Chapter 9

# Soft-Tissue and Open Joint Injuries

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

**Introduction**
The goals in the treatment of soft-tissue wounds are to save lives, preserve function, minimize morbidity, and prevent infection 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. Less than 1 hours from injury is ideal.
  - 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 are unnecessary.

**Surgical Wound Management Priorities**
- Lifesaving procedures have priority over limb and soft-tissue wound care.
- Save limbs.
  - Vascular shunt, bypass, or repair.

- Compartment release (see Chapter 34, Compartment Syndrome).
- Prevent infection.
  - Early antibiotic administration (<1 hour).
  - Wound debridement as early as possible, preferably within 6 hours of wounding (infection is increased 3% per hour when debridement is delayed).
  - Sterile dressing.
  - Fracture immobilization = soft tissue stabilization.
- Superficial penetrating fragment (single or multiple) injuries usually do not require surgical exploration.
  - Wounds should be assessed for the presence of pressurized dirt/debris along with fragments.
  - Limited wound extension may be reasonable to remove deep wound contamination.
  - If there is no significant deep contamination, superficial wounds and skin can be cleansed with antiseptic and scrub brush.
  - Avoid "Swiss cheese" surgery—connection of multiple small wounds into a single surgical wound is preferred over the creation of multiple large wounds that will result in prolonged healing or may limit the ability to accomplish a delayed repair.
  - Maintain high suspicion for vascular injury and concurrent fragment wounding to head, chest, abdomen, and pelvis.

## 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.
  - Extend wounds parallel to the longitudinal axis of the extremity to facilitate deep exposure.

- o Longitudinal incisions allow for proximal and distal extension for more thorough visualization and debridement.
- o Avoid transverse incisions; they do not facilitate subsequent extension if needed.
- o Incise obliquely across flexion creases to prevent flexion contracture.
- Wound excision (current use of the term **debridement**).
  - o Skin.
    - ♦ Perform conservative excision (1–2 mm) of damaged skin edges (Fig. 9-1a).
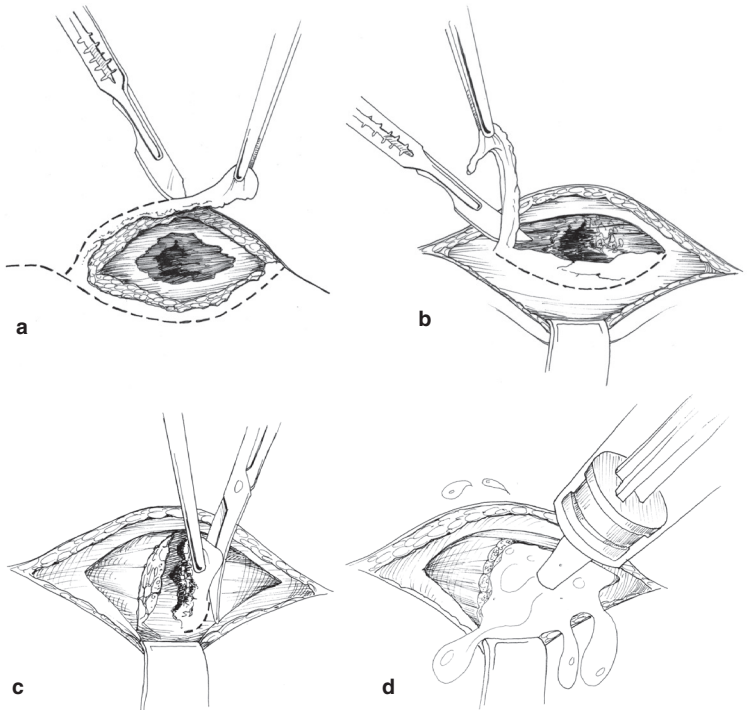    - ♦ Questionable areas can be assessed at the next debridement.



