Chapter 22

Soft-Tissue Injuries

All war wounds are contaminated and should not be closed primarily.

The goal in treatment of soft-tissue wounds is to save lives, preserve function, minimize morbidity and prevent infections through early and aggressive surgical wound care far forward on the battlefield.

Presurgical Care

- Prevent infection.
  - Antibiotics:
    - **Antibiotics are not a replacement for surgical treatment.**
    - Antibiotics are therapeutic, not prophylactic, in war wounds.
    - Give antibiotics for **all** penetrating wounds as soon as possible.
  - Sterile dressing.
    - Place a sterile field dressing as soon as possible.
    - Leave dressing undisturbed until surgery. **A one-look** soft-tissue examination may be performed on initial presentation. Infection rate increases with multiple examinations prior to surgery. Initial wound cultures unnecessary.

Surgical Wound Management Priorities

- Life-saving procedures before limb and soft-tissue wound care.
- Save limbs.
  - Vascular repair.
  - Compartment release.

- Prevent infection.
  - o Wound surgery within 6 hours of wounding.
  - o Antibiotics.
  - o Sterile dressing.
  - o Fracture immobilization.
- **Superficial penetrating fragment (single or multiple) injuries usually do not require surgical exploration.** Simply cleanse the wounds with antiseptic and scrub brush. Nonetheless, depending on location and clinical presentation, maintain high suspicion for vascular injury or intraabdominal penetration.
  - o Avoid "Swiss cheese" surgery (in an attempt to excise all wounds and retrieve fragments).

Wound Care

Primary Surgical Wound Care
- **Limited longitudinal incisions.**
- **Excision of foreign material and devitalized tissue.**
- **Irrigation.**
- **Leave Wound Open—No Primary Closure.**
- **Antibiotics and tetanus prophylaxis.**
- **Splint for transport** (improves pain control).

- Longitudinal incisions.
  - o Wounds are extended with incisions parallel to the long axis of the extremity, to expose the entire deep zone of injury. At the flexion side of joints, the incisions are made obliquely to the long axis to prevent the development of flexion contractures.
  - o The use of longitudinal incisions, rather than transverse ones, allows for proximal and distal extension, as needed, for more thorough visualization and debridement.
- Wound excision (current use of the term **debridement**).
  - o Skin.
    - ♦ Conservative excision of 1–2 mm of damaged skin edges (Fig. 22-1a).
    - ♦ Excessive skin excision is avoided; questionable areas can be assessed at the next debridement.

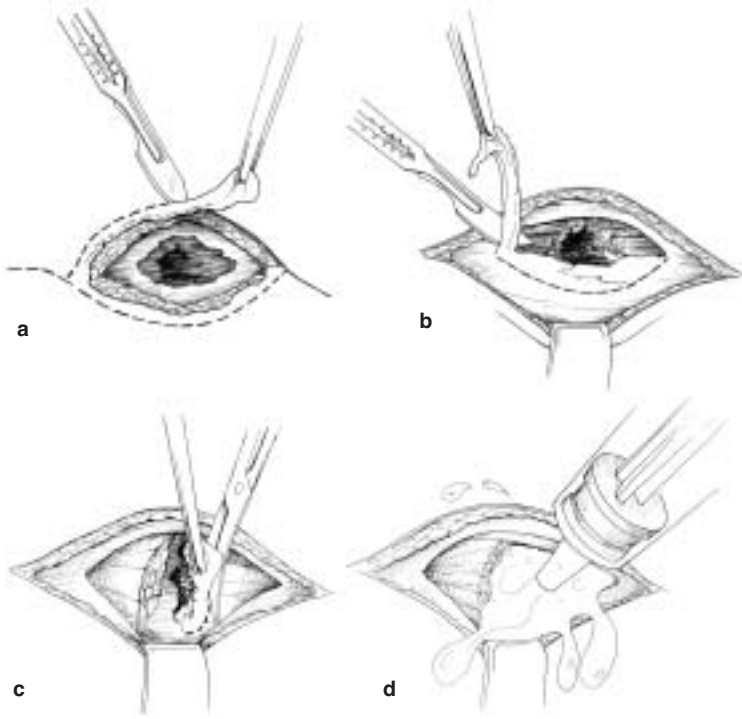

Fig. 22-1. (**a**) Skin excision, (**b**) removal of fascia, (**c**) removal of avascular tissue, (**d**) irrigation.

