Moderators' Summary: Stabilization of Long Bones

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Two common themes pervade this symposium. First, advances in body armor and far-forward surgical capability have resulted in increased survivability of the injured military combatant. Along with improved survivability has come a relative increase in the quantity and severity of extremity trauma. Second, the magnitude of soft-tissue and bony injury, regardless of mechanism of injury, dictates treatment at all levels of care.

Far-forward stabilization of long-bone trauma in the global war on terrorism is performed mostly by orthopaedic surgeons positioned at level II (the second echelon of care). Significant equipment limitations exist at the lower levels of care—specifically, lack of power equipment and fluoroscopy. At the most forward locations, these equipment deficiencies make formal open reduction and internal fixation (ORIF) difficult, if not impossible. More important, however, are the limits imposed by the lack of a sterile environment. Even with the proper equipment, ORIF would be ill-advised at best in unclean environments.

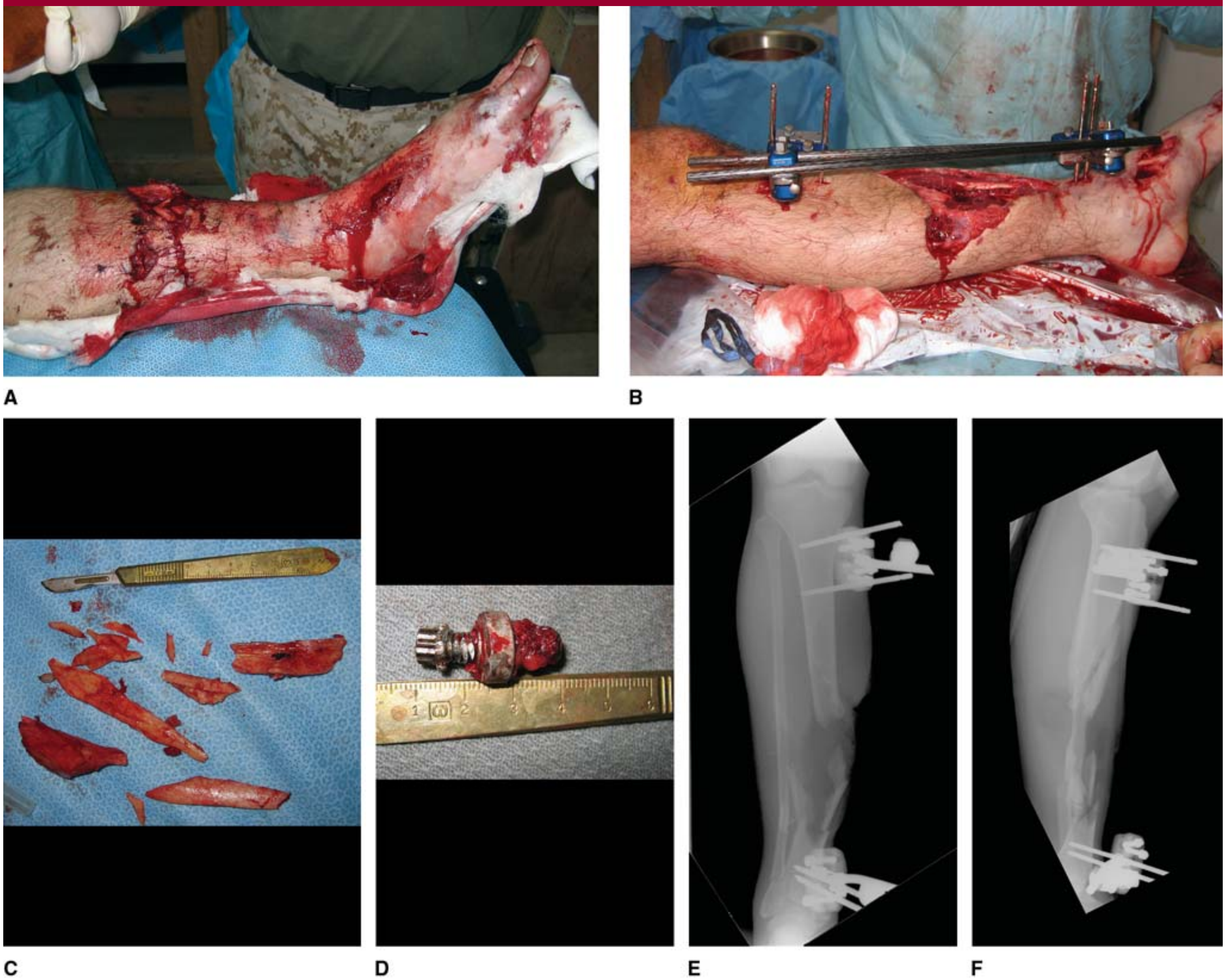
Having orthopaedic surgeons positioned at far-forward areas has two very distinct advantages. First, the orthopaedic surgeon has more knowledge of extremity anatomy than does the general surgeon. This allows better and safer débridement, thus limiting surgical insult, preserving maximal function and limb viability, and preventing infection. Second, knowledge of the options for definitive care enables the orthopaedic surgeon to perform provisional stabilization and débridement of extremity wounds on the battlefield that does not limit the definitive treatment options available to the receiving surgeon.

Casualties with long-bone fracture are not returned to the battlefield. Instead, they are quickly medevac'd to one of the large military treatment facilities (usually in the continental United States [CONUS]) for definitive treatment, where the environment is sterile and advanced soft-tissue care (eg, plastic surgery) is available.

This session of the symposium focused on five specific issues: (1) What can be done to maximize treatment of extremities on the battlefield? (2) What is appropriate conversion of battlefield extremity long bone shaft fractures from external to definitive external or internal fixation? (3) What is appropriate conversion of battlefield periarticular fractures from external to definitive fixation? (4) When is it best to use external fixation as definitive treatment? (5) What is the difference between blast and high-velocity gunshot wounds (GSWs)?

Current treatment of battlefield casualties at level II and III medical treatment facilities involves initial débridement and provisional stabilization. New technologies are needed that help the surgeon judge the adequacy of wound débridement; even for a surgeon with a wealth of experience, assessing tissue viability in these high-energy injuries can be challenging. Continued education on débridement techniques is imperative if we are to remain effective in preventing infection in the far-forward surgical setting. We must continue to develop advanced mobile wound care and wound containment methods, such as the wound VAC (Kinetic Concepts, Inc, San An-

Figure 1



A, Gustilo type IIIB open tibia fracture caused by an improvised explosive device (IED). **B,** Débridement, irrigation, and provisional stabilization is performed at the field hospital. **C,** Multiple devitalized fragments of débrided bone. **D,** Metallic object placed in an IED, which became a high-velocity projectile. Anteroposterior **(E)** and lateral **(F)** radiographs before transport to CONUS for definitive treatment.

tonio, TX), which is currently available at some level III facilities.

For US casualties in Afghanistan and Iraq, stabilization options consist of external fixation and splinting. Definitive fixation is reserved for select fractures that are difficult to temporize. Camuso notes that the surgeon deciding between external fixation and splinting must take into account several factors: tactical environment, injury severity, injury location, available resources, and his or her own level of experience. The advantages of external fixation versus splinting for patients with long-bone injuries are more rigid stabilization for prolonged transport to CONUS (usually 4 to 7 days) and ease of wound access while in transport. External fixation systems currently used in theater provide adequate stability for provisional fixation, but they are most useful in ease of placement, particularly for the deployed orthopaedic surgeon who uses external fixation in his or her civilian or state-side military orthopaedic practice (Figure 1).

Dougherty and coauthors report on temporary fixation of diaphyseal fractures with conversion to intramedullary (IM) nailing, small-pin external fixation, or a modified external fixator once the patient reaches a more stable environment. They recommend further research to determine the appropriate timing for conversion from temporary to definitive fixation. Such studies could not only benefit wounded soldiers but also improve care for civilians injured in regions of conflict.

Figure 2

A B C

A, Blast injury to an elbow. Preoperative **(B)** and postoperative **(C)** anteroposterior radiographs demonstrating severe comminution and articular loss.

