26 MUSCULOSKELETAL TRAUMA

CORE CONCEPTS

- Recognize appendicular skeletal injuries and relate their classification to priority of care.
- State trauma assessment procedures for injuries of the appendicular skeleton.
- Describe hemorrhage in both open and closed fractures of the long bones, pelvis, and ribs.
- Discuss mechanisms of injury, clinical findings, and management of femur fractures.
- State the purpose and procedures of amputations.

INTRODUCTION

Musculoskeletal injuries are common in tactical and garrison environments. Combat-related trauma can result in shattered bones and torn muscles. Many musculoskeletal injuries also occur during physical training and recreational sports. Injuries sustained during impromptu sports (eg, football, basketball, and ultimate Frisbee) are significant contributors to soldiers being placed on a nondeployable status. Through knowledge of the underlying anatomy and physiology (see Limited Primary Care, Chapter 10, Orthopedic Primary Care), **kinematics**, and appropriate medical and trauma management techniques, combat medics can manage new injuries and prevent further injuries or permanent disability.

ASSESSING AND MANAGING MUSCULOSKELETAL INJURIES

Assess and manage life-threatening hemorrhage and injuries that affect the casualty's airway, breathing, and circulation first. When assessing a musculoskeletal extremity injury, consider the mechanism of injury (MOI). Visualize possible primary injuries (most obvious) and secondary injuries (less obvious). The MOI provides important clues to the type and severity of musculoskeletal injuries. The presence of non-life-threatening musculoskeletal injuries may be an indicator of more serious problems. Do not allow musculoskeletal injuries to distract you from assessing for life-threatening injuries. Consider the following possibilities for musculoskeletal injuries:

- If enough force was delivered to **fracture** the humerus, there may also be damage to the chest and lungs.
- A rib fracture or bruising may be signs of serious injury to the thorax or upper abdomen.
- Life-threatening injury may be present if the casualty has lacerations or fractures to the face.

Place musculoskeletal injuries in one of three categories, to help you understand the priority of care:

1. Multisystem, life-threatening trauma with non-life-threatening musculoskeletal trauma (ie, life-threatening injuries and limb fractures).
2. Life-threatening musculoskeletal trauma (ie, pelvic and femur fractures with life-threatening blood loss).
3. Isolated, non-life-threatening musculoskeletal trauma (ie, isolated limb fractures).

After completing the primary survey using MARCH (massive hemorrhage, airway, respirations, circulation, head injuries-hypothermia), and depending on the tactical situation and time until evacuation, proceed to your secondary survey and assess the extremities. If not done during the primary survey, remove the casualty's clothing if the environment allows.

Pain, weakness, or abnormal extremity sensation occurs in most patients with significant musculoskeletal injury. Use DCAP-BTLS (deformities, contusions, abrasions, punctures/penetrations, burns, tenderness, lacerations, and swelling, [Figure 26-1]) for further evaluation.

Figure 26-1. Swelling and bruising still present one month after a grade III high ankle sprain.

Fractures

Combat medics may encounter open (compound) or closed long bone fractures. Open fractures of long bones occur when a high-energy transfer event like a vehicle accident, gunshot wound, or fall breaks a long bone and causes the jagged edges of the bone to pierce through the soft tissue (skin) (Figure 26-2). A closed fracture of long bones can also occur following a high-energy event. In this case, the fractured bone does not pierce through the skin (Figure 26-3). Open fractures have a higher risk of infection. Closed fractures still could be life threatening because the jagged edges of the long bone could sever a major vessel (artery) within that extremity. For example, a femur fracture could result in the loss of 1 to 2 L of blood. Likewise, pelvic fractures can cause severe hemorrhage and may be fatal if a rapid assessment for the presence of a fracture is not complete.

The signs and symptoms of a fracture will vary based on the extent of the injury but will most likely include a combination of the following:

- swelling,
- deformities,
- crepitus,
- limited range of motion,
- pain, and
- loss of distal pulses.

Do not take additional or repetitive steps to reproduce a sign or symptom. By reproducing signs and symptoms of an injury, you could possibly dislodge clots or cause further injury.

Extremity fractures are generally evident in the prehospital setting because of the shortening, deformity, and swelling. Control bleeding with direct pressure or

Figure 26-2. An open fracture with the tibia and fibula emerging from a wound. Photograph by Saltanat. Reproduced from Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Open_fracture_01.JPG

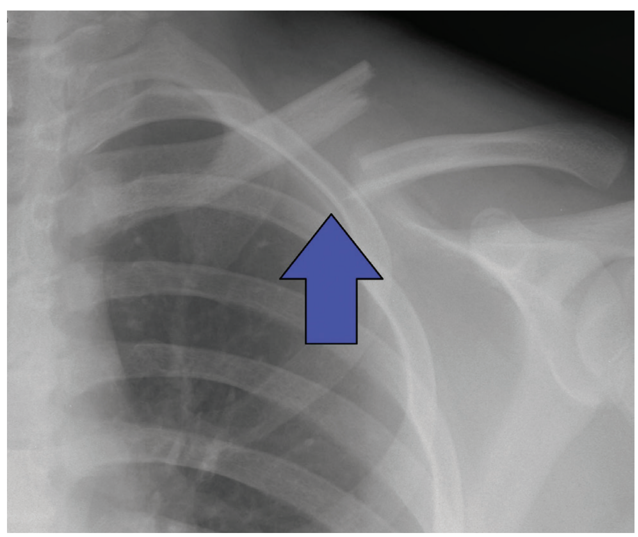


Figure 26-3. A closed fracture of the clavicle. Radiograph by Majorkev, CC BY 3.0. Reproduced from Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Clavicle_Fracture_Left.jpg

tourniquet as indicated. Stabilize or immobilize fractures as soon as possible. Complete a neurovascular pulses, motor, and sensory (PMS) assessment distal to all extremity injuries before and after splinting the extremity. Loss of motor and sensory function usually indicates a nerve injury, while loss of motor and sensory function and pulses indicates a serious arterial and nerve injury.