- o Fat.
  - ♦ Damaged, contaminated fat should be generously excised.
- o Fascia.
  - ♦ Damage to the fascia is often minimal relative to the magnitude of destruction beneath it (Fig 22-1b).
  - ♦ Shredded, torn portions of fascia are excised, and the fascia is widely opened through longitudinal incision to expose the entire zone of injury beneath.
  - ♦ Complete fasciotomy is often required as discussed below.
- o Muscle.

Removal of dead muscle is important to prevent infection. ACCURATE INITIAL ASSESSMENT OF MUSCLE VIABILITY IS DIFFICULT. Tissue sparing debridement is acceptable if follow-on wound surgery will occur within 24 hours. More aggressive debridement is required if subsequent surgery will be delayed for more than 24 hours.

- ♦ Sharply excise all nonviable, severely damaged, avascular muscle (Fig. 22-1c).
- ♦ The "4 Cs" may be **unreliable** for initial assessment of muscle viability (**color**, **contraction**, **consistency**, **circulation**).
  - ◊ Color is the least reliable sign of muscle injury. Surface muscle may be discolored due to blood under the myomesium, contusion, or local vasoconstriction.
  - ◊ Contraction is assessed by observing the retraction of the muscle with the gentle pinch of a forceps.
  - ◊ Consistency of the muscle may be the best predictor of viability. In general, viable muscle will rebound to its original shape when grasped by a forceps, while muscle that retains the mark has questionable viability.
  - ◊ Circulation is assessed via bleeding tissue from a fresh wound. Transient vasospasm, common with war wounds, may not allow for otherwise healthy tissue to bleed.

o Bone.

- ♦ Fragments of bone with soft-tissue attachments and large free articular fragments are preserved.
- ♦ Remove all devitalized, avascular pieces of bone smaller than thumbnail size that have no soft-tissue attachment.
- ♦ Deliver each of the bone ends of any fracture independently, clean the surface and clean out the ends of the medullary canal.

o Nerves and tendons.

- ♦ Do not require debridement, except for trimming frayed edges and grossly destroyed portions.
- ♦ **Primary repair is not performed**. To prevent desiccation, use soft-tissue or moist dressings for coverage.

- Vessels.
  - Only minimal debridement of vessel is required for a successful repair.
- Irrigation.
  - Following surgical removal of debris and nonviable tissue, irrigation is performed until clean (Fig. 22-1d).
  - While sterile physiologic fluid is preferred, do not deplete resuscitation fluid resources. May use potable water as an alternative. The last liter of irrigant should be a sterile solution with antibiotics.
- Local soft-tissue coverage.
  - The development and rotation of flaps for this purpose should not be done during primary surgical wound care.
  - Local soft-tissue coverage through the gentle mobilization of adjacent healthy tissue to prevent drying, necrosis, and infection is recommended. Saline-soaked gauze is an alternative.

No Primary Closure of War Wounds.

- Dressing.
  - **Do not plug the wound** with packing as this prevents wound drainage. Leaving the wound open allows the egress of fluids, avoids ischemia, allows for unrestricted edema, and avoids the creation of an anaerobic environment.
  - Place a nonconstricting, nonocclusive dry dressing over the wound.

Wound Management After Initial Surgery

- The wound undergoes a planned second debridement and irrigation in 24–72 hours, and subsequent procedures until a clean wound is achieved.
- Between procedures there may be better demarcation of nonviable tissue or the development of local infection.
- Early soft-tissue coverage is desirable within 3–5 days, when the wound is clean, to prevent secondary infection.

- Delayed primary closure (3–5 days) requires a clean wound that can be closed without undue tension. This state may be difficult to achieve in war wounds.
- Soft-tissue war wounds heal well without significant loss of function through secondary intention. This is especially true of simple soft-tissue wounds.
- Definitive closure with skin grafts and muscle flaps should not be done in theater when evacuation is possible. These techniques may be required, however, for injured civilians or prisoners of war.

Crush Syndrome

- When a victim is crushed or trapped with compression on the extremities for a prolonged time, there is the possibility for the crush syndrome (CS), characterized by ischemia and muscle damage or death (rhabdomyolysis).
  - With rhabdomyolysis there is an efflux of potassium, nephrotoxic metabolites, myoglobin, purines, and phosphorous into the circulation, resulting in cardiac and renal dysfunction.
  - Reperfusion injury can cause up to 10 L of third-space fluid loss per limb that can precipitate hypovolemic shock.
  - Acute renal failure (ARF) can result from the combination of nephrotoxic substances from muscle death (myoglobin, uric acid) and hypovolemia resulting in renal low-flow state.
- Recognition.
  - History.
    - Suspect in patients in whom there is a history of being trapped (eg, urban operations, mountain operations, earthquakes, or bombings) for a prolonged period (from hours to days).
    - Clear history is not always available in combat, and the syndrome may appear insidiously in patients who initially appear well.
  - Physical findings.
    A thorough examination must be done with attention to extremities, trunk, and buttocks. The physical findings depend on the duration of entrapment, treatment rendered, and time since the victim's release.

