Chapter 8: Extremity Trauma

Objectives:

On completion of this topic, the physician will be able to:

A. Identify life- and/or limb-threatening injuries to the extremities, as well as less serious, but potentially disabling injuries.

B. Outline priorities in the assessment of extremity trauma.

C. Outline the proper principles of initial management for extremity injuries.

D. Demonstrate the ability to assess, assign priorities to, and initially manage injuries on a simulated patient, including application of dressings, splints, and traction splints.
I. Introduction

Extremity trauma is rarely life-threatening by itself, but associated injuries can be. Certain injuries and combinations of injuries to the skeleton may be permanently disabling if not properly managed. Appropriate early management of the patient with extremity injuries can reduce the risks of death and disability. Therefore, this chapter focuses on the initial management of extremity injuries, emphasizing related assessment and management procedures that can have a significant impact on the long-term outcome of patients with extremity trauma.

Extremity injuries that pose an immediate threat to life are those with major, uncontrolled hemorrhage. Although this may be external and obvious, life-threatening blood loss also may be internal and thus occult. This is typical of severe pelvic fractures, bilateral femur fractures, and other multiple closed fractures. Severe crush injuries, with large amounts of necrotic tissue, and contaminated open fractures also are potentially fatal, due to renal failure or overwhelming infection (eg, clostridial gangrene). The same is true for traumatic proximal amputations, which may be incomplete or complete. Presence of major fractures increases the risk of multiple organ failure syndrome. This risk can be reduced by a comprehensive plan for early management, including operative fracture stabilization.

Limb-threatening extremity injuries include vascular injuries with distal ischemia, compartment syndromes with localized neuromuscular ischemia, open fractures, crushing-type injuries, and dislocations of major joints.

Extremity injuries usually involve more than one tissue element. Severity is reflected by the extent of damage to each. Therefore, a severe closed fracture may have significant skin and muscle contusion, possible nerve and/or vessel injury, marked comminution and displacement of bone, and is at increased risk of developing a compartment syndrome. In this chapter, fractures are discussed after other extremity injuries as a reminder not to allow obvious fractures to distract the physician from a full evaluation of the injured limb.

A. Primary Survey and Resuscitation

1. Airway with cervical spine control.
2. Breathing.
3. Circulation with hemorrhage control.
4. Disability; brief neurologic evaluation.
5. Exposure and Environmental control: Completely undress the patient, but prevent hypothermia.

During the primary survey, the extremities are assessed only briefly for obvious bleeding that requires immediate control and to assess perfusion. Patients with an apparently isolated extremity injury should be assessed and managed like any other potential multiple trauma patient. However, additional occult injuries may be present, and evaluation and early
care of extremity injuries must be an integral part of the overall approach to the patient.

**B. Secondary Survey**

The secondary survey is the time for detailed evaluation of the extremities, to determine the specifics of any obvious injury, and to identify other injuries that are less apparent or occult. The order of priority is:

1. Assess perfusion.
2. Identify open wounds.
3. Identify closed wounds, including fractures, joint injuries, and contusions (deformity, swelling, tenderness, instability, and crepitus).
4. Assess neuromuscular function (active motion, sensation).
5. Identify abnormal joint mobility.

Once an open wound is inspected, it should be covered promptly with a sterile dressing. If necessary, a splint is then applied to the involved extremity. Although many roentgenograms may be required, these must not interfere with other, more urgent aspects of the patient's evaluation and management. Most skeletal radiographs can be deferred until the patient has been treated for life- and limb-threatening injuries or transferred to a more appropriate institution, if required. Ultimately, any extremity with signs or symptoms of injury require adequate roentgenograms but these must not interfere with more urgent priorities.

**C. Early Management of Extremity Injuries**

1. Immobilize with splints and/or traction. For example, early application of a traction splint to a femoral shaft fracture reduces internal hemorrhage.
2. Restore limb alignment.
4. Restore perfusion.

**II. Extremity Assessment**

Except in cases of obvious, exsanguinating hemorrhage, evaluation of extremity injuries is carried out during the secondary survey.

**A. History**

Information obtained from the patient, relatives, or bystanders at the accident scene should be documented and included as a part of the patient's medical record. Information, pertinent to the patient's extremity trauma, to consider and inquire about includes:
1. Mechanisms of injury

If the patient is injured in a vehicular crash, this information should be determined, if possible: (1) where the patient was in the vehicle (driver, passenger, seat location); (2) where the patient was found (inside the vehicle or ejected), and if ejected, how far; (3) if the vehicle sustained external damage, eg, front, side, or rear impact; (4) if the vehicle sustained internal damage, eg, steering wheel, dashboard, windshield, etc; and (5) whether a seat belt (lap or shoulder) was worn. Other common mechanisms include vehicle-pedestrian collisions, falls from a height, crushing injuries, and explosions/fires. For each type of injury, efforts should be made to quantify the force of injury in terms of speed, distance, vehicular damage, weight of crushing object, etc, and also the time the injury occurred. (See Resource Document 2, Prehospital Triage Criteria, and Flow Chart 1, Triage Decision Scheme.)