Midshaft femoral fractures are generally seen in younger patients secondary to high-energy trauma; associated traumatic injuries are common. Muscle contractions can cause bone ends to ride over each other. Clinical features include pain, swelling, deformity, and shortening. Stabilize the fracture by applying gentle pressure with a traction splint to realign the bone. A traction splint will help reduce pain, prevent further fracture comminution, and minimize blood loss. Maintain traction until the patient reaches a higher echelon to prevent further injuries within the limb.

Note: Traction splints are contraindicated in cases of pelvic fracture or in suspected knee or vascular injury. For the latter, splint without traction.

Treat pelvic fracture with a pelvic binder (Figure 26-4), which prevents movement of the pelvis and reduces the possibility of the jagged ends of the bones severing major vessels within the pelvis.

Figure 26-4. A pelvic binder.

Multisystem Trauma

When faced with a severely wounded casualty with extremity injuries, life takes precedence over limb. Focus on maintaining vital functions first by treating life-threatening injuries. Limit measures to address musculoskeletal injuries of the extremities until after all treatable life-threatening injuries are managed.

Amputations and Avulsions

Amputation refers to a severed body part, usually a digit or extremity. A partial amputation refers to a body part that has not been completely detached from the body. Amputation can result from ripping, crushing, or cutting of the tissue, and can cause life-threatening hemorrhage. Avulsions refer to a flap of skin and possible underlying tissue, such as muscle, that have been partially removed or completely torn off. Amputations (Figure 26-5) occur because of high-energy events like exposures to an improvised explosive device (IED) blast. If left untreated, an amputation will lead to death due to hemorrhagic shock.

Figure 26-5. A soldier places a tourniquet on a simulated amputation. Photograph by Sergeant Arjenis Nunez. Reproduced from NARA & DVIDS Public Domain Archive. https://nara.getarchive.net/media/soldiers-with-the-3rd-infantry-division-fasten-a-simulated-a75226

Figure 26-6. A hasty tourniquet.

Figure 26-7. A deliberate tourniquet.

The best approach to treating an amputation is to apply a tourniquet. Tourniquet choice is based on the situation (current phase of tactical combat casualty care) and the severity of the amputation. Place a hasty tourniquet as high on the limb as possible and over the uniform (Figure 26-6). Place a deliberate tourniquet on the skin, 2 to 3 inches above the wound, or 2 to 3 inches above the joint if the joint space falls within 2 to 3 inches above the wound (Figure 26-7).

Note: Amputations require surgical intervention, so place the casualty in the urgent surgical priority for tactical evacuation.

Note: Amputations may not immediately bleed due to vascular spasms of the injured vessels. Always place a tourniquet to control bleeding because when spasms subside, bleeding will occur.

Compartment Syndrome

In compartment syndrome, pressure is exerted against the muscle fascia (the dense connective tissue that envelops the muscles) compartments within the extremity. Muscle fascia has minimal ability to stretch, so increasing pressure in the compartment crushes structures and impairs capillary flow. Tissue served by the impaired capillaries becomes ischemic. Nerves are the most vulnerable and the first to become injured.

Acute compartment syndrome usually results from trauma when arterial blood flow continues into an extremity, but venous flow is restricted from returning to the system. However, a chronic compartment syndrome can also occur and is often seen in athletes with insidious onset of pain.

Consider compartment syndrome if there is a causative MOI and the patient's pain is out of proportion to the injury sustained. Assess the injury using the "classical Ps" to further support and confirm your diagnosis. The classical Ps aid in diagnosing a suspected compartment syndrome in conjunction with a tense, swollen compartment (an early sign). Check for the following:

- **Pain** out of proportion with the injury during passive stretching, or extreme tenderness (early symptom);
- **Pressure** and pain with passive stretch (an early symptom);
- **Paresthesia**—the sensation of pins and needles;
- **Pallor** and **pulselessness**—pale skin or poor capillary refill and diminished or absent pulses in the injured extremity (late signs);
- **Paralysis** or the inability to move (a late sign).

The earliest indicator of developing compartment syndrome is severe pain. Pain that is difficult to control and/or pain that is present with passive stretching are hallmarks of compartment syndrome. Not all classical Ps need to be present to suspect and treat for compartment syndrome.

If you suspect compartment syndrome, loosen tightly applied splints or dressings and reassess for presence of a distal pulse. Tighten tourniquets or apply a second tourniquet directly above the first until the distal pulse becomes undetectable. If possible, administer oxygen (eg, on evacuation platforms, Role 1 or higher).

Note: Hypotensive patients do not tolerate elevated compartment pressure as well as normotensive patients. Correct hypotension and elevate the affected limb to the level of the heart.

Note: The definitive treatment for compartment syndrome is surgical fasciotomy (Figure 26-8), usually done by a medical provider.

Figure 26-8. A surgical fasciotomy with skin transplant performed to relieve the swelling and pressure of compartment syndrome. Photograph by Sarte, CC BY-SA 3.0. Reproduced from Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Fasciotomy_leg.jpg

Crush Syndrome

Crush syndrome (Figure 26-9) occurs when a body part sustains a high degree of force or pressure, usually after being squeezed between two heavy objects.

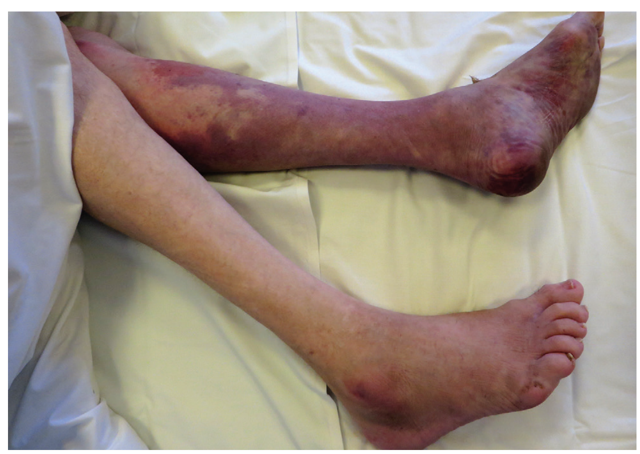


Figure 26-9. A crush injury resulting in tissue necrosis. Photograph by AfroBrazilian, CC-BY-SA-4.0. Reproduced from Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Crush_syndrome_03.JPG

Damaged muscle tissue releases myoglobin and potassium. Crush syndrome is a reperfusion injury that leads to traumatic **rhabdomyolysis**. Myoglobin is a storage site for oxygen within muscle tissue. When released from damaged muscle tissue, myoglobin can damage the kidneys. Elevated potassium levels can cause cardiac arrhythmias. The free myoglobin released during muscle breakdown causes **myoglobinuria**, indicated by dark or cola-colored urine. When the crush pressure is relieved and the injury is reperfused, new blood washes the old blood and accumulated toxins into the circulatory system.

