Extremity and Orthopaedic Injuries

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Abstract

The extremities remain the most common sites of wounding in combat, and are often a combination of injuries to soft tissues, bones, vessels and nerves. While these injuries are managed only after life threatening injuries are tackled first, precise evaluation and prompt management strategies to attain optimal outcome remain the goals of treatment. With advancements in tourniquet science, broader spectrum antibiotics, use of negative pressure wound therapy, easier options for fracture stabilization and continuously evolving reconstructive procedures have all increased the tools available to the surgeon to salvage severely damaged limbs.

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Introduction

Wounds inflicted in combat result from high energy fragments. Despite improvements in personnel protective gear in combat, the injury patterns of extremities have not changed and account for 40-70% of the total combat wounds [1]. Often these are mangled extremity wounds with extensive soft tissue loss and segmental defects of the bone and vessels which make their management challenging. While treatment goal is aimed at extremity salvage, these wounds carry a high potential for morbidity and amputation [2].

Despite our extensive knowledge of wound patterns, decision-making in complex extremity trauma in combat remains controversial.

Prehospital Care

Practical Use of Emergency tourniquets

Haemorrhage from injured limbs continues to be a leading source of combat death, and tourniquet use remains controversial [3,4]. Emergency tourniquet use in battle field has been associated with complications such as vascular thromboses, nerve paralyses, myonecrosis, and renal failure. Today, better application of tourniquet science to the interrelationship of tourniquet width, limb girth and arterial occlusion has led the US army to advocate that benefits in compressible extremity haemorrhage far outweigh the risks. Its use resulted in halving of the mortality rates in the prehospital setting and 16% improvement in survival rate in first level medical care setting. However using tourniquets after extrication, transport, or shock, or distal to the wound

caused increased mortality [5]. Tourniquets are a temporary measure allowing effective haemorrhage control and must be applied early before the casualty is in shock. Some relevant points to be borne in mind before application of tourniquets are (i) in most of the cases direct pressure using a pad or shell dressing is likely to control haemorrhage; (ii) Only life threatening extremity haemorrhage (severed limb) especially under direct enemy fire should be controlled by tourniquets; (iii) Use scientifically designed, laboratory tested and clinically validated tourniquets like CAT (Combat application tourniquet); (iv) Two hours tourniquet time is the maximum safe limit. Label tourniquet time and reassess tourniquet effectiveness after two hours; (v) Tourniquets may become loose and venous and can be cause of increased bleeding. Release and reapplication is indicated in such a situation.

Splinting of fractures

Correct use of splintage of fractures will relieve pain and facilitate transport. Femoral shaft fractures can be adequately controlled by a Thomas splint. Thomas splint though simple in its design and application, provides adequate immobilization of fractures besides allowing easy surgical access for debridement of compound injuries and providing a simple means for transporting patients comfortably. Tibial, ankle and forearm fractures can be splinted using POP slabs, Kremmer wire or any other suitable device. Today low pressure inflatable double-walled polyvinyl jacket splints and malleable aluminum padded splints are available for immobilization. However inflatable splints are to be used with caution

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in patients with associated vascular injuries and transportation time exceeding 6 hours.

Hospital Care

With the exception of pelvic fractures, orthopedic injuries are accorded low priority in management. Stabilizing a pelvic fracture using a sheet or towel clip as a stop gap (Pending application of a clamp or fixator) can be life saving. In most cases of fractures of shaft of long bones, restoration of longitudinal alignment and splintage is enough in early management.

Role of Scoring Systems for Lower Extremity Trauma (Amputate or Salvage)

Proper evaluation of extremity injuries in the context of overall general condition is essential for quality decision making. As a predictive tool several scoring systems have been developed, with threshold values for likelihood of amputation [6-10]. The simplest score and the one easiest to use in a conflict environment is the mangled extremity severity score (MESS), (Fig. 1). This scoring system takes into account the severity of local injury, vascular compromise along with patients inherent reserve, associated injuries and/or likelihood of organ dysfunction (hypotension).