It is essential to estimate the severity of extremity wounds. The injury mechanism provides helpful clues. The most significant issues are the amount of energy absorbed and whether an open wound is present. The actual amount of tissue damage may not be evident until the wound has been explored surgically in the operating room.

2. Environment

Prehospital care personnel should be asked about: (1) patient exposure for any length of time to temperature extremes; (2) patient exposure to toxic fumes or agents; (3) broken glass fragments (which also may injure the examiner); and (4) sources of bacterial contamination (dirt, animal feces, fresh or salt water, etc).

3. Preinjury status and predisposing factors

It is important to determine the patient's baseline condition prior to injury. The patient's overall health, including exercise tolerance and activity level, should be determined. Frequently noted factors that may alter the patient's condition, treatment regimen, and outcome include: (1) ingestion of alcohol and/or other drugs; (2) emotional problems or illnesses; (3) underlying medical illnesses; (4) previous injuries, especially to the same extremity; and (5) allergies.

4. Findings at the incident site

Findings at the incident site that may help the physician identify potential injuries include: (1) the position in which the patient was found; (2) bleeding or pooling of blood at the scene and the estimated amount; (3) bone or fracture ends that may have been exposed; (4) open wounds in proximity to obvious or suspected fractures; (5) obvious deformity or dislocation; and (6) whether or not the patient could move each extremity.

5. Prehospital care

Prehospital observations and care must be reported and documented. Information to obtain, pertinent to extremity injuries, includes: (1) changes in the limb's function, perfusion, or neurologic state; (2) reduction of fractures or dislocations during extrication or splinting at the scene; (3) exposed bone ends that were withdrawn into wounds; (4) dressings and
splints applied; (5) extrication procedures; and (6) any delay incurred at the accident site or en route to the hospital.

**B. Physical Examination**

The patient must be completely undressed for adequate examination. Always compare an injured extremity with the opposite, uninjured one. Assessment of the trauma patient's extremities has three goals: (1) identification of life-threatening injury; (2) identification of limb-threatening injuries; and (3) systematic review to avoid missing any other extremity injury.

1. **Look**

   Visually assess the extremities for: (1) color and perfusion; (2) wounds; (3) deformity (angulation, shortening); and (4) swelling, discoloration, and bruising.

2. **Feel**

   The extremities should be assessed for sensation, tenderness, crepitation (feel carefully but avoid overvigorously), capillary filling, warmth, and especially pulses.

3. **Movement**

   **Active**, voluntary motion confirms the function of a muscle-tendon unit. It is rarely normal if the joints involved are injured. However, presence of some active motion does not guarantee a normal joint. **Passive** motion, by the examiner, is most important for identifying motion that should not exist, as in ligament injuries or unstable, occult fractures. If an obvious injury is present, passive motion maneuvers may be unnecessary, painful, and potentially damaging to local soft tissues.

4. **Pelvic stability**

   A pelvic ring injury may produce potentially, life-threatening hemorrhage, and often is associated with other local injuries. Its subtle signs may not be appreciated on a routine pelvic roentgenograms. To identify a mechanically unstable pelvic ring, grasp the iliac crests anteriorly and attempt to rotate them inward toward the midline, and outward away from it. Any motion is abnormal and confirms the presence of a significant pelvic disruption. (See Chapter 5, Abdominal Trauma.)

**C. Vascular Injuries**

Vascular injuries may result in bleeding or ischemia. Blood loss threatens life. Loss of perfusion distal to an injury threatens survival or function of the injured limb. Brisk bleeding from a wound suggests a major vessel injury. It is notable that complete arterial tears usually bleed less than partial tears, because of the hemostatic contraction and thrombosis of a transected artery. Persistent bleeding is typical of a partial tear. A large hematoma or a neurologic deficit suggests a significant vascular injury.
External bleeding begins at the time and site of injury. The amount of blood shed is not easy to calculate, and the physician may underestimate the degree of prehospital blood loss. Obtaining an accurate history and carefully monitoring the patient's blood volume and response to fluid resuscitation help determine the amount of blood loss. As a rule, hemorrhage from open fractures is far greater than expected.