Little may be done for these casualties, especially if the affected body part is still trapped. If possible, achieve vascular access before extrication and provide aggressive fluid resuscitation. Start intravenous (IV) or intraosseous (IO) IV crystalloids IMMEDIATELY (before extrication). Administer an initial 2 L bolus and adjust to the urine output, with a goal of 100 to 200 mL/h. The best way to achieve this is by placing a foley catheter. If a foley catheter is not available, you can improvise and capture urine in a premade or improvised graduated cylinder or canteen.

Contact a medical officer (MO) as soon as possible, even prior to extrication. Tourniquets may delay the life-threating complications of a reperfusion injury if immediate fluid resuscitation or monitoring is not initially available. Consider tourniquet placement for crush injury before extrication if the length of entrapment exceeds 2 hours.

Rhabdomyolysis

Rhabdomyolysis (rhabdo) is a skeletal muscle injury that results in cellular death with resultant leakage of intracellular contents. Common cellular contents that leak include myoglobin, creatinine kinase, and potassium, but there are many more.

The MOI should raise suspicion for rhabdo. Consider compartment syndrome, prolonged muscular compression (eg, crush injury), prolonged immobilizations (eg, backboard), excessive muscular activity (eg, ruck marches and marathon running), strenuous exercise (eg, power lifting, CrossFit), heatstroke, and electrical injuries as potential causes of rhabdo. In addition, alcohol and drugs play a role in up to 80% of rhabdo cases.

Figure 26-10. Secondary blast injuries to the lower extremities. There are two Combat Application Tourniquets on each leg. Reproduced from O'Brien PJ, Cox MW. Stents in tents: endovascular therapy on the battlefields of the global war on terror. *J Surg Radiol*. 2011;Jan 1;2(1). CC BY-SA 3.0, via Wikimedia Commons https://commons.wikimedia.org/wiki/File:Blast_injury-lower_extremities.PNG

Typical signs and symptoms include common muscle aches and stiffness, malaise, muscle tenderness, and myoglobinuria. Nausea, vomiting, abdominal pain, and tachycardia are signs and symptoms of severe cases.

Achieve vascular access and conduct aggressive fluid resuscitation with normal saline prior to evacuation. Definitive diagnosis for this injury requires laboratory studies that assess creatine kinase levels. Patients with rhabdo typically have potassium levels five times higher than normal.

Mangled Extremities

Mangled extremities are significant injuries involving skin, muscle, tendons, bones, vessels, and nerves due to high energy transfer (Figure 26-10). The primary focus is still on addressing life-threatening conditions. Apply tourniquets to control hemorrhage and evacuate the casualty as an urgent surgical priority.

Check on Learning

1. During a fractured extremity assessment, when should you assess distal neurovascular function? What findings indicate a nerve injury and an arterial injury?
2. What is the most common cause of acute compartment syndrome in combat casualties?
3. List the classical Ps of compartment syndrome.
4 Define crush syndrome.
5. What are five common causes of rhabdomyolysis?
6. Your patient has a traumatic amputation of his left leg below the knee from an IED explosion. She has significant blood loss with signs of shock. What is her evacuation category?

IMMOBILIZING BONES AND JOINTS

Before splinting a fractured extremity, manage life-threatening hemorrhage and injuries that affect MARCH. The objective of splinting is to prevent motion in broken bone ends. The nerves that cause the most pain in a fractured extremity lie in the membrane surrounding the bone (periosteum). The broken bone ends irritate these nerves, causing a very deep and distressing type of pain. Splinting not only decreases pain but also eliminates further damage to muscles, nerves, and blood vessels and helps control hemorrhage.

Generally, you should return a fractured extremity to its normal anatomical position before applying a splint. If necessary, use traction to realign an extremity to its normal length (within reasonable clinical judgment). A fracture that is in normal anatomical alignment is easier to splint.

Splinting Considerations

In a life-threatening situation, splint injuries while the patient is being transported. In a hostile environment, there may not be time to splint an injury.

If the tactical situation allows, expose the injury and check distal pulses, movement, and sensation before and after splinting. When an initial assessment is completed and pulses are located, you may mark them with a pen to identify where (radial, dorsalis pedis, posterior tibial) and when they were last checked. If distal pulses are absent, attempt to realign the injured extremity by applying gentle traction. This assists in returning perfusion. However, realigning an extremity to regain a distal pulse should not be the focus of your management. If resistance is encountered, splint the extremity in the position in which it was found.

> **Caution:** An absent pulse distal to an extremity wound is a surgical emergency.

Splints must be long enough to immobilize the joint above and the joint below the injury and rigid enough to keep the bone from moving (Figure 26-11). If possible, use at least four ties (two above and two below the fracture) with nonslip knots to secure the splints (Figure 26-12). If splinting material is not available, use swaths or a combination of swathes and slings to immobilize an extremity with an anatomic splint. Also, consider using elastic bandages for support.

> **Caution:** Do not attempt to place a fractured bone back into the wound. This could cause further injury by cutting into muscle tissue or vessels.

Figure 26-11. A splint. Photograph by Corporal Juan D. Alfonso. Reproduced from DVIDS Hub. https://www.dvidshub.net/image/164074/afghanistan-deployed-corpsmen-sharpen-life- saving-skills

Figure 26-12. Correct use of ties on a splint.

Common Splinting Techniques

There are multiple ways to splint upper extremity injuries. Two of the most common splinting techniques for upper extremity injuries are the sugar tong arm splint and the ulnar gutter splint. However, there are various splinting techniques you can use, depending on the location of the injury.