- ♦ Extremities.
  - ◊ May initially appear normal just after extrication.
  - ◊ Edema develops and the extremity becomes swollen, cool, and tense.
  - ◊ May have severe pain out of proportion to examination.
  - ◊ Anesthesia and paralysis of the extremities, which can mimic a spinal cord injury with flaccid paralysis, but there will be normal bowel and bladder function.
- ♦ Trunk/buttocks: may have severe pain out of proportion to examination in tense compartments.

o Laboratory findings.

- ♦ Creatinine phosphokinase (CK) is elevated with values usually > 100,000 IU/mL.
- ♦ The urine may initially appear concentrated and later change color to a typical reddish–brown color, so called "port wine" or "iced tea" urine. The urine output decreases in volume over time.
- ♦ Due to myoglobin, urine dipstick is positive for blood, but microscopy will not demonstrate red blood cells (RBCs). The urine may be sent to check for myoglobin, but results take days and should not delay therapy.
- ♦ Hematocrit/hemoglobin (H/H) can vary depending on blood loss, but in isolated crush syndrome H/H is elevated due to hemoconcentration from third spacing fluid losses.
- ♦ With progression, serum potassium and CK increase further with a worsening metabolic acidosis. Creatinine and BUN will rise as renal failure ensues. Hyperkalemia is typically the ultimate cause of death from cardiac arrhythmia.

● Therapy.

o On scene while still trapped.

- ♦ The primary goal of therapy is to prevent acute renal failure in crush syndrome. Suspect, recognize, and treat rhabdomyolysis early in victims of entrapment.
- ♦ Therapy should be initiated as soon as possible, preferably in the field, while the casualty is still trapped. Ideally it is recommended to establish IV access in a free arm or leg vein.

- ◊ Avoid potassium and lactate containing IV solutions.
- ◊ At least 1 L should be given prior to extrication and up to 1 L/h (for short extrication times) to a maximum of 6–10 L/d in prolonged entrapments.

♦ As a last resort, amputation **may** be necessary for rescue of entrapped casualties (ketamine 2 mg/kg IV for anesthesia and use of proximal tourniquet).

o Hospital care.

♦ Other injuries and electrolyte anomalies must be treated while continuing fluid resuscitation, as given above, to protect renal function.

♦ Foley catheter for urine output monitoring.

♦ Establish and maintain urine output > 100 cc/h until pigments have cleared from the urine. If necessary, also

- ◊ Add sodium bicarbonate to the IV fluid (1 amp/L D5W) to alkalinize the urine above a pH of 6.5.
  - ▪ If unable to monitor urine pH, put 1 amp in every other IV liter.
- ◊ Administer mannitol, 20% solution 1–2 g/kg over 4 hours (up to 200 g/d), in addition to the IV fluids.

♦ Central venous monitoring may be needed with the larger volumes (may exceed 12 L/d to achieve necessary urine output) of fluid given.

♦ Electrolyte abnormalities.

- ◊ Hyperkalemia, hyperphosphatemia, hypocalcemia, hyperuricemia must be addressed.

♦ Dialysis.

- ◊ ARF requiring dialysis occurs in 50%–100% of those with severe rhabdomyolysis.

♦ Surgical management centers on diagnosis and treatment of **compartment syndrome**—remember to check torso and buttocks as well.

- ◊ Amputation**:** consider in casualties with irreversible muscle necrosis/necrotic extremity.

♦ Hyperbaric oxygen therapy: may be useful after surgical therapy to improve limb survival.