MESS score is the sum of individual points. A MESS of ≥ 7 is a predictor of likely amputation. However, MESS has been shown to have low sensitivities (22%) in the civilian setting by Bonanni et al. When applied in a combat setting, Kate Brown and colleagues have shown that given the relatively young age of the soldiers and high energy blast/missile injury pattern, the presence of vascular injury that required repair and a physiologically unstable patient were the main factors

Skeletal/soft tissue injury

- Low energy (stab, simple fracture, pistol gunshot wound) 1
- Medium energy (open or multiple fractures, dislocation) 2
- High energy (high speed MVA or rifle GSW) 3
- Very high energy (high speed trauma + gross contamination) 4

Limb ischaemia

- Pulse reduced/absent but perfusion normal 1*
- Pulse less/paraesthesia/diminished capillary refill 2*
- Cool/paralyzed/insensate/numb 3*

*doubled if ischaemic time >6hours

Shock

- Systolic BP always >90mmHg 0
- Hypotensive transiently 1
- Persistent hypotension 2

Age (years)

- <30 0
- 30-50 1
- >50 2

Fig. 1 : Mangled extremity severity score (Johansen) skeletal/soft tissue injury.

in patients who eventually required an amputation. If the patient is neither shocked, nor has an ischemic limb, an attempt at salvage should be made [11]. To summarize a MESS of 6 or less can be salvaged. As far as patients with MESS of 7, 8 and 9, one should never choose early nonelective amputation over limb salvage except in the case of a mass casualty situation where resources are minimal and assets to perform revascularization are not available.

Infective Complications

Wound and bone infections remain an important source of morbidity in combat casualties. Gustilo and Anderson classified open fractures in to three types taking the variables of tissue devitalisation and contamination in to account (Table 1).

Type I fractures are those with minimal soft tissue damage and no gross contamination. The wound is usually small. Type II fractures have moderate soft tissue damage and minimal contamination. Type III fractures are high-energy injuries typically with bone comminution or loss and wounds with severe contamination or soft tissue injury irrespective of the size. There are three subtypes of III: IIIa, characterized by extensive soft tissue injury but with adequate soft tissue coverage; IIIb, which includes extensive soft tissue injury along with bone exposure requiring soft tissue coverage as an additional procedure and IIIc, which has the need for arterial repair [12]. The percentage of patients who develop infection is approximately 0-2% in type I, 2-5% in type II, 5-10% in type IIIa, 10-50% in type IIIb, and 25-50% in type IIIc. Timely (early) administration of antibiotics along with a meticulous debridement is the key to reduction of infection. At the time of injury in a combat zone, the bacteria contaminating the wound are typically gram-positive. However, during care further in the evacuation chain, more resistant gram-negative pathogens get inoculated [13].

Controversy exists on the preferred antibiotics and their duration of use. The International Committee of the Red Cross recommends penicillin for compound fractures, amputations, and major soft tissue wounds in

Table 1

Gustilo and Anderson's classification of open fractures

Type	Size of wound	Contamination	Soft tissue injury
I	<01 cm	Clean	Minimal
II	1-10 cm	Moderate	Moderate
III A	>10 cm	High	Severe with crushing
III B	Any size	High	Need soft tissue recon
III C	Any size	High	Severe with vascular injury

intravenous form for 48 hours and then orally till delayed primary closure, for a total of five days [14]. However penicillin use in combat has its own set of problems. The current literature supports use of intravenous first generation cephalosporins for all extremity injuries, although substitutions should be considered if concomitant CNS or abdominal or thoracic injuries are present, with enhanced gram-negative and anaerobic activity. There is very little evidence in support of continuing antibiotics during evacuation or until the wound is covered or all drains are removed [15].

Wound Management

The cornerstone of combat extremity wound management is aggressive surgical debridement and wound irrigation at the earliest. Thorough inspection of the wounds with liberal use of surgical wound extension to inspect all levels of tissue and fascial planes is mandatory. A surgical debridement or wound excision, includes meticulous debridement of all nonviable tissue until bright and fresh capillary bleeding occurs. Detached bone fragments smaller than thumbnails are discarded. Larger fragments that contribute to the structural integrity of the long bone should be retained. Nerves and tendons do not require debridement, except for trimming frayed edges and grossly destroyed portions. These structures are tagged with sutures and to prevent desiccation, soft-tissue or moist dressings coverage is instituted. In open joint injuries, all intra-articular foreign material, loose cartilage (including flaps), blood clots, and detached bony fragments without major articular surface must be removed. All recesses must be explored. The joint must be thoroughly irrigated with normal saline (pulse lavage and 6 to 9 L is recommended). The capsule is closed, if possible, without tension and without surgical tissue advancement. If synovial closure is not possible, the joint should be dressed open with moist fine mesh gauze occlusive dressing.

