and a stationary object, such as the ground. The foot may also be injured in head-on car crashes, in which the driver is at risk for floorboard-modulated injuries. These wounds are similar to a crush by a falling object, but can be more severe due to greater energy absorption by the bone and soft tissues. They are also more likely to be open and have gross contamination by dirt and other foreign bodies.

The principles of treatment of crush injuries also apply to these injuries. Patients often have other extensive and life-threatening injuries; however, care of the foot should not be overlooked. Because of the high risk of infection in open contaminated wounds, initial irrigation and debridement in the operating room are recommended. Repeat debridement is usually necessary as demarcation of nonviable tissue becomes apparent.

External fixation is a well-accepted form of treatment of the fractures accompanying this kind of foot injury. The fixators maintain axial length, which casts and Kirschner wires do not. The use of fixators does not require extensive soft-tissue dissection and does not entail the foreign-body effect at the fracture site produced by plates and screws. Furthermore, access to the wound for dressing change and secondary reconstruction is facilitated by the use of external fixation devices. The appropriate pin sizes for the tarsus, metatarsals, and phalanges are 3, 2, and 1.5 mm, respectively. Kirschner wires measuring 0.045 inch in diameter may be useful for supplemental fixation of the toes. Three-dimensionally stable frames can be constructed to stabilize the arch. Specific techniques have been suggested for application of the fixator and for care and monitoring of the soft tissues, including preconstruction of the frame in plastic bone, intraoperative fluoroscopy, distraction for indirect reduction by ligamentotaxis, and pin care to prevent infection.[7]

Nail-Puncture Wounds (Low-Velocity Penetrating Trauma)

Nail-puncture wounds are common and may present acutely or later. In later presentations, the symptoms and findings are variable. For example, years after a vague history of stepping on a nail, a child may present with a short middle metatarsal, which may be a consequence of osteomyelitis and physeal growth arrest due to the nail puncture. In another scenario, a patient may present to the emergency room with a progressively swollen, red, tender foot 1 week after stepping on a nail while wearing a shoe. In these nonacute situations, radiographs should be obtained to look for signs of bone involvement. If equivocal signs are present, a bone scan may be useful. The nail tract itself may be draining or may be hard to identify.

Treatment should include debridement of the tract, curettement of involved bone, irrigation and drainage of infected joints or tendons, careful search for and removal of any foreign body (e.g., a piece of the shoe), tissue biopsy for culture, and packing the wound with a wick. Systemic antibiotics with specific coverage for *Pseudomonas* infection should be given for several days after the wound has clinically resolved.[8]

A patient may present to the family physician a few hours after having stepped on a nail with minimal local signs of inflammation. In these cases, a radiograph should be obtained to look for direct bone trauma or the presence of a radiopaque foreign body. The shoe should also be inspected for missing fragments that might have been driven into the foot. If either trauma or a foreign body is present, formal debridement in the operating room should be performed by a surgeon. If neither is present, debridement can be performed with local anesthesia and subsequent close observation.

Controversy exists regarding the aggressiveness of operative treatment and the use of intravenous antibiotics. Some orthopaedists recommend debridement of all nail-puncture wounds. However, there are no definitive studies in the literature on the rate of chronic infection of nail-puncture wounds of the foot as a function of initial treatment, in part because many patients do not come to the emergency room after this type of injury.

Tetanus immunization status should always be investigated in any patient with a nail-puncture wound. Prophylaxis should be administered if necessary.[9]

Lawn Mower Injuries (High-Velocity Penetrating Trauma)

Lawn mower injuries to the foot are relatively common in both rural and suburban communities. Children are very often involved, most commonly when riding with an adult or playing in the yard during mowing. In the latter situation, because of the noise from the mower, the adult may be unaware of the exact location of the child and may run the mower over the child's foot with devastating consequences. Adult injuries are often associated with mowing slick grass on an incline. The typical scenario is that the person slips in the grass and gravity causes the mower to roll over his foot. A person mowing downhill can also slip, and his feet can then go under the mower.[10]

Tremendous injury occurs as a consequence of the combination of the high velocity of the mower blades and the repeated blows. A standard 26-inch mower blade turns at 3,000 rpm and supplies three times the energy of a .357 magnum pistol. Extensive deep contamination with grass, shoe leather, sock fabric, and dirt typically occurs. Rarely is an amputated part replantable. The extent of soft-tissue injury is greater than its initial appearance suggests, and the treating orthopaedist should never make an early decision concerning the ultimate viability of the tissue. The physes are particularly likely to be injured proximally. When a child suffers such an injury, both the parents and the child should be made aware of the potential for growth abnormalities or deformity from tendon imbalance.