Sugar Tong Arm Splint

The sugar tong arm splint is used for distal radius and ulna fractures. Use the items listed below to apply a sugar tong arm splint:

- lightweight, flexible splint (eg, SAM splint)
- elastic bandage
- cravats
- 3-inch tape
- trauma shears

Use the following steps to apply a sugar tong splint:

1. Gather and check the required equipment.
2. Don body substance isolation (BSI) items, gloves at a minimum.
3. Remove clothing and equipment as needed to expose the casualty's injury.
4. Visually inspect the casualty's injured forearm against the uninjured forearm and note any abnormalities that would indicate the use of a sugar tong splint.
5. Fold a flexible splint in half.
6. Place the folded splint against the casualty's uninjured arm as a template and adjust the length as necessary.
7. Place the folded splint around the casualty's uninjured elbow so the end of the top half extends past the knuckles.
8. Fold the bottom half down, even with the top.
9. Form a C curve in each half and extend the C curve no more than two-thirds the length of each half. If folded further, it will limit the ability to fold the splint around the elbow.
10. Check the radial pulse of the casualty's injured arm before placing the splint.
11. Apply the splint to the casualty's injured arm.
12. Pinch and fold any excess gap at the bottom of the splint around the casualty's injured elbow to ensure a snug fit.

13. Wrap the casualty's injured arm to secure splinting material in place with an elastic bandage.
    a. Starting at the knuckles, wrap the casualty's fingers together on first wrap.
    b. Wrap around thumb on second wrap, working your way toward the casualty's elbow.
    c. Leave a window in the wrap to provide access for radial pulse assessment.
14. Cover all splint material with the wrap and secure it with 3-inch tape.
15. Check the casualty's pulse once again to ensure proper circulation.

Ulnar Gutter Splint

The ulnar gutter splint is used to immobilize fractures of the 4th and 5th metacarpal (hand). Use the items listed below to apply a sugar tong arm splint:

- lightweight, flexible splint (eg, SAM splint)
- elastic bandage
- cravats
- 3-inch tape
- trauma shears

Use the following steps to apply an ulnar gutter splint:

1. Gather and check equipment.
2. Don BSI, gloves at a minimum.
3. Remove clothing and equipment as needed to expose the casualty's injury.
4. Visually inspect the casualty's injured hand against the uninjured hand and note any abnormalities that would indicate the use of an ulnar gutter splint.
5. Fold the flexible splint in half lengthwise.
6. Extend the splint from the casualty's little finger to the elbow on the uninjured arm.
7. Mold the splint around the casualty's uninjured arm as a template.
8. Have the casualty position their injured arm out, with thumb toward the ceiling.
9. Check radial pulse of the casualty's injured arm before placing the splint.
10. Place the molded splint so that it extends from the tip of the casualty's little finger to the elbow.
11. Make any necessary adjustments to ensure a snug fit and ensure stability.
12. Wrap the casualty's injured arm to secure splinting material in place with an elastic bandage.
    a. Start wrapping at casualty's little finger.
    b. Wrap proximally to the elbow and leave a window in the wrap for access to the casualty's radial pulse.
13. Cover all splinting material and secure the wrap with 3-inch tape.
14. Check the casualty's pulse once again to ensure proper circulation.

Upper Extremity Sling and Swath

A sling and swath may reduce pain and stabilize the injured arm and shoulder more than the splint alone by securing the injured arm in a position close to the body and with little movement allowed. This technique is used for casualty transport and for other situations to further stabilize and reduce painful movement of the injured limb.

Gather two cravats and use the following steps to apply a sling and swath:

1. Unfold one cravat.
2. Tie a small knot in the 90° corner of the material.
3. Ask the casualty to use their uninjured hand to support their injured hand across their chest at about a 45° angle.
4. Place the knot of the cravat at the back of the casualty's elbow (injured arm) to create a pocket for the arm to rest in the sling.
5. Run the inside corner of the cravat under the casualty's arm, straight up over the shoulder of the injured arm, and around the back of the casualty's neck.
6. Run the other corner of the cravat over the outside of the arm and over the shoulder of the casualty's uninjured arm.
7. Tie the two ends together behind the casualty's neck and make sure the knot is not over the casualty's cervical spine.
8. Fold another cravat into a 2-inch band (most cravats come folded this way in the package).
9. Run the cravat circumferentially around the casualty's torso, just above the elbow of the injured arm and extending around the chest of the casualty's uninjured side.
10. Secure the cravat in place with a knot and make sure the knot is not over the casualty's spine.

Pelvic Binder

Pelvic fractures are associated with mortality rates ranging from 9% to 20%. The greatest immediate concern associated with a pelvic fracture is blood loss due to internal bleeding. This is difficult to manage or control, and close monitoring is essential. Treat the casualty for shock as indicated. If a pelvic fracture is suspected, apply a pelvic binder.

The items required to apply a pelvic binder include the following:

- commercial pelvic binder (eg, SAM pelvic sling, SAM Medical, Tualatin, OR)
- cravat
- 3-inch tape

Use the following steps to apply a pelvic binder:

1. Gather and check equipment.
2. Don BSI, gloves at a minimum.
3. Expose the injury site, assess the injury, and check for an exit wound.
4. Slide the belt underneath the casualty's lower back and slide it down until it is centered over the greater trochanter.
5. Route the black strap through the buckle assembly and pull it completely through.
6. Pull the two handles away from each other until you hear an audible click.
7. Fasten excess belt material in place by pressing it down on the hook-and-loop fastener (you may hear a second click once the belt is secure).
8. Secure the device with a nonslip knot by applying a cravat from one handle to the other and extending it around the casualty's back. Secure the tails with tape.

Note: Combat medics may overtighten pelvic binders when in high-stress environments. Use pelvic binders with integrated limits on compression force (eg, no more than 33 lb) to avoid further harming the casualty.

Traction Splint

When a femoral shaft fracture is suspected based on the MOI or exam, a traction splint is indicated. Femoral fractures, like pelvic fractures, can be deadly, due to the severe blood loss associated with this type of injury. You must suspect hemorrhage and monitor the patient for signs of hemodynamic instability and shock and treat appropriately. Contraindications for a traction splint include the following:

- pelvic fracture;
- ipsilateral fracture;
- avulsion or amputation of the ankle, foot, and or lower leg; and
- ipsilateral knee injury.