Compartment Syndrome (see Chapter 27, Vascular Injuries)

- Compartment syndrome may occur with an injury to any fascial compartment. The fascial defect caused by the injury may not be adequate to fully decompress the compartment, and compartment syndrome may still occur.
- Mechanisms of injuries associated with compartment syndrome.
  - o Open fractures.
  - o Closed fractures.
  - o Penetrating wounds.
  - o Crush injuries.
  - o Vascular injuries.
  - o Reperfusion following vascular repairs.
- Early clinical diagnosis of compartment syndrome.
  - o Pain out of proportion.
  - o Pain with passive stretch.
  - o Tense, swollen compartment.
- Late clinical diagnosis.
  - o Paresthesia.
  - o Pulselessness and pallor.
  - o Paralysis.
- Measurement of compartment pressures: **Not recommended, just do the fasciotomy**.
  - o The diagnosis of a compartment syndrome is made on clinical grounds.
  - o Measurement of compartment pressures is not recommended in the combat zone.
- Consider **prophylactic fasciotomy.**
  - o High-energy wounds.
  - o Intubated, comatose, sedated.
  - o Closed-head injuries.
  - o Circumferential dressings or casts.
  - o Vascular repair.
  - o Prolonged transport.
  - o High index of suspicion.

Fasciotomy Technique

- Upper extremity.
  - o Arm: The arm has two compartments:
    The **anterior flexors** (biceps, brachialis) and the **posterior extensors** (triceps).
    - ♦ Lateral skin incision from the deltoid insertion to the lateral epicondyle.
    - ♦ Spare the larger cutaneous nerves.
    - ♦ At the fascial level the intermuscular septum between the anterior and posterior compartment is identified, and the fascia overlying each compartment is released with longitudinal incisions.
    - ♦ Protect the radial nerve as it passes through the intermuscular septum from the posterior compartment to the anterior compartment just below the fascia.
    - ♦ Compartment syndrome in the hand is discussed in Chapter 26, Injuries to the Hands and Feet.
  - o Forearm: The forearm has three compartments:
    The **mobile wad** proximally, the **volar** compartment, and the **dorsal** compartment (Fig 22-2).
    - ♦ A palmar incision is made between the thenar and hypothenar musculature in the palm, releasing the carpal tunnel as needed.
    - ♦ This incision is extended transversely across the wrist flexion crease to the ulnar side of the wrist, and then arched across the volar forearm back to the ulnar side at the elbow.
    - ♦ At the elbow, just radial to the medial epicondyle, the incision is curved across the elbow flexion crease. The deep fascia is then released.
    - ♦ At the antecubital fossa, the fibrous band of the lacertus fibrosus overlying the brachial artery and median nerve is carefully released.
    - ♦ This incision allows for soft-tissue coverage of the neurovascular structures at the wrist and elbows, and prevents soft-tissue contractures from developing at the flexion creases.
    - ♦ A second straight dorsal incision can be made to release the dorsal compartment, reaching proximally to release the mobile wad if necessary.

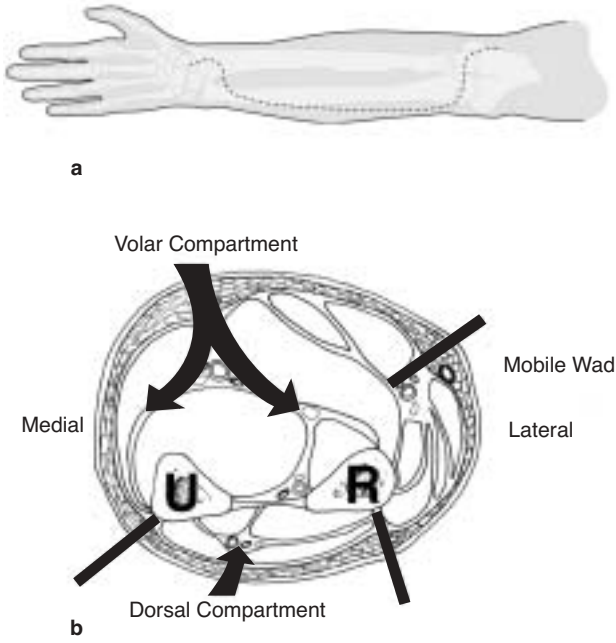

Fig. 22-2. Forearm compartments.

- Lower extremity.
  - o Thigh: The thigh has three compartments:
    The **anterior** (quadriceps), the **medial** compartment (adductors), and the **posterior** compartment (hamstrings).
    - ♦ A lateral incision is made from greater trochanter to lateral condyle of the femur.
    - ♦ Then iliotibial band is incised, and the vastus lateralis is reflected off the intermuscular septum bluntly, releasing the anterior compartment.
    - ♦ The intermuscular septum is then incised the length of the incision, releasing the posterior compartment.
    - ♦ This release of the intermuscular septum should not be made close to the femur, because there are a series of perforating arteries passing through the septum from posterior to anterior near the bone.
    - ♦ The medial adductor compartment is released through

a separate anteromedial incision.