The old idiom "Solution to pollution is dilution and irrigation", still holds true in the combat setting. There are no definitive trials looking at the type and quantity of fluid or method of delivery to remove contamination from a combat wound adequately. Studies in animal models comparing irrigation utilizing bulb syringe versus pulsatile lavage have shown that pulsatile lavage results in pushing bacteria deeper into wounds besides causing further macroscopic and soft tissue damage [17, 18]. The recommendation today is to use traditional volumes to irrigate wounds with normal saline or ringer lactate without any additives. In a disaster management or multiple casualties' situation an alternative is to use large volumes of boiled cooled tap water for irrigation of wounds.

From lessons learned during the World Wars, primary closure is still not indicated. Loose approximation of tissues with one or two retention sutures is appropriate to cover nerves, vessels, and tendons with provision for free drainage. All wounds should be planned for second look and irrigation in 24–72 hours, and may require repeated wound excisions until a clean wound is achieved. Early soft-tissue coverage is desirable within 3–5 days; when the wound is clean, to prevent secondary infection. Vacuum assisted closure (VAC) after surgical debridement in extremity injuries with soft tissue loss has shown promise [19]. Definitive closure with skin grafts and muscle flaps should not be done in combat theatre when evacuation is possible.

Fracture Fixation : Damage Control Orthopedics

The beneficial effects of fixation of open fractures, including improved wound care, tissue healing, preventing further soft tissue damage and reduction in infection rates have been well documented. In civilian practice, the preferred method of fixation is an internal fixation. However certain caveats have to be entertained. The initial injury leads to release of inflammatory mediators resulting in Systemic Inflammatory Response Syndrome (SIRS) or a singular lack of inflammatory response (anergy) making the patient prone to sepsis, depending on the level of his immunity. At this stage a surgery of some magnitude leads to further release of similar substances resulting in what is called a *second hit*. Hence the current recommendation is to do the minimum to stabilize the fracture by what has been termed as Damage Control Orthopaedics (DCO). DCO, used for the first time by orthopedic surgeons from R. Adams Cowley Shock Trauma Center, provides systemic benefits of reduced operative trauma (avoiding the second hit') and improvement in the clinical status in multiple injured patient.

The current literature suggests that the favored tool for DCO in lower limbs is the application of external fixators. External fixations provide the advantages of decreased operating time, decreased blood loss and does not increase local complications besides not impairing the quality of definite osteosynthesis [20]. There are many types of external fixators, but the AO type tubular fixator is the commonest and most user friendly. Pin less fixators are simple and designed exclusively for use in open fractures of tibia. Further definitive fixation is to be done at higher levels of care but the optimal timing is still controversial. It may, however, be worth remembering that in non poly trauma situations there is increasing acceptance of a definitive internal fixation even in open fractures up to type IIIA. The application of interlocking intra medullary nailing for patients with

no infections and ring fixators with indicators of infection is the definitive management. For most open humerus and forearm fractures, the use of splint immobilization placed at forward surgical centres and transition to open plate osteosynthesis after soft tissue closure is recommended [15].

Compartment Syndrome

In combat, causes of acute extremity compartment syndrome (ECS) include hemorrhage from a fracture or arterial injury into an intact compartment, myocyte oedema after ischemia-reperfusion injury or resuscitation. Use of tight external dressings may be another cause [21]. The most common sites of ECS are the lower leg (53-62%), followed by forearm (24-26%), thigh (4-15%), foot (4-5%) and hand [22].

A clinical diagnosis of ECS may be made when one or more signs and symptoms are present: pain out of proportion to the injury with or without pain on passive stretch, sensory changes, weakness, or paralysis. Combat surgeons should have a high index of suspicion of this entity and have a low threshold to perform 2-incision, 4-compartment liberal fasciotomy of the distal extremity. In addition to surgical technique, timing of fasciotomy is critical, because after 8 hours of total ischemia irreversible damage occurs in the muscle and peripheral nerve [23]. Delayed ECS manifests after large volume resuscitation, delayed effects of primary blast injury or air evacuation. Delayed fasciotomies in such clinical scenario is controversial, but it is advisable still to err on the side of performing a fasciotomy.

Conclusion

Extremity injuries due to high energy missiles are a challenge to manage in combat environment. Though they remain secondary to resuscitation and management of life threatening conditions, early recognition of limb injuries avoids limb loss and improves chances of limb salvage. As a working guide an algorithm is suggested (Fig. 2).

Conflict of Interest

None identified

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Fig. 2: Suggested algorithm for combat extremity trauma. Modified from the EAST practice management guidelines for penetrating trauma to the lower extremity.

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ANNOUNCEMENT

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