Note: Although traction is beneficial for femur fracture management, it can harm fractures or ligaments of injuries distal to the femur.

Use the items listed below to apply a traction splint:

- traction pole
- ankle hitch
- ischial strap
- 3 elastic straps
- 3-inch tape

Use the following steps to apply a traction splint:

1. Gather and check equipment.
2. Don BSI.
3. Remove the boot and sock from the casualty's injured leg.
4. Check the pedal pulse of the casualty's injured leg.

Note: If a second rescuer is available, they should support and stabilize the casualty's injured leg to minimize movement while the ankle hitch is applied. When the ankle hitch is applied, they can apply gentle traction to realign the extremity.

5. Apply the ankle hitch tightly around the casualty's injured leg, slightly above the ankle bone.
6. Tighten the stirrup by pulling the green-tabbed strap until the stirrup is snug under the casualty's heel.
7. Apply the ischial strap by sliding the male buckle under the casualty's injured leg at the knee.
8. Move the strap back and forth upward until it is positioned in the casualty's groin area.

Note: The angle of the strap must be at least 45° to apply proper countertraction on the pubic symphysis.

9. Insert the male end of buckle into the female end until a click is heard, signifying the buckle is locked.
10. Cinch the strap until the traction pole receptacle is positioned at the casualty's belt line or pelvic crest.
11. Extend the traction pole. Make sure that each joint of the pole is securely seated.
12. Use the casualty's uninjured leg to measure the proper length for the traction pole.
13. Place the traction pole along the injured leg so that the red marking on the bottom section of the tubing is lined up at or below the bottom of the casualty's foot. This length allows enough space for application of constant traction.

Note: "Before Traction" is sewn into the fabric of a SAM pelvic binder.

14. Insert the pole end into the traction pole receptacle.
15. Secure an elastic strap around the casualty's knee.
16. Place the yellow tab of the ankle hitch over the dart end of the traction pole.
17. Apply traction by pulling the red tab of the ankle hitch.
18. Apply traction smoothly by simultaneously pushing up on the bottom of the traction splint and pulling down on the red tab (with equal pressure).
19. Reassess the casualty's pedal pulse.
20. Use 3-inch tape to secure the red, yellow, and green tabs together to prevent the straps from slipping after traction is applied.
21. Apply a thigh elastic strap and shin elastic strap. Splint as required to further stabilize the injured leg using available options, such as a long spine board, litter, or the uninjured leg.

Note: "After Traction" is sewn into the fabric of a SAM pelvic binder's thigh and shin straps.

8 and U Splint

Ankle fractures or dislocations are common injuries among soldiers. There are numerous ways to immobilize an ankle. Apply a splint and instruct the casualty to avoid bearing weight on the injured ankle until cleared by a medical provider.

Use the items listed below to apply an 8 and U splint:

- 2 lightweight flexible splints
- elastic bandage
- 3-inch tape
- trauma shears

Use the following steps to apply an 8 and U splint:

1. Gather and check equipment.
2. Don BSI, gloves at a minimum.
3. Remove the boot on the casualty's injured foot to access the dorsalis pedis artery.

Note: If the casualty's boot will remain on, cut the boot laces and slide your fingers down the side of the tongue to check the posterior tibial pulse.

4. Obtain a pulse check before applying a lightweight, flexible splint.
5. Use the casualty's uninjured leg as a template to start forming the 8 and U splint.
6. Form the 8 by first forming a U with the splint placed directly under the heel of the casualty's uninjured foot, then form the 8 by folding the splint in opposite directions. Remove the formed 8 and place aside.
7. Using another flexible splint, form a U shape under the casualty's uninjured heel, extending up the lateral and medial aspect of the leg.
8. Transfer both formed splints to the casualty's injured ankle.
9. Apply the 8 over the casualty's foot or boot and secure it in place with a strip of 3-inch tape.
10. Apply the U around the casualty's heel and secure it in place with 3-inch tape. Fold the sides down to adjust if necessary.
11. Using the elastic bandage, place a knot just above the ankle, leaving a tail.
12. Wrap the bandage around the casualty's ankle to create an anchor point. Make sure you leave a window to access the pulse.
13. Use a figure 8 wrap to secure the splinting material in place and secure the wrap with 3-inch tape.

14. Recheck the casualty's pulse after splinting is complete.

Splinting Materials in the Tactical Environment

Commercial splints come in many varieties, but you can improvise splints if necessary. Commercial devices include rigid splints, pressure splints, traction splints, formable splints, vacuum splints, sling and swathe, and long backboards. Improvised splints can be made from boards, poles, sticks, rolled magazines, newspapers, cardboard, blankets, or pillows (Figure 26-13 and 26-14). Avoid using narrow materials such as wire or cord to secure a splint in place. If raw materials are not available, use anatomical splints. Use the casualty's chest wall to immobilize a fractured arm (Figure 26-15). Use the casualty's uninjured leg to immobilize a fractured leg (Figure 26-16). Pad splints to prevent pressure points on bony prominences (see Figure 26-16). You may improvise padding from items such as clothing, blankets, ponchos, and poncho liners.

Figure 26-13. Service members provide aid to an injured hiker by applying an improvised splint using sticks and 550 cord. Note: In general, do not use narrow materials for holding a splint in place. Photograph by Staff Sergeant Alan Ricker. Modified from https://www.dvidshub.net/image/7344165/airmen-sailor-assist-injured-hiker

Figure 26-14. Example of an improvised leg splint using duct tape, wood, and the uninjured leg. Photograph by Joe Loong, CC BY-SA 2.0. Reproduced from flickr.com. https://www.flickr.com/photos/joelogon/13410875953/in/photostream/

Figure 26-15. An arm-to-chest anatomical splint.

Figure 26-16. An anatomical leg splint with padding placed between the injured and uninjured leg.

Check on Learning

7. What are the correct length and consistency of a splint?
8. When treating a casualty with an extremity fracture, you find the distal pulse is absent. What should you do?
9. One of the vehicles in your convoy rolled while trying to avoid an improvised explosive device in the road. One soldier in the vehicle has a closed mid-shaft femur fracture with edema and an absent distal pulse. What is the objective of splinting broken bones in this case?