Closed extremity injuries may produce enough blood loss to cause hypovolemic shock. Patients with multiple closed fractures, particularly those of the femur and pelvis, are at greatest risk. The bleeding may go undetected because it is sequestered in the retroperitoneal space or the injured extremity.

Blood loss from pelvic fractures may be six or more units. Closed femur fractures may account for two or three units of blood loss. However, fractures must not be assumed to be the cause of hypovolemic shock in trauma patients until other sources, particularly abdominal and thoracic, are excluded.

Vascular injuries associated with circulatory impairment represent an immediate or potential threat to limb viability. They must be recognized and managed promptly. In a hemodynamically stable patient, pulse discrepancies, coolness, pallor, paresthesia, hypesthesia, and any abnormality of motor function suggest possible impairment of blood flow to the extremity. Such findings may be due to arterial injury or elevated compartmental pressure with impairment of local capillary perfusion. Examination of distal pulses is crucial for early identification of arterial injuries. The mere presence of pulses does not exclude vascular injury, especially if the pulse is weak or obtained only by Doppler. Any abnormality of distal pulses strongly suggests a vascular injury and must be explained. Diminished pulses or pallor of the skin should not be attributed to vasospasm. It is important to realize that abnormal motor and sensory function may be due to one or more of three potentially coexistent causes - nerve injury, arterial injury, and compartment syndrome.

Vascular injuries are unequivocally indicated by these signs:

1. Brisk, external bleeding.
2. Expanding hematoma (rapid, progressive swelling).
3. Abnormal pulses.

Additional signs that suggest arterial injury are:

4. Bruit or thrill.
5. Pallor.
7. Decreased capillary refill.
8. Relative coolness.
9. Wounds close to the course of a major artery.

10. Decreased sensation.

11. Motor weakness.

12. Progressively increasing pain after immobilization of an extremity injury.

If any of these abnormalities (particularly any change in pulse) persist after aligning and immobilizing the extremity, a careful investigation for possible vascular injury should be undertaken. With all cases of suspected vascular injury, the physician should (1) check the immobilization device, (2) reassess the fracture alignment, and (3) reassess distal perfusion. If distal perfusion remains abnormal, immediate surgical consultation is mandatory.

If a traction device has been applied to an injured extremity with vascular impairment, its status must be assessed and any necessary adjustments must be made. Vascular impairment can result from failure to align a fracture or dislocation, or from excessive traction. If a circular dressing, splint, or cast has been applied, assess for constriction. Release the device if there is any suspicion of its being too tight.

Blood pressure measurement, with or without Doppler assistance, is useful for evaluation of extremity perfusion. Vascular imaging provides important, additional information in the evaluation of a suspected arterial injury. Imaging studies should be considered whenever the diagnosis is in doubt. The surgeon is responsible for determining what, if any, vascular imaging studies are necessary. This is not to say that arteriography is necessary whenever an arterial injury is present. Roentgenographic studies may interfere with life- or limb-saving therapy. When a limb is ischemic, tissue is dying. Immediate surgical treatment is required. If a fracture or joint injury is involved, both vascular and orthopedic surgeons should be consulted immediately.

An associated injury often guides the surgeon to the site of vascular trauma. If needed, the surgeon can obtain an arteriogram rapidly in the operating room. Roentgenograms and angiograms should not be done until the patient's condition is stabilized and the injured extremity is evaluated, dressed, and splinted.

Arteriography is valuable in identifying the site of a vascular injury when more than one is possible and in excluding an occult arterial injury, eg, an incomplete intimal tear that may result in delayed thrombosis with complete arterial occlusion. This is especially likely when a distal pulse remains weak after fracture reduction or after typical injuries, eg, knee dislocations or analogous fractures. If arteriography must be delayed for these patients, careful, frequent clinical monitoring of the injured limb's pulses and neurovascular status is essential. The goal of managing such patients is to identify and treat vascular injuries before irreversible ischemia develops.

D. Traumatic Amputation

Amputation is a catastrophic and obvious extremity injury. As a severe open fracture, all but the most distal amputations represent a significant threat to life and to survival of the
residual limb. Hemostasis and wound care deserve highest priority in limb management. It is important to recognize that some severe open fractures represent incomplete amputations. An early decision is vital if the patient is to be considered a candidate for replantation or revascularization of the injured limb. However, the potential for replantation should not detract from initial assessment and management efforts. Amputation is the best available treatment for some severe, lower extremity injuries. This possibility should be remembered in communications with the patient and family members.

E. Open Wound

Any skin wound near a fracture or joint must be assumed to communicate with a skeletal injury until proven otherwise. There is no doubt that an open fracture exists when bone ends are seen in the wound or roentgenograms show intra-articular air, etc. Probing the wound is an unreliable method to exclude an open fracture and has an associated significant risk of infection. Serious soft-tissue wounds may not involve bones or joints, but they still pose significant threats to the patient and the limb.