**Fig. 9-1.** (**a**) Skin excision, (**b**) removal of fascia, (**c**) removal of avascular tissue, and (**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. 9-1b).
  - ♦ Shredded, torn portions of fascia are excised, and the fascia is widely opened through a longitudinal incision to expose the entire zone of injury beneath.
  - ♦ Complete fasciotomy should be performed for compartment syndrome.
  - ♦ Limited fasciotomy is reserved for localized fascial injury without evidence of compartment syndrome.
- o Muscle.
  - ♦ Sharply excise all nonviable, severely damaged avascular muscle (Fig. 9-1c).

**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.**

- ♦ The "4 Cs" (**color**, **contraction**, **consistency**, and **circulation**) may be **unreliable** for initial assessment of muscle viability. They should be used together to assist in determining the extent of muscle damage.
  - ◊ **Color**—Assessment may be unreliable when used independently. Surface muscle may be discolored due to blood under the myomysium, contusion, or local vasoconstriction. Muscle at the wound margin may also be transiently hypoperfused in an incompletely resuscitated patient.
  - ◊ **Contraction**—Assessed by observing the retraction of the muscle with the gentle pinch of forceps or a response to electrocautery.

◊ **Consistency**—May be the best predictor of viability. In general, viable muscle will rebound to its original shape when grasped by forceps, whereas muscle that retains indentation from the forceps has questionable viability.

◊ **Circulation**—Assessment 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 vascularized 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.

♦ Remove large fragments of diaphyseal and metadiaphyseal bone that have no soft-tissue attachments, but consider retention of osteoarticular fragments after thorough debridement if they were not grossly contaminated from the wounding mechanism.

♦ 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.

♦ Debridement—Not normally required except frayed edges and resecting grossly destroyed portions.

♦ **Primary repair is not performed**. To prevent desiccation, use soft-tissue or moist dressings for coverage. Mark the ends of the nerve or tendon with a suture (Prolene or other monofilament/nonabsorbable) to facilitate reidentification at later operations.

o Vessels.

(Refer to Chapter 25, Vascular Injuries, for a discussion of considerations in vascular shunting, bypass, and repair.)

♦ Debridement—Generally only a minimal debridement of the vessel is recommended for purposes of decreased infection risk. Priority should be given to restoration of flow to minimize distal tissue ischemia at the time of initial debridement.

- o  Irrigation.
  - ♦ Irrigation should begin after thorough surgical debridement has been accomplished.
  - ♦ Irrigation should be performed until the wound is visibly clean (Fig. 9-1d).
  - ♦ Irrigation volume between 6 and 12 L should be utilized for large, significantly contaminated open wounds.
  - ♦ Low-pressure irrigation is preferred for acute wounds. High pressure may force wound contaminants deeper into soft tissues. Mechanical irrigation may be necessary if wounds have been chronically contaminated.
  - ♦ Sterile physiological fluid (0.9% normal saline) may be used as an alternative when resources are scarce. May consider terminal irrigation with sterile solution (1–2 L).
  - ♦ A sterile, loose, bulky dry dressing is most appropriate for patients being transported through and out of the battlefield.
- o  Negative pressure wound therapy (NPWT).
  - ♦ NPWT devices may be helpful in maintaining an isolated wound environment.
  - ♦ NPWT devices may enhance the local wound environment and vascular permeability for wound healing.
  - ♦ NPWT devices may be placed over split-thickness skin grafts to facilitate graft adherence.
  - ♦ Malfunction of NPWT devices can create an environment with a higher risk of infection. When utilized, NPWT devices need to be checked frequently to ensure operational performance.
  - ♦ Makeshift and improvised NPWT devices should not be used in a combat theater or during aeromedical transport.
- o  Antibiotic beads.
  - ♦ Antibiotic beads are not used for the majority of open wounds.
  - ♦ Antibiotic beads may be helpful in delaying the period of bacterial regrowth after initial debridement.
  - ♦ Antibiotic beads are normally made using 1 g of vancomycin/1.2 g of tobramycin per 40 g of polymethyl-methacrylate (PMMA) cement.