Timing of definitive fixation has yet to be determined for periarticular injuries stabilized with temporary external fixation. Carmack delineates the several factors that must be taken into account when making that decision: condition of the soft tissue, nature of the initial injury (ie, open, closed), the possible need for further débridement, associated fasciotomy wounds, location of previously placed external fixator pins, condition of existing external fixator pins, mechanical stability of external fixator configuration, bone and soft-tissue loss, associated neurovascular injury, and the presence or absence of infection. To facilitate better far-forward care, Carmack recommends developing a best-practices guide for the deployed orthopaedic surgeon, using the resources of all US military branches in conjunction with the Orthopaedic Trauma Association and the American Academy of Orthopaedic Surgeons.

Although most battle trauma results in penetrating injuries, blunt trauma may cause closed fracture. Della Rocca notes that closed long bone fractures are usually stabilized in theater with external fixation for ease of transport to CONUS. Limited evidence exists regarding appropriate timing for conversion of external fixation to definitive fixation, but it is generally considered safe to do so within 2 weeks for one-stage IM nailing of a tibia fracture. Although the femur and tibia tend to behave differently, these guidelines generally are applied in the United States to all long bone trauma. It is reasonable to employ this rationale for closed injuries temporized on the battlefield, assuming clean pin sites at the time of IM nailing. For closed periarticular injuries, the staged protocol used in the United States for civilians obviates temporization until the soft-tissue envelope has recovered (usually 2 weeks), which seems like a logical approach to similar injuries acquired on the battlefield.

What remains unclear is whether we can approach blast and high-velocity missile wounds in the same way we do in converting temporized lower extremity trauma in the United States. Civilian trauma experience with upper extremity periarticular injuries provides little guidance for such injuries on the battlefield (Figure 2). Weil and coauthors review the effects of blast and penetrating injury to the extremities. The energy level of penetrating extremity trauma on the battlefield is greater than that in most injuries seen in the United States, where the typical GSW is low-velocity and blast injuries are rare. Blast injuries are unique for two reasons. First, blast effect has four differing mechanisms that cause trauma to human tissue: (1) injury to air-fluid interfaces, (2) penetrating fragment injury, (3) blunt trauma caused by the blast wind, and (4) thermal or chemical injury caused by the heat and fumes of the explosives or chemicals released from the environment. All types of blast injury can be devastating, depending on the proximity of the individual to the blast and location of the blast (ie, enclosed space, open space). Second, the gross contamination along multiple tissue planes from blast particles and debris makes these wounds qualitatively

Figure 3

A B

A, Anteroposterior radiograph demonstrating metallic fragments from a large improvised explosive device. **B,** Traumatic amputation with gross contamination after blast injury.

Figure 4

A B C D

A, Anteroposterior radiograph of an improvised explosive device blast injury to the tibia temporized in an external fixator. **B,** Multiple fragment wounds to the leg. **C,** Because of concern of intramedullary sepsis, a bridge plate technique was chosen rather than an intramedullary nail, using a long locking plate. **D,** Infection-free union was established after bone grafting.

different from GSWs. Blast injuries differ from GSWs in that they are usually higher energy and involve greater contamination; they also possess greater potential for polytrauma and usually have a higher Injury Severity Score (Figure 3, A). Blast wounds have a much larger zone of injury than meets the eye, requiring larger débridements to prevent infection. The result is larger soft-tissue defects and greater potential for flap requirements or a higher level of amputation (Figure 3, B).

More than anything else, soft-tissue injury and large bony defects dictate the treatment of severe extremity injuries. Long bone trauma involving shaft and periarticular injuries from blast and high-velocity GSWs have large zones of injury, considerable contamination and soft-tissue loss, and bony and articular cartilage defects that are challenging to treat. Concerns regarding infection resulting from contaminated and compromised soft-tissue envelopes may influence the surgeon to use definitive fixation methods that differ from the usual approach to certain patterns of injury (Figure 4). Close tracking and follow-up of battlefield casualties is necessary to establish proper guidelines for timing of conversion to definitive fixation. It is hoped that experience with injuries in the current conflict will indicate whether certain hardware choices are better for blast-injured patients or high-velocity GSWs, or whether these wounds behave similarly after adequate débridement and coverage.