MEDICATIONS

Analgesic Pain Management

Once the injury is splinted and stabilized, the casualty should experience significant pain relief. Analgesics are recommended for isolated joint and limb injuries but not for patients who have any of the following contraindications:

- unconscious,
- respiratory compromise,
- altered mental status,
- hypoperfusion, or
- known morphine allergies.

Always use the least sedating pain control medication first, provided it is effective. Tactical Combat Casualty Care (TCCC) guidelines give the following analgesic options[1]:

Option 1

Treat mild to moderate pain in casualties who are still able to fight with the pill pack from the TCCC Combat Wound Medication Pack (CWMP). The pill pack includes:

- acetaminophen—500 mg tablet, 2 per os every 8 hours and
- meloxicam—15 mg per os once per day.

Option 2

Treat mild to moderate pain in casualties who are NOT in shock or respiratory distress AND NOT at significant risk of developing either condition with:

- oral transmucosal fentanyl citrate (OTFC)—800 μg and
- a repeated dose after 15 minutes if pain remains uncontrolled.

Option 3

Treat moderate to severe pain in casualties who ARE in hemorrhagic shock or respiratory distress OR ARE at significant risk of developing either condition with:

- ketamine (low dose)—20 to 30 mg (or 0.2–0.3 mg/kg) slow IV or IO push and
  - o repeat doses every 20 minutes as needed for IV or IO.
  - o The end point for low-dose ketamine is control of pain or development of nystagmus (rhythmic back-and-forth movement of the eyes).
- ketamine (high dose)—50 to 100 mg (or 0.5–1 mg/kg) intramuscular (IM) or intranasal (IN) and
  - o repeat doses every 20 to 30 minutes as needed for IM or IN administration.
  - o The end point for high dose ketamine is sleepiness.

If acetaminophen and meloxicam are not effective, and the patient status allows, use fentanyl as the next analgesic. Ketamine is the preferred medication for moderate to severe pain with a combat casualty. Morphine may be available in some circumstances. It is effective in patients who are not at risk of respiratory distress or developing hemorrhagic shock; however, it is no longer part of the current recommendations. Defer to local standard operating procedures or the MO.

Narcotic drugs can cause severe adverse effects, such as respiratory depression. In addition, they are metabolized by the liver and excreted through the kidneys; therefore, use these drugs cautiously in those with hepatic or renal impairment. Finally, because they increase intracranial pressure, these drugs are contraindicated in patients with severe head trauma. Do not give narcotic analgesics without having naloxone (eg, Narcan® nasal spray [Emergent Biosolutions, Plymouth Meeting, PA]) available to reverse the respiratory depression, if required. Remember to document the effect of any drugs given to a casualty.

Antibiotics

Infection is an important cause of morbidity and mortality in battlefield wounds. Assume all open wounds on the battlefield are infected and treat them with antibiotics. Choose antibiotics that cover a broad spectrum of organisms, with specific medications based on available delivery routes. If the casualty is conscious and able to swallow, administer one 400 mg moxifloxacin tablet by mouth each day. If the casualty is unable to take oral medications (due to shock or unconsciousness), administer ertapenem 1 g, IV, IO, or IM once per day.

Check on Learning

10. List the five contraindications for administering analgesics to casualties with musculoskeletal trauma.

SUMMARY

In patients with musculoskeletal trauma, focus first on identifying and managing all life-threatening injuries, including internal or external hemorrhage in the extremities. Then evaluate for distal neurovascular function and support the area of injury. Immobilize injuries to bones and joints (above and below the injury site) prior to moving the casualty. If the casualty is a high priority for evacuation, immobilize the whole casualty on a long spine board. Re-evaluate the injured extremity after immobilization for changes in distal neurovascular function. Provide pain management as needed with attention to the responsiveness, airway, spontaneous ventilation, and cardiovascular function of the casualty; always save a life over a limb.

SUGAR TONG SPLINT

STEP 1: Gather and check the required equipment.

STEP 2: Don body substance isolation (BSI) items.

STEP 3: Remove clothing and equipment as needed to expose the casualty's injury.

STEP 4: Visually inspect the casualty's injured forearm against the uninjured forearm and note any abnormalities that would indicate the use of a sugar tong splint.

STEP 5: Fold a flexible splint in half.

STEP 6: Place the folded splint against the casualty's uninjured arm as a template and adjust the length as necessary.

SUGAR TONG SPLINT, CONT.

STEP 7: Place the folded splint around the uninjured elbow so the end of the top half extends past the knuckles.

STEP 8: Fold the bottom half down, even with the top.

STEP 9: Form a C curve in each half and extend the C curve no more than two-thirds the length of each half.

STEP 10: Check the radial pulse on the casualty's injured arm before placing the splint.

STEP 11: Apply the splint to the casualty's injured arm.

STEP 12: Pinch and fold any excess gap at the bottom of the splint around the casualty's injured elbow to ensure a snug fit.

SUGAR TONG SPLINT, CONT.

STEP 13a: Wrap the casualty's injured arm to secure splinting material in place with an elastic bandage. Starting at the knuckles, wrap the casualty's fingers together on first wrap.

STEP 13b: Wrap around the thumb on the second wrap, working your way toward the casualty's elbow.

STEP 13c: Leave a window in the wrap to provide access for radial pulse assessment.

STEP 14: Cover all splint material with the wrap and secure it with 3-inch tape.

STEP 15: Check the casualty's radial pulse once again to ensure proper circulation.

ULNAR GUTTER SPLINT

STEP 1: Gather and check the required equipment.

STEP 2: Don BSI.

STEP 3: Remove clothing and equipment as needed to expose the casualty's injury.

STEP 4: Visually inspect the casualty's injured hand against the uninjured hand and note any abnormalities that would indicate the use of an ulnar gutter splint.