♦ May consider use of PMMA antibiotic beads beneath NPWT devices.
o Local soft-tissue coverage.
♦ The development and rotation of flaps for this purpose should not be done during primary surgical wound debridement.
♦ 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

o Dressing.
♦ Cavitary wounds—Wound may be gently packed with gauze to serve as a wick for fluid egress. **Do not plug the wound** with packing because this prevents wound drainage and creates an anaerobic environment.
♦ Loosely apply circumferential bandages in anticipation of swelling during initial 72 hours postoperative.

**Wound Management After Initial Surgery**
● The wound undergoes a planned second debridement and irrigation in 24–48 hours, and subsequent procedures until a clean wound is achieved.
● The time interval between debridements may be extended to 48–72 hours if NPWT devices are utilized, provided all nonviable tissue and gross contamination has been removed.
● 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 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 host nation casualties.

**Crush Syndrome**
● When a victim is crushed or trapped with compression on the extremities for a prolonged time, there is the possibility for crush syndrome, 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, thus 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 a 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).
    ♦ A 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 the extremities, trunk, and buttocks.
    ♦ 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 with 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 with examination in tense compartments.

o Laboratory findings.

♦ Creatinine phosphokinase (CPK) 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—the so-called "port wine" or "iced tea" urine. Urine output decreases in volume over time.

♦ Due to myoglobin, urine dipstick is positive for blood but microscopy will not demonstrate red blood cells. 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 CPK 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 ARF 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). "Skin to skin" technique with Gigli saw works quickly in this situation.

o Hospital care.

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

♦ Foley catheter for urine output monitoring.

♦ Establish and maintain urine output >100 mL/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, and 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 25, Vascular Injuries, and Chapter 34, Compartment Syndrome)

● Compartment syndrome is an urgent surgical condition.

- Combat extremity injuries are at an elevated risk of developing a compartment syndrome within 48–72 hours postinjury.
- Compartment syndrome may occur with an injury to any fascial compartment: extremities, buttocks, or trunk.
- Compartment syndrome may occur with fascial defects or open wounds. The defect may not be adequate to fully decompress the compartment.
- Compartment syndrome is a clinical diagnosis. Pressure measurement is not necessary or advised in a combat setting.
- All compartments within a surgical-treated extremity should be released. Do not perform single or selective compartment release, especially in the lower leg and forearm.
- Mechanisms of injuries associated with compartment syndrome include the following:
  - Open fractures.
  - Closed fractures.
  - Penetrating wounds.
  - Crush injuries.
  - Vascular injuries.
  - Reperfusion following vascular repairs.
  - Burns/electrical shock.
- Early clinical diagnosis of compartment syndrome.
  - Pain out of proportion with injury and treatment.
  - Tense, swollen compartment.
  - Pain with passive stretch.
- Late clinical diagnosis.
  - Paresthesia.
  - Pulselessness and pallor.
  - Paralysis.
- Treatment: Emergent fasciotomy.
- Measurement of compartment pressures.
  - Not indicated for patients with a clear examination.
  - May be considered for patients who cannot be accurately assessed (obtunded, intubated, sedated, body habitus), with low clinical suspicion, but entering prolonged transport.
- **Consider prophylactic fasciotomy for high index of suspicion and limited capacity for serial examination.**
  - Intubated, comatose, sedated.
  - Closed head injuries.

> o Vascular repair independent of ischemia time.
> o Prolonged transport.

**Fasciotomy Technique**
(See Chapter 34, Compartment Syndrome)
- **Use full-length incisions to ensure that skin and subcutaneous tissues do not constrict the underlying muscle tissue.**
- **Keep fasciotomy wounds covered with moist dressing or an NPWT device. Do not use closure/approximation techniques during the initial fasciotomy if being transported. These may be appropriate to consider if the patient is not transported and can be adequately monitored.**

**For Clinical Practice Guidelines, go to
http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs**