Damage Control Orthopaedics: An In-Theater Perspective

LTC(P) Romney C. Andersen, MD,[1–3] MAJ Victor A. Ursua, MD,[1,4] MAJ John M. Valosen, MD,[1,5] LTC Scott B. Shawen, MD,[2,3] Col Jeffrey N. Davila, MD,[2,3] LTC(P) Martin F. Baechler, MD,[2,3] and CDR John J. Keeling, MD[2,3]

Damage control orthopaedics is well described for civilian trauma. However, significant differences exist for combat-related extremity trauma. Military combat casualty care is defined by levels of care. Each level of care has a specific role in the care of the wounded patient. Because of lack of equipment, austere environments, and significant soft tissue wounds, most combat fractures are stabilized with external fixation even in a stable patient, unlike civilian trauma. External fixation allows for rapid stabilization of fractures and easy access to wounds and requires little shelf stock of implants. Unique situations exist in the care of the combat-injured casualty, which include working in an isolated facility, caring for enemy combatants, large soft tissue wounds, and the need to rapidly transport patients out of the theater of operations.. (Journal of Surgical Orthopaedic Advances 19(1):13–17, 2010)

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The use of damage control orthopaedic surgery has been widely described (1). The term damage control was adopted from the US Navy policy on controlling damage aboard a ship while being able to continue on with its mission (2). In surgery the term refers to a systematic approach to caring for the most severely injured patients who may be put at further risk by aggressive early total care algorithms that were initially championed by Bone (3). Damage control surgery concepts involve three phases: minimal surgery to rapidly control exsanguination, secondary resuscitation in the intensive care unit, and finally definitive repair of injuries. Damage control surgery in the civilian sector has been shown to increase overall survival of the critically injured patient (4).

From [1]10th Combat Support Hospital, Ibn Sina Hospital, Baghdad, Iraq; [2]Orthopaedic Surgery Service, Walter Reed National Military Medical Center, Bethesda, MD and Washington, DC; [3]Department of Surgery, Uniformed Services University of the Health Sciences, Bethesda, MD; [4]Orthopaedic Surgery Service, Weed Army Community Hospital, Fort Irwin, CA; [5]Orthopaedic Surgery Service, Winn Army Community Hospital, Fort Stewart, GA. Address correspondence to: LTC(P) Romney C. Andersen, MD, 8901 Wisconsin Avenue, Bethesda, MD 20889; e-mail: romney.andersen@us.army.mil.

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Damage control orthopaedics is an extension of the principles of damage control surgery as applied to musculoskeletal trauma. This is characterized by early rapid temporary fracture stabilization to minimize blood loss followed by physiologic stabilization and finally definitive orthopaedic management (5, 6). Patients benefit from quickly stabilizing the extremities with external fixation to limit ongoing damage and quickly transferring the patient to the intensive care unit for resuscitation (1). Once the patient is stable, usually within 24 to 36 hours, the patient is brought back to the operating room for removal of the temporary external fixation devices and conversion to definitive internal fixation.

The civilian damage control model is significantly different from combat damage control. In the civilian setting the entire process is usually conducted at one hospital. In the military, however, the opposite is usually true. Patients are moved along a continuum of care with care sequentially being handed off to a higher level of care. These levels of care define what capabilities are available for each role as well as getting the patient back to the United States.

Military Levels of Care

Care of the combat extremity wound is defined by levels of care where each level corresponds to its capability. Level I consists of care provided to the casualty prior to entering into the medical chain. Care provided is usually self-aide, buddy aide, medic, or corpsman. At this level

of care patients may receive combat dressings and tourniquets to stop major hemorrhage and are met or transported to level II medical personnel. Level II is defined by entrance into the medical system where the patient is cared for by a provider with a higher level of medical training. This can be as simple as an aid station or all the way to independent forward surgical teams. At this level the patient may have an extremity splinted and may receive analgesia as well as antimicrobial prophylaxis. If this facility is equipped with a forward surgical team, simple surgical procedures may be performed, such as an irrigation and debridement and external fixation of fractures. The first level at which patient holding capability is available is level III. Level III is comprised of expanded forward surgical teams with patient holding capacity and combat support hospitals that are in theater and where patients receive their initial or subsequent surgical care. Here the patients undergo removal of any tourniquets, hemorrhage control, surgical debridement and irrigation of open wounds, amputation of nonviable limbs, and external fixation of long bone fractures. It is not infrequent for a patient to be transported directly from the battlefield to a level III facility, bypassing level II care if the level III facility is close or it is obvious that the patient needs level III care. This happens more frequently in well established theaters such as currently exist in Iraq and Afghanistan. It is also frequent for aeromedivac transportation to fly directly from the point of injury to a level III combat support hospital. Level III care also provides a location where patients can be monitored for short periods as inpatients and stabilized by the trauma team prior to being transported back throughout the evacuation chain. Care is continued throughout level III hospitals along the evacuation chain until patients reach level IV care centers in Germany and in areas outside of the combat zone. Finally, level V care occurs in the United States, where definitive operative care and rehabilitation are provided at technically specialized surgical and rehabilitation centers (7). Table 1 outlines these levels of care as well as orthopaedic damage control provided by civilian trauma centers.

Early Fracture Stabilization

Rigid skeletal stability minimizes secondary injury to an already traumatized soft tissue envelope. In the multiply injured patient, early fracture stabilization has beneficial systemic effects, such as decreased risk of infection and better pain management. Skeletal stabilization also facilitates medical evacuation (8–10).

The majority of open and closed fractures are stabilized with external fixation. External fixation allows more rigid bone stabilization, which offers better pain management during transport along the evacuation chain. The vibration and motion experienced during ground and air transport causes movement at the fracture site which causes increased pain. Improved stability at the fracture site provided by an external fixator may help to improve pain control and narcotic requirement during transport.

Some fractures, such as closed lateral malleolar ankle fractures and some forearm fractures, can be effectively splinted. Long bone fractures, however, such as femur shaft and tibia–fibula fractures, may benefit from external fixation for better stability during transport. Periarticular fractures, such as tibia plateau fractures, may be better stabilized with spanning external fixation.

Consideration of In-Theater Definitive Fixation

Fractures prone to osteonecrosis, such as femur neck and talar neck fractures, should be considered for emergent stabilization with open reduction internal fixation

TABLE 1 Comparison of military and civilian levels of care

Level	Military	Civilian
I	Self-care/buddy care Combat lifesaver Combat medic/Navy corpsman	EMT care
II	Area medical support facility Forward surgical team Forward resuscitative surgical system (may have surgical capability)	EMT care continues
III	Combat support hospital Expanded forward surgical team Medical/surgical/trauma care (patient holding capacity available)	Trauma center care
IV	Landstuhl Regional Medical Center (limited definitive surgical management outside of combat zone)	Continue trauma center care
V	Walter Reed National Military Medical Center Brooke Army Medical Center San Diego Naval Medical Center Specialized care and follow-up care	Continue trauma center care

in theater. However, there is controversy over this principle and some feel that infective risks of operating in theater outweigh the potential benefits.

Open reduction and internal fixation of fractures performed in theater subjects the patient to increased risk of infection. Fractures are stabilized with external fixation to allow transport throughout the evacuation chain. Definitive open reduction is delayed until the wounds appear stable or until coverage procedures can be safely performed. Forty-six percent of upper extremity wounds from Operation Iraq Freedom and Operation Enduring Freedom were culture positive on admission to Bethesda (11). Civilian experience has demonstrated that external fixation can be converted to definitive intramedullary nail with no significant increase in risk of infection compared to primary nailing if performed within 2 weeks and if there is no sign of pin-tract infection (1, 12). Military experience with conversion of external fixation to intramedullary nail, however, has been quite different. No studies are available comparing treatment options for battle-related injuries, but differences at least seem to be likely, based on differences in the injury mechanism. Opinions vary about the best method for management of open tibial fractures secondary to blast or high-velocity gunshot injuries, but concerns have been raised regarding anecdotally high infection rates in fractures treated with intramedullary nailing; good experiences have been reported with ring fixation for definitive treatment of these injuries (13).

Additional benefits of external fixation include access to wounds without compromising stability. In the multiply injured patient, external fixation helps limit ongoing hemorrhage by limiting the available soft tissue space in which blood can accumulate as the bone is reduced and brought out to length (6). Indirectly, external fixation helps reduce narcotic requirements and helps improve ventilation. External fixation also protects vascular repairs in fractures with vascular injuries (6).

Negative Pressure Wound Therapy

In addition to the osseous trauma in the combat casualty, the soft tissue envelope provides a challenging scenario in the evacuation chain. Of the severe soft tissue wounds encountered in Operation Iraqi Freedom in Iraq (OIF) and Operation Enduring Freedom in Afghanistan (OEF), 96% are accounted for by either high-velocity gunshot wounds or explosive blast injuries (14). These complicated soft tissue injuries are usually highly contaminated wounds that most often require numerous operative irrigations and debridements. These procedures are usually done at each stop on the evacuation chain. How to best care for these wounds during transportation along the evacuation route has evolved during OIF and OEF, with the standard now being placement of a negative pressure wound therapy dressing (NPWT) (Fig. 1).

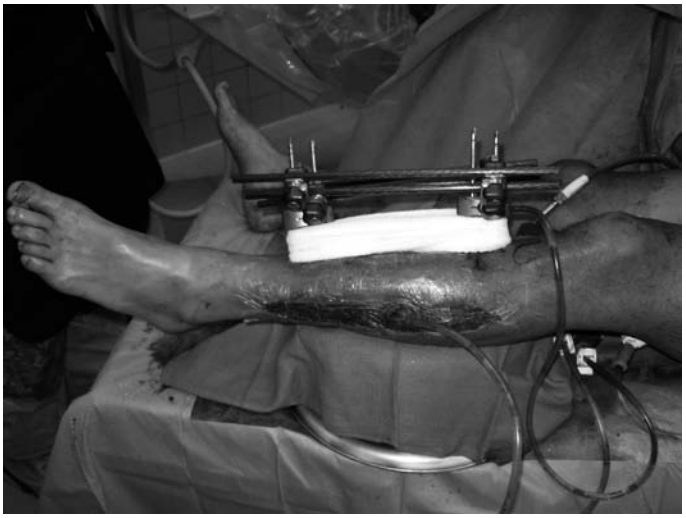

FIGURE 1 Open tibial fracture treated with external fixation on negative pressure wound therapy.

In recent years, in both civilian and military trauma scenarios, NPWT (V.A.C. Therapy, KCI Licensing, Inc., San Antonio, TX) has become an accepted and valuable adjunct in the management of severe soft tissue envelope injuries secondary to high-energy mechanisms (15–17). The reasons for this transition from conventional wound dressings is that NPWT allows for a decreased number of dressing changes, promotion of a granulation bed, facilitation of wound drainage, edema control, and avoidance of exposure of the wound to nonsterile environments (18). Also, the first prospective randomized study comparing NPWT versus conventional dressing techniques for severe open fractures has just been published, and the results reveal that patients treated with NPWT have one-fifth the rate of infection as those treated with conventional dressing techniques (19).

Early in OIF and OEF, it was reported that flights during the air evacuation process were leading to a large number of NPWT complications. More recently, this tenet has been shown not to be accurate. The current wound care algorithm utilizes NPWT. It has been found to be employed safely for the management of complex wounds during aeromedical evacuation of combat-related blast injuries where there is sufficient crew training and establishment of a process that mandates early evaluation of patients and wounds upon arrival at the next echelon of care along the evacuation route (20).

Special Situations

In-Route Care

Once patients are stabilized at the combat support hospitals in theater, they are transported to an aeromedical evacuation hub in theater where patients are routed back to the level IV facility in Landstuhl, Germany. Transport is considered one of the most dangerous times in a patient's care because the air frame transporting them is generally very loud, there is continuous motion along the route, and there is very little space to work if a patient decompensates en route. In order to accommodate for this situation, extra care is taken to ensure that fixators are stable and often external fixators are built up to provide extra stability. Wounds are checked to ensure that their NPWT dressing is functioning or that wet-to-dry dressings are fresh and not constrictive so that a compartment syndrome does not evolve in flight. In flight there are no orthopaedic surgeons available and any care provided in flight is provided by a flight surgeon with no formal surgical training. The mainstay of their care is to loosen dressings, remove nonfunctioning NPWT dressings to keep them from becoming occlusive dressings, and provide pain control.

Austere Care

Some orthopaedic surgeons are assigned to austere forward fighting units, which are highly mobile and thus have very little operative equipment available to them. They infrequently have access to power equipment and radiological assets. The instruments they have are usually very basic and surgeons operate relying on sound orthopaedic principals rather than the latest technology. The mainstay of this care provided is through wound cleansing and bony stabilization. Frequently these surgeons utilize splinting for immobilization of fractures. They also have the capability to use external fixation with a sterile "peel-packed" fixator containing a hand-powered pin driver (Fig. 2). If treating local casualties, they use what assets they have available to treat the injuries presented to them. When possible, the care of these patients is transferred to host national care.

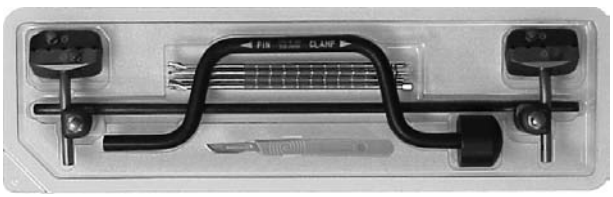

FIGURE 2 Peel-packed expedient external fixation set.

Detainee Care

Other surgeons are designated to work at large detainee facilities where hardened facilities exist and advanced orthopaedic equipment is available. Many of these sites have the latest in periarticular plating systems, intramedullary nails, and circular external fixation. Since the patients are detainees, there are no local national facilities available and they take on all of their care. The care provided by these hospitals is the same high level of care provided by the level V facilities in the United States to wounded U.S. service members. Many of the surgeons who man these hospitals are on rotations from the major hospitals treating casualties in the United States.

Summary

The use of external fixation and NPWT in the treatment of blast injuries and gunshot wounds resulting in open fractures with severe soft tissue injuries has become the mainstay of combat damage control orthopaedics. In the aeromedical evacuation process, these two treatments have afforded a less a complicated transition of the injured American service member from the battlefield to military medical centers in the United States where definitive treatment can be undertaken.

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