- o Calf: The calf has four compartments:
  The **lateral** compartment, containing peroneal brevis and longus; the **anterior** compartment, containing extensor hallucis longus, extensor digitorum communis, tibialis anterior, and peroneus tertius; the **superficial posterior** compartment, containing gastrocnemius and soleus; and the **deep posterior** compartment, containing the flexor hallucis longus, flexor digitorum longus, and the tibialis posterior (Fig. 22-3).
  - ♦ Two-incision technique.

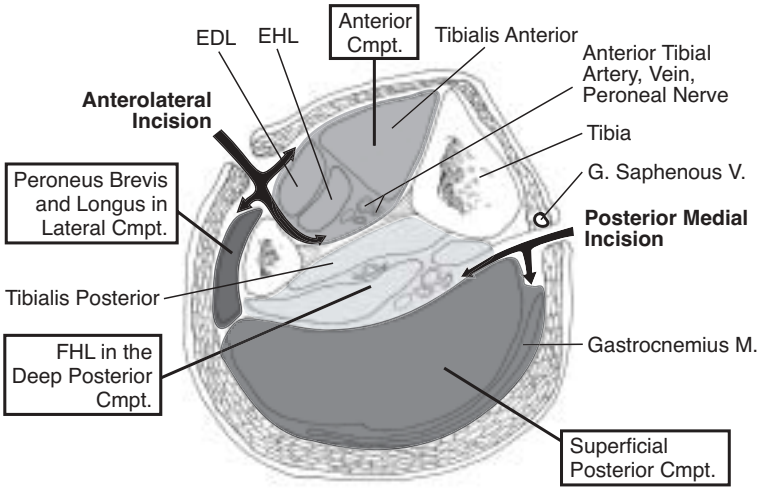

Fig. 22-3. Calf compartments.

- ◊ Incisions must extend the entire length of the calf to release all of the compressing fascia and skin (Fig. 22-4).
- ◊ A lateral incision is made centered between the fibula and anterior tibial crest.
- ◊ The lateral intermuscular septum and superficial peroneal nerve are identified, and the anterior compartment is released in line with tibialis anterior

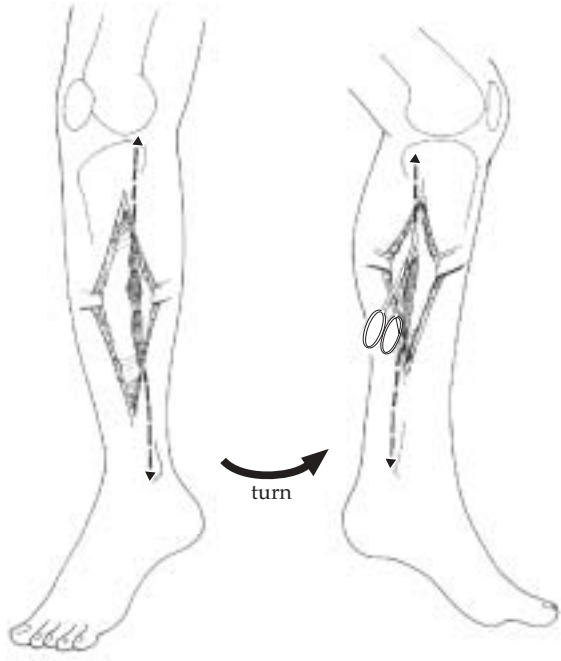

Fig. 22-4. Anteromedial incision of the calf.

muscle, proximally toward the tibial tubercle, and distally toward anterior ankle.

◊ The lateral compartment is then released through this incision in line with the fibular shaft, proximally toward the fibular head, distally toward the lateral malleolus.

◊ A second incision is made medially at least 2 cm medial to the medial-posterior palpable edge of the tibia.

◊ A medial incision over or near the subcutaneous surface of the tibia is avoided, preventing exposure of the tibia when the tissues retract.

◊ The saphenous vein and nerve are retracted anteriorly.

◊ The superficial compartment is released through its length, and then the deep posterior compartment over the FDL is released. Then identify the tibialis posterior and release its fascia.

  - Foot: See Chapter 26, Injuries to Hands and Feet.
- Fasciotomy wound management.
  - Following the fasciotomy, the fasciotomy wound undergoes primary surgical wound management, removing all devitalized tissue.
  - As with all war wounds, the fasciotomy is left open, and covered with sterile dressings.

The treatment of soft tissue injury is the most common denominator in the management of war wounds. This chapter summarizes some principles of this mangement.