Penetrating injuries may produce lacerations with little tissue necrosis. Examples are knife wounds, low-velocity gunshot wounds, and indirectly produced open fractures (spiral fractures in which a sharp bone spike lacerates the skin from inside-out). These wounds have a significant risk of infection if not managed appropriately.

Small skin wounds may be noted after a direct injury, eg, a leg crushed against a bumper by another speeding car. However, such wounds may have considerable amounts of crushed necrotic muscle. Devascularized bone fragments and neurovascular injuries are often present. Degloving injuries, which occur when skin and subcutaneous tissues separate from the underlying muscle, are common. Progressive swelling poses the risk of compartmental syndrome with further local ischemia. In open wounds, there is little correlation between the severity of injury and the size of any associated skin opening. In addition to crush injuries, which may have no skin opening, high-velocity missile wounds, close-range shotgun wounds, and open fractures due to direct trauma are typical mechanisms for severe soft-tissue wounds.

Severe, open wounds are at greater risk for delayed vascular compromise, compartment syndromes, infection, and disturbances of wound and fracture healing. Their prompt identification and proper surgical management improve outcome.

Open fracture wounds are classified according to severity, as discussed later in this chapter. The risk of tetanus is increased in certain wounds: (1) wounds more than six hours old; (2) contused, abraded, or avulsed wounds; (3) wounds more than one centimeter deep; (4) injuries resulting from high-velocity missiles; (5) injuries due to burns or cold; (6) wounds with significant contamination; and (7) wounds with denervated or ischemic tissue. (See Resource Document 6, Tetanus Immunization.)

F. Compartment Syndrome

Whenever interstitial tissue pressure rises above that of the capillary bed, local ischemia of nerve and muscle occurs. Permanent paralysis and/or necrosis may result. The end-stage is called Volkmann's ischemic contracture.
Elevated tissue pressures typically develop within one or more fascial compartments of the leg or forearm, but can involve any such space (thigh, foot, hand, etc). Prompt recognition of a compartment syndrome is essential so that a fasciotomy can be done to release tight muscle compartments, thereby lowering interstitial pressure and restoring perfusion before necrosis occurs.

Compartment syndromes usually develop over a period of several hours and may not be present when the patient first arrives at the hospital. They may be initiated by crush injuries, closed or open fractures, sustained compression of an extremity in a comatose patient, or after restoration of blood flow to a previously ischemic extremity. The pneumatic antishock garment (PASG) may be associated with compartment syndrome, particularly if applied over an injured leg or legs and left inflated for prolonged periods of time. Prolonged application of the PASG on an **uninjured** extremity also may produce a compartment syndrome.

The signs and symptoms of compartment syndrome are: (1) pain, typically increased by passively stretching involved muscles; (2) decreased sensation of nerves traversing the involved compartment; (3) tense swelling of the involved region; and (4) weakness or paralysis of involved muscles. Diminished distal pulses and capillary filling do not reliably identify compartment syndromes, because they may be intact until late in the evolution of a compartment syndrome, after irreversible changes have occurred. Intracompartmental pressure measurement may help diagnose a suspected compartment syndrome. Tissue pressures greater than 35 to 45 mm Hg suggest impaired capillary blood flow, with the need for fasciotomy. When physical examination cannot exclude a compartment syndrome (swollen limb in an unconscious patient), pressure measurements may permit observation rather than fasciotomy. Experienced surgical judgment is required. Some patients with an intact neuromuscular examination may not require fasciotomy, despite transiently elevated pressures. If neuromuscular compromise and tense swelling are present, fasciotomy is urgent, and pressure measurements only delay necessary treatment.

G. Nerve Injury

Assessment of nerve function usually requires a cooperative patient. For each significant peripheral nerve, distal voluntary motor function and sensation must be systematically confirmed. Muscle testing must include palpation of the contracting muscle, as well as assessment of its strength. (See Tables 1 and 2, Peripheral Nerve Assessment of Lower and Upper Extremities.)