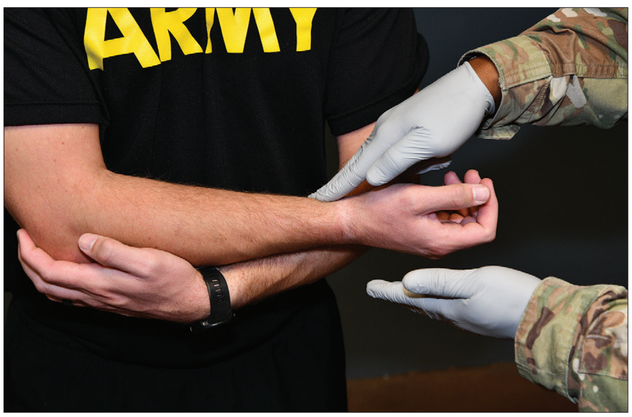
STEP 5: Fold the flexible splint in half lengthwise.

STEP 6: Extend the splint from the casualty's little finger to the elbow on the uninjured arm.

ULNAR GUTTER SPLINT, CONT.

STEP 7: Mold the splint around the casualty's uninjured arm as a template.

STEP 8: Have the casualty position their injured arm out, with the thumb toward the ceiling.



STEP 9: Check radial pulse of the casualty's injured arm before placing the splint.

STEP 10: Place the molded splint so that it extends from the tip of the casualty's little finger to the elbow.

STEP 11: Make any necessary adjustments to ensure a snug fit and stability.

STEP 12a: Wrap the casualty's injured arm to secure splinting material in place with an elastic bandage, starting at the little finger.

ULNAR GUTTER SPLINT, CONT.

STEP 12b: Wrap proximally to the elbow and leave a window in place to access the casualty's radial pulse.

STEP 13: Cover all splinting material and secure the wrap with 3-inch tape.

STEP 14: Check the casualty's pulse once again to ensure proper circulation.

UPPER EXTREMITY SLING AND SWATH

STEP 1: Unfold one cravat.

STEP 2: Tie a small knot in the 90° corner of the material.

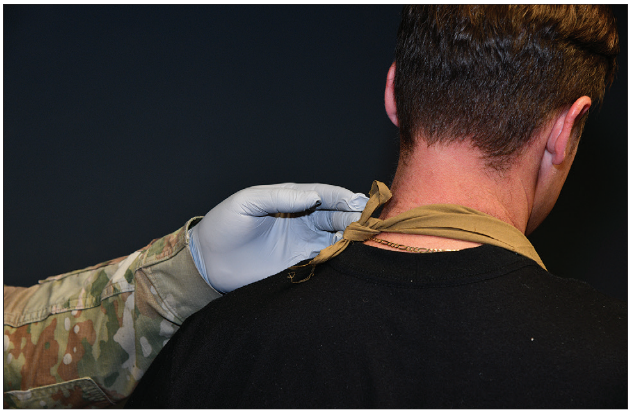
STEP 3: Ask the casualty to use their uninjured hand to support their injured hand across their chest at about a 45° angle.

STEP 4: Place the knot of the cravat at the back of the casualty's elbow (injured arm) to create a pocket for the arm to rest in the sling.

STEP 5: Run the inside corner of the cravat under the casualty's arm, straight up over the shoulder of the injured arm, and around the back of the casualty's neck.

STEP 6: Run the other corner of the cravat over the outside of the arm and over the shoulder of the casualty's uninjured arm.

UPPER EXTREMITY SLING AND SWATH, CONT.



STEP 7: Tie the two ends together behind the casualty's neck and make sure the knot is not over the casualty's cervical spine.

STEP 8: Fold another cravat into a 2-inch band (most cravats come folded this way in the package).

STEP 9: Run the cravat circumferentially around the casualty's torso, just above the elbow of the injured arm and extending around the chest of the casualty's uninjured side.

STEP 10: Secure the cravat in place with a knot and make sure the knot is not over the casualty's spine.

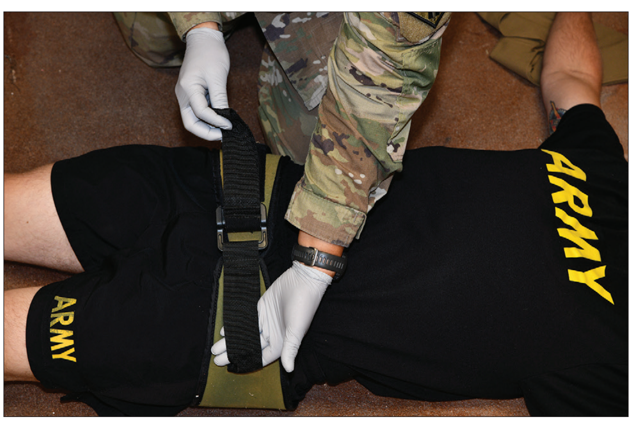
PELVIC BINDER

STEP 1: Gather and check equipment.

STEP 2: Don BSI.

STEP 3: Expose the injury site, assess the injury, and check for an exit wound.

STEP 4: Slide the belt underneath the casualty's lower back and slide it down until it is centered over the greater trochanter.



STEP 5: Route the black strap through the buckle assembly and pull it completely through.

STEP 6: Pull the two handles away from each other until you hear an audible click.

PELVIC BINDER, CONT.

STEP 7: Fasten excess belt material in place by pressing it down on the hook-and-loop fastener (you may hear a second click once the belt is secure).

STEP 8: Secure the device with a nonslip knot by applying a cravat from one handle to the other and extending it around the casualty's back. Secure the tails with tape.

TRACTION SPLINT

STEP 1: Gather and check equipment.

STEP 2: Don BSI.

STEP 3: Remove the boot and sock from the casualty's injured leg.

STEP 4: Check pedal pulse of the casualty's injured leg.

STEP 5: Apply the ankle hitch tightly around the casualty's injured leg, slightly above the ankle bone.

STEP 6: Tighten the stirrup by pulling the green-tabbed strap until the stirrup is snug under the casualty's heel.

TRACTION SPLINT, CONT.

STEP 7: Apply the ischial strap by sliding the male buckle under the casualty's injured leg at the knee.

STEP 8: Move the strap back and forth upward until it is positioned in the casualty's groin area.

STEP 9: Insert the male end of the buckle into the female end until a click is heard, signifying the buckle is locked.