Vigorous debridement and irrigation in the operating room are indicated initially, with packing of the open wound. Repeated debridements usually are necessary as nonviable tissue demarcates. In severe cases, a split-thickness skin graft may be used for temporary coverage 4 days after the injury. Major reconstructive coverage procedures performed early have a high rate of failure due to trauma to surrounding and supporting structures; therefore, they should be delayed for several weeks.[11]

Intravenous antibiotic therapy should be given for 72 hours, utilizing a broad-spectrum cephalosporin and an aminoglycoside to provide coverage against Gram-negative organisms. Penicillin should be given as protection against clostridial infection in severe injuries contaminated with dirt. If a wound infection develops, the sensitivities of the cultured organisms should direct the choice and duration of intravenous antibiotic therapy.

Because of poor circulation to bone in general and to these wounds in particular, the local use of an antibiotic bead pouch may be helpful. The antibiotic beads may be created by mixing 2.4 g of tobramycin powder in 20 g (a half batch) of polymethylmethacrylate and then forming 10-mm-diameter beads over a 20-gauge stainless-steel wire. After irrigation and debridement, the beads are packed into the wound and covered with a semipermeable plastic membrane that allows oxygen into the wound but retains fluid to prevent desiccation. The antibiotic leaches out of the beads in a high local concentration in the wound milieu, unlike systemic antibiotics, which produce only low tissue levels. The undesirable systemic effects of the aminoglycoside are minimized because of the very low blood levels produced. The beads can be exchanged at each redebridement until definitive coverage has been achieved or reconstruction is possible.[12]

Recommended measures to prevent lawn mower injuries include wearing sturdy shoes with a tread sole, not mowing wet grass, mowing sideways on slopes, using mowers that automatically turn off when the user is not pressing a lever, not allowing children to play in the vicinity of a mower, not allowing passengers on a riding mower, not allowing more than one person to mow at a time, and prohibiting bystanders from the immediate surroundings.

Burns and Frostbite (Thermal Injury)

Burns can be caused by heat, chemicals, radiation, and electricity and commonly involve the foot. Isolated foot burns produced by spilled hot liquids can occur at home or at work. Identification of the injury and prevention of further injury are important at the time of initial presentation.

Emergency treatment should include immersion in cool (25°C [77°F]), clean water for 30-minute periods. Blisters should be left intact and covered with nonadhesive dressing. Escharectomy and fasciotomy may be necessary to restore circulation if circumferential constriction occurs. Elevation and antibiotics help control swelling and infection. Secondary skin coverage is usually necessary in more severe injuries.

Emergency treatment of chemical burns includes removal of shoes, socks, and any particulate matter. Immediate copious irrigation with tap water helps dilute the chemical, restores normal pH, cools tissues, and slows further chemical injury. Some specific acid burns (e.g., hydrofluoric acid) are better treated initially with an alkaline solution of sodium bicarbonate.

Thermal injury can also occur from the cold, and the foot is the most common site for frostbite. Superficial frostbite appears as a white patch of skin, which usually heals within a few days with minimal consequences. Deep frostbite is a serious injury, with direct tissue damage from freezing as well as indirect injury from thrombosis of blood vessels. Residual problems include numbness, cold intolerance, deformity of the nails and toes, scarring, and hyperhidrosis. Dry gangrene and autoamputation of the forefoot can occur in the most severe cases.

For treatment, the foot should be placed in a warm-water bath (40°C

[104°F]). When general hypothermia is present, the normal body temperature should be restored before thawing the foot. The foot should be elevated and splinted in neutral, and range-of-motion exercises should be used to maintain flexibility even in the presence of severe tissue injury. Debridement of nonviable tissue may speed eventual resolution, but should be delayed until clear demarcation has occurred (usually after 2 weeks). Immediate amputation or aggressive initial debridement is not necessary.

Heparin and dextran have been utilized to combat sludging of red blood cells at low flow rates, but their benefit has not been proved. Adequate hydration is important. The potential benefit of hyperbaric oxygen is controversial, but it is used in a few centers. Sympathectomy may be beneficial in patients who have clear evidence of increased sympathetic tone several weeks after injury. This seems to occur most commonly following injuries due to prolonged immersion in cold water.[11]

Summary

The management of traumatic foot wounds is based on general principles and the expectation of specific problems that are encountered in the common varieties of these injuries. An injury due to low-velocity blunt trauma, such as a crush injury due to the fall of a heavy object, should be carefully observed to detect extension of the injury and to allow recognition and early fasciotomy of compartment syndrome. Treatment of high-velocity blunt trauma associated with vehicular injuries should emphasize aggressive debridement and skeletal fixation. Nail-puncture wounds are an example of low-velocity penetrating trauma. Their treatment requires a logical approach to the relative risk in order to prevent tetanus, *Pseudomonas* osteomyelitis, and other chronic sequelae. Lawn mower injuries are characteristic of high-velocity penetrating trauma. Their treatment should emphasize early careful debridement and later restoration of function. Thermal injuries require slow reversal of the temperature insult by means of water immersion. Generally, debridement should be delayed until the extent of necrosis is apparent.

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