**Table 1. Peripheral Nerve Assessment of Lower Extremities**

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Motor</th>
<th>Sensation</th>
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<tbody>
<tr>
<td>Femoral</td>
<td>Knee extension</td>
<td>Anterior knee</td>
</tr>
<tr>
<td>Obturator</td>
<td>Hip adduction</td>
<td>Medial thigh</td>
</tr>
<tr>
<td>Tibial</td>
<td>Toe flexion</td>
<td>Sole of foot</td>
</tr>
<tr>
<td>Superficial peroneal</td>
<td>Ankle eversion</td>
<td>Lateral dorsum of foot</td>
</tr>
<tr>
<td>Deep peroneal</td>
<td>Ankle/toe dorsiflexion</td>
<td>Dorsal first to second toe web</td>
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Superior gluteal  
Inferior gluteal

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Motor</th>
<th>Sensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulnar</td>
<td>Index finger abduction</td>
<td>Little finger</td>
</tr>
<tr>
<td>Median - distal</td>
<td>Thenar contraction</td>
<td>Index finger</td>
</tr>
<tr>
<td>Median - anterior interosseous</td>
<td>Index tip flexion</td>
<td></td>
</tr>
<tr>
<td>Musculocutaneous</td>
<td>Elbow flexion</td>
<td>-</td>
</tr>
<tr>
<td>Radial</td>
<td>Thumb extension / abduction</td>
<td>Dorsal web between thumb and index</td>
</tr>
<tr>
<td>Axillary</td>
<td>Deltoid contraction with shoulder abduction</td>
<td>Lateral shoulder</td>
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</tbody>
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Table 2. Peripheral Nerve Assessment of Upper Extremities

Nerve injuries may be complete, without any motor or sensory function, and with or without any anatomic interruption of the nerve. A significant nerve injury also may be present with only partial loss of function, so that subtle differences deserve further assessment. It is important to remember that impaired sensation and muscle function also may be due to arterial occlusion or compartment syndrome.

H. Joint Injury

Injuries of joints and adjacent structures may be obvious or occult. Even obvious periarticular injuries may be misdiagnosed without careful evaluation, including roentgenograms. Joint injuries include penetrating wounds, dislocations, fracture-dislocations, adjacent fractures, and ligament disruptions that may be complete or partial (sprains). It usually is not possible, without roentgenograms, to differentiate between dislocations and fracture-dislocations, or adjacent fractures.

Local pain and difficulty moving a joint are the most important symptoms of joint injuries. The signs of such an injury are a nearby open wound, deformity, swelling and/or effusion, instability (motion that should not be present), tenderness, impaired motion, and ecchymosis, which usually is delayed. If obvious deformity is present, radiographs are essential before the part is manipulated. Prompt distal nerve and vessel evaluation also is urgent.

In certain injuries, e.g., knee dislocations and severely displaced fractures adjacent to the knee, there is a significant risk of an arterial intimal tear with delayed occlusion that may lead to amputation. An arteriogram is often advisable to exclude such occult arterial injuries. The severe deformity of a dislocated joint may result in necrosis of tightly stretched overlying skin, unless reduction is gained promptly. Prolonged delay in reducing a dislocated hip
increases the risk of avascular necrosis of the femoral head, with associated permanent disability.

All dislocations, even of small joints, are usually painful. They cannot be splinted easily, and pain is difficult to relieve until the dislocation is reduced.

If a joint has no obvious fracture or dislocation, the possibility of an occult ligament injury must be excluded. The physician should assess for abnormal motion - the direction or degree of motion normally prevented by functioning ligaments. For example, in an unstable knee, the leg can be angulated laterally or medially, or there may be excessive anterior or posterior movement of the tibia relative to the femur. Gross instability indicates a major ligament disruption. Pain or lesser degrees of instability also may indicate a significant ligament injury. In children, such instability may be due to an occult growth plate fracture instead of a ligament disruption.

Involvement of a joint by an adjacent wound can be confirmed by attempting to distend the joint with an intra-articular injection of sterile saline solution. Egress of the fluid from the wound confirms communication with the joint.

I. Fractures

Fractures involve not only a broken bone, but the adjacent soft-tissue injury as well. Both injuries must be assessed. Fractures associated with severe soft-tissue injuries (open or closed) have a significant risk of early and delayed complications.

Open fractures are graded according to severity. More severe injuries have absorbed more energy and sustained more soft-tissue damage. (See Table 3, Open Fracture Grading.) Any open fracture may have serious consequences because of the high risk of infection if prompt, appropriate surgical treatment is not provided. Therefore, a careful circumferential inspection of the injured limb is essential to avoid overlooking an inconspicuous wound. If a fracture and wound are in proximity, it should be assumed that the fracture is open, even if the bone cannot be seen in the wound. Exploration of open wounds in the emergency department is inappropriate. Such practices often fail to identify an open fracture and increase wound contamination.

Table 3. Open Fracture Grading

<table>
<thead>
<tr>
<th>Grade</th>
<th>Injury Description/Characteristics</th>
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<tbody>
<tr>
<td>I.</td>
<td>Small skin laceration by tip of spiral (indirect) fracture</td>
</tr>
<tr>
<td>II.</td>
<td>Small to moderate, well-circumscribed wound with little contamination and no significant tissue necrosis or periosteal stripping</td>
</tr>
<tr>
<td>IIIA.</td>
<td>Longer laceration, with significant contused or nonviable tissue, but after debridement, delayed suture or split-thickness skin graft (STSG) can close the wound</td>
</tr>
<tr>
<td>IIIB.</td>
<td>Extensive soft-tissue wound with crush, contamination and/or periosteal stripping; a local or free muscle flap usually is required to close</td>
</tr>
<tr>
<td>IIIC.</td>
<td>An open fracture with a vascular injury that requires repair to salvage limb</td>
</tr>
<tr>
<td>IV.</td>
<td>Total or subtotal amputation.</td>
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</tbody>
</table>
Pain, swelling, deformity, tenderness, instability, and crepitus each suggest a fracture. Roentgenograms in at least two planes (anteroposterior and lateral) are required for evaluation of a suspected fractured extremity. However, it is important to realize that definitive evaluation of an extremity fracture must not interfere with higher priority treatment. If the neurovascular status of the limb is satisfactory, and it is splinted so as to prevent further harm, essential extremity radiographs may be postponed until more pressing care is underway.

Fractures are often missed in patients with multiple or severe trauma. Therefore, it is important to be aware of clues to their diagnosis. The most frequent error is to find only one of several injuries.

J. Associated Injury Patterns

Certain musculoskeletal injuries with common mechanisms occur together often enough that the presence of one should lead to a search for the other.

1. The joints above and below a long-bone fracture are always suspect.

2. Hip and pelvis injuries are frequently associated with femoral shaft fractures, making a pelvis roentgenogram mandatory. Look carefully for a femoral neck fracture, a hip dislocation, an acetabular fracture, or a pelvic ring disruption.

3. Knee injuries may be present with either a femur or tibia fracture. They are especially common when both the femur and tibia are involved ("floating knee" injury), which is a reliable indicator of a severely injured patient.

4. Calcaneal fractures, usually caused by a fall from a height, may have associated vertebral compression or burst fractures.

5. Shaft fractures of the radius or ulna may be associated with injuries of the elbow or wrist joints. A fall onto an outstretched hand may produce injuries at one or more levels in the upper extremity, from the wrist to the shoulder girdle.

K. Occult Skeletal Injuries

Definitive assessment of the multiply injured patient with obvious, life-threatening injuries is a major challenge. Occult fractures and joint injuries may be overlooked easily. Repeated examinations are essential to ensure that all such injuries are identified. The following skeletal regions must be specifically considered.

1. Cervical spine

In cases of head trauma or trauma above the clavicle, cervical spine injuries can be overlooked clinically, especially from C-6 to T-1. They also may be missed roentgenographically or misinterpreted on screening roentgenograms because of the overlying shoulder shadows. Shoulder retraction is necessary and should be routine in obtaining cervical roentgenograms of the trauma patient. If this method fails to demonstrate all seven cervical vertebrae, a swimmer's view should be obtained. An anteroposterior view of the entire
cervical spine is essential as well, if injuries are to be excluded reliably. **Remember,** any injury above the clavicles implies a cervical spine injury until it is definitely excluded.

2. **Pelvis**

Because of its extensive overlying soft-tissue coverage, the pelvis may be seriously injured without obvious external deformity. An anteroposterior screening radiograph and a careful physical examination for tenderness, instability, and leg shortening are essential to avoid overlooking pelvis ring disruptions, acetabular fractures, and dislocations or fractures of the proximal femur.

3. **Knee**

Significant knee injuries with ligamentous instability but with normal-appearing radiographs are easily overlooked, especially in the unconscious patient. All potential knee injuries must be assessed for instability. This is easiest if the patient is unconscious or anesthetized and is more difficult when pain and tenderness are present. If an adequate stress examination is impossible, it should be assumed that the knee is unstable. Orthopedic consultation is then essential.

4. **Shoulder girdle**

Fractures and dislocations involving the clavicle, scapula, and proximal humerus may be overlooked easily. They may be associated with the thoracic injuries. Careful examination of the patient and inspection of the chest roentgenogram aids in identifying shoulder girdle injuries. (See Chapter 4, Thoracic Trauma, Scapular and Rib Fractures.)

5. **Distal injuries**

The wrist, hand, ankle, and foot may sustain one or more easily overlooked injuries with significant functional consequences. Tenderness, swelling, and impaired function are clues to occult injuries. Roentgenograms in multiple projections are helpful, but they may appear normal or be hard to interpret when injuries are primarily ligamentous rather than bony, eg, carpal dislocations at the wrist or tarsometatarsal (Lisfranc's) joint injuries in the midfoot.

6. **Hand injuries**

Space does not permit a complete review of hand injuries in this section. The referenced texts at the conclusion of the chapter should be consulted. Any or several of the complex anatomic structures of the hand may be injured, with little external evidence unless a meticulous examination is carried out. Innocuous wounds may communicate with vital underlying structures. Skin perfusion can be assessed by inspection or pulse oximetry. An injury to the digital nerve that produces distal anesthesia also may involve the adjacent digital artery. Sensation must be assessed systematically in the field of each digital nerve. For initial screening purposes, light touch usually is sufficient. Dislocations and fractures may be obvious, but unless each joint is assessed for tenderness, active and passive motion, and stability, occult injuries may be missed. The function of each tendon must be assessed for
each digit. The extrinsic deep flexors act on the distal interphalangeal (IP) joints, and the superficial flexors act on the proximal IP joints. The long extensors primarily extend (dorsiflex) the metacarpophalangeal (MP) joints, while the intrinsic muscles flex the MP joints and extend the IP joints, as well as abducting (dorsal interossei) and adducting (palmar interossei) the MP joints. (See Table 2, Peripheral Nerve Assessment of the Upper Extremity.) Adequate, skillfully interpreted, roentgenograms are essential for complete evaluation of an injured hand or wrist.

III. Management

A. Vascular Injuries

Bleeding from an injured extremity usually can be controlled by direct pressure, preferably applied over sterile dressings. Occasionally, direct pressure must be applied to a proximal artery. A tourniquet is used only as a last resort, and with the understanding that it may compromise salvage of the distal extremity. Attempts to explore a wound in the emergency department and clamp vessels are ill-advised. Such measures rarely are successful and often result in injury to adjacent structures.

Distal ischemia may be present when a vascular injury occurs. Perfusion must be restored rapidly by correcting hypovolemia and gross limb deformity. Prompt surgical restoration of blood flow, within four to six hours from injury, is essential to salvage a limb with ischemia. Therefore, surgical consultation is the next step in treatment. If obvious ischemia is present, an arteriogram may be unnecessary.

B. Traumatic Amputation

A bulky sterile dressing is applied to the wound, with pressure as needed to control bleeding. Tetanus prophylaxis and antibiotics are given, as for any severe open fracture. Surgical consultation is obtained promptly.

Replantation may be possible. Some patients, particularly those with upper extremity amputations, may be good candidates for replantation. Clean lacerations, rather than crush or avulsion injuries, shorter ischemia times, more distal injuries, and younger, healthier patients have higher replantation success rates.

The technique and equipment for replantation are highly sophisticated, and usually are found only in specialized replantation centers. Patients with amputation injuries require rapid assessment and consultation with a specialized center. The surgeon at the definitive-care facility who will be treating the patient decides whether or not the patient is a candidate for replantation.

If the patient is a candidate for replantation, the amputated part should be carefully preserved and rapidly transported with the patient to the replantation center. Time is of the essence. An amputated part remains viable for only four to six hours at room temperature or up to 18 hours if cooled. The amputated part should be cleansed of any gross dirt or debris, wrapped in a sterile towel moistened with sterile saline, placed in a sterile, sealed plastic bag, and transported in an insulated cooling chest filled with crushed ice and water. Do not allow
the amputated part to freeze, do not place it in dry ice, and make certain that the amputated part accompanies the patient.

If the patient is not a replantation candidate, consider saving some of the amputated parts for grafts to injured areas of the body, including the amputation stump. The treating surgeons make the final decision whether to use such parts.

C. Open Wounds

While minor wounds are routinely treated in the emergency department, major wounds are best treated by a surgeon in the operating room. The same may be true of less extensive wounds in multiply injured patients who require an anesthetic for other injuries. Primary care for such injuries does not require significant efforts at wound toilette in the emergency department. A sterile dressing is applied, and the limb is splinted if necessary. Circumferential dressings must not constrict the limb and interfere with venous drainage. If bone ends are exposed, these may be drawn into the wound to permit correction of gross deformity, and to prevent desiccation. Ensure that the surgical team is informed about all wounds, and the reduction of exposed bone ends. If contamination is significant or a fracture or joint is involved, tetanus prophylaxis and antibiotics are given.

There is no urgency to close open extremity wounds. This may be done after all higher-priority treatment is accomplished. Contaminated wounds need adequate surgical debridement. Delayed closure (five to seven days) reduces the risk of infection.