STEP 10: Cinch the strap until the traction pole receptacle is positioned at the casualty's belt line or pelvic crest.

STEP 11: Extend the traction pole. Make sure that each joint of the pole is securely seated.

STEP 12: Use the patient's uninjured leg to measure the proper length for the traction pole.

TRACTION SPLINT, CONT.

STEP 13: Place the traction pole along the injured leg so that the red marking on the bottom section of the tubing is lined up at or below the bottom of the casualty's foot.

STEP 14: Insert the pole end into the traction pole receptacle.

STEP 15: Secure an elastic strap around the casualty's knee.

STEP 16: Place the yellow tab of the ankle hitch over the dart end of the traction pole.

STEP 17: Apply traction by pulling the red tab of the ankle hitch.

STEP 18: Apply traction smoothly by simultaneously pushing up on the bottom of the traction splint and pulling down on the red tab (with equal pressure).

TRACTION SPLINT, CONT.

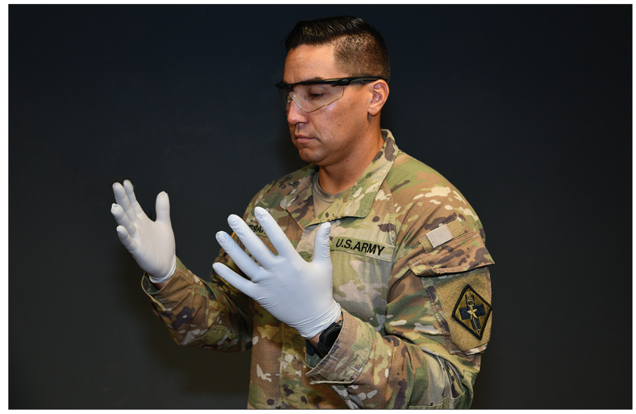
STEP 19: Reassess the casualty's pedal pulse.

STEP 20: Use 3-inch tape to secure the red, yellow, and green tabs together to prevent the straps from slipping after traction is applied.

STEP 21: Apply a thigh elastic strap and shin elastic strap. Splint as required to further stabilize the injured leg.

8 & U SPLINT

STEP 1: Gather and check equipment.



STEP 2: Don BSI.

STEP 3: Remove the boot on the casualty's injured foot to access the dorsalis pedis artery.

STEP 4: Obtain a pulse check before applying a light-weight, flexible splint.

STEP 5: Use the casualty's uninjured leg as a template to start forming the 8 and U splint.

STEP 6: Form the 8 by first forming a U with the splint placed directly under the heel of the casualty's uninjured foot, then form the 8 by folding the splint in opposite directions. Remove the formed 8 and place aside.

8 & U SPLINT, CONT.

STEP 7: Using another flexible splint, form a U shape under the casualty's uninjured heel, extending up the lateral and medial aspect of the leg.

STEP 8: Transfer both formed splints to the casualty's injured ankle.

STEP 9: Apply the 8 over the casualty's foot or boot and secure it in place with a strip of 3-inch tape.

STEP 10: Apply the U around the casualty's heel and secure it in place with 3-inch tape. Fold the sides down to adjust if necessary.

STEP 11: Using the elastic bandage, place a knot just above the ankle, leaving a tail.

STEP 12: Wrap the bandage around the casualty's ankle to create an anchor point. Make sure you leave a window to access the pulse.

8 & U SPLINT, CONT.

STEP 13: Use a figure 8 wrap to secure the splinting material in place and secure the wrap with 3-inch tape.

STEP 14: Recheck the casualty's pulse after splinting is complete.

KEY TERMS AND ACRONYMS

Fracture. A disruption of bone tissue. Fractures may be caused by an application of force exceeding the strength of the bone, repetitive stress, or an invasive process that undermines the bone's integrity.

Kinematics. The study of motion and its required forces. This includes the different forces at work during the movement of a single part of the body and more complex movements such as running and climbing.

Myoglobinuria. Myoglobin (a muscle protein) in urine.

Rhabdomyolysis. A skeletal muscle injury that results in cellular death with resultant leakage of intracellular contents.

CHECK ON LEARNING ANSWERS

1. During a fractured extremity assessment, when should you assess distal neurovascular function? What findings indicate a nerve injury and an arterial injury?

   Assess before and after splinting. Loss of motor and sensory function usually indicates a nerve injury, and loss of distal neurovascular function usually indicates arterial or nerve injury.

2. What is the most common cause of acute compartment syndrome in combat casualties?

   Trauma or interventions placed, such as a tourniquet, that cause the arterial blood flow to continue into an extremity, but venous flow is restricted from returning to the system.

3. List the "classical Ps" of compartment syndrome.

   Pain, pressure, paresthesia, pallor, pulselessness, and paralysis.

4. Define crush syndrome.

   A reperfusion injury leading to traumatic rhabdomyolysis. Damaged muscle tissue releases myoglobin that can damage kidneys and potassium that can cause arrhythmias.

5. What are five common causes of rhabdomyolysis?

   Any five of the following: compartment syndrome, prolonged muscular compression, prolonged immobilization, excessive muscular activity, strenuous exercise, heatstroke, or electrical injuries.

6. Your patient has a traumatic amputation of his left leg below the knee from an IED explosion. She has significant blood loss with signs of shock. What is her evacuation category?

   Urgent surgical.

7. What are the correct length and consistency of a splint?

   Splints must be long enough to immobilize the joint above and below the injury to keep the bones from moving.

8. When treating a casualty with an extremity fracture, you find the distal pulse is absent. What should you do?

   Apply gentle traction in an attempt to realign it. If there is resistance, splint the extremity in the position found.

9. One of the vehicles in your convoy rolled while trying to avoid an improvised explosive device in the road. One soldier in the vehicle has a closed mid-shaft femur fracture with edema and an absent distal pulse. What is the objective of splinting broken bones in this case?

   Splinting decreases pain; eliminates further damage to muscles, nerves, and blood vessels; and helps control hemorrhage.

10. List the five contraindications for administering analgesics to casualties with musculoskeletal trauma.

    Unconscious, respiratory compromise, altered mental status, hypoperfusion, and known morphine allergies.

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