D. Compartment Syndrome

Once compartmental pressure is high enough to prevent capillary perfusion, irreversible damage occurs to muscles and nerves unless adequate fasciotomy is done within four hours. When symptoms or suspicion of a compartment syndrome are present, all potentially constricting materials, ie, circumferential dressings, casts, etc, must be released. If symptoms do not respond rapidly to external decompression, prompt fasciotomy may be required unless compartment pressure measurements exclude compartment syndrome definitively. Compartmental tissue pressures from 35 to 45 mm Hg may be dangerously elevated. However, other factors are involved, including the duration of ischemia, muscle damage due to blunt trauma, and the difference between mean arterial pressure and intracompartmental pressure. Unless mean arterial pressure is 30 to 40 mm Hg above compartmental tissue pressure, neuromuscular survival is threatened. Immediate surgical consultation is required for a suspected compartment syndrome.

E. Nerve Injury

When a peripheral nerve injury is identified by loss of sensation and motor power, it is important to ensure that the diagnosis is correct and that ischemia (arterial occlusion or compartment syndrome) or central nervous system injuries are not present. Specific emergency treatment for the injured nerve is rarely required, but immediate repair deserves consideration when a clean laceration is the cause of injury. Abundant padding is required when splints are applied to an insensate limb.
F. Joint Injury

Prompt orthopedic consultation should be obtained for all joint injuries. Occasionally the consultant may recommend immediate reduction of a dislocated joint, especially if his examination is delayed. However, reduction of a dislocation should not be attempted without adequate radiographs and preliminary consultation with the orthopedic surgeon. A more or less obvious fracture may be present. All dislocations should be reduced as rapidly as possible. Hip, and occasionally other dislocations, may require a general anesthetic and muscle paralysis for reduction. Since attempts at realignment without reduction may be painful, the limb should be supported in the most comfortable position with pillows, etc.

G. Fractures

1. Open wounds

Any wound associated with a fracture must be managed as if it were an open fracture. Appropriate wound management is essential to minimize the chances of infection which threatens the patient and limb and ultimate functional outcome. Excessive delay risks serious complications. These injuries require consultation and/or transfer to a facility with an orthopedic surgeon.

Primary care involves the removal of only gross contamination from the wound and the prevention of further contamination by applying a sterile dressing. Bulky reinforcement of the dressing is advisable. Open fractures should be aligned with proper splinting techniques. Administer tetanus prophylaxis and appropriate systemic antibiotics without delay.

**Tetanus prophylaxis** is essential for the multiply injured patient, particularly if open extremity trauma is present. Although most individuals in the industrialized world have had adequate antitetanus immunization, some have not, and immigrants from other areas may be less likely to have completed their immunization series. Therefore, it is essential to determine the patient's immunization status, if possible, and to modify treatment as required by both immunization and the nature of the wound. (See Resource Document 6, Tetanus Immunization.)

**Antibiotics**, administered intravenously, are recommended for the care of severe extremity wounds associated with open fractures or joint injuries. For all open fractures it is essential to provide adequate coverage for beta-lactamase-producing staphylococci. Antibiotics for Grade III open fractures should include gram-negative coverage as well. If clostridial contamination is likely, high-dose penicillin should be given, in addition to other agents. Intravenous antibiotics should be started early in the management of open fractures, with the choice determined in consultation with the treating surgeon.

**Proper surgical care remains the mainstay of wound treatment. It is not replaced by antibiotics.**
2. Immobilization

Any fracture or suspected fracture must be immobilized to control pain and prevent further injury. Severely angulated fractures should be aligned first, although alignment should not be forced.

Distal pulses, skin color, temperature, and neurologic status are assessed before and after alignment. Gentle traction, as an adjunct to splinting and to facilitate alignment, is beneficial when immobilizing long-bone fractures. If possible, the splints should extend one joint above and below the fracture site. For dislocations and other joint injuries, immobilize the bone above and below the joint. Roentgenograms, including arteriograms, should not be obtained until the extremity is dressed and splinted. (See IV. Immobilization, in this chapter.)

H. Pain Control

Analgesic drugs may prevent prompt identification of serious but occult problems. Always consider the possibility of intracranial lesions, abdominal trauma, and limb ischemia. Limb ischemia is likely to become progressively more painful until ischemic necrosis causes anesthesia. Immobilization of fractures and prompt reduction of dislocations are the safest and most effective means of controlling pain. If they are not successful, intravenous, short-acting narcotics are appropriate to prevent unnecessary suffering. However, the aforementioned conditions must be excluded first, and a determination must be made as to whether the patient may have taken substances that could potentiate the effects of narcotic analgesics. Intramuscular analgesics should not be administered to a patient who may be in shock with impaired peripheral perfusion, because the drugs are not absorbed at a predictable time and rate. If a painful procedure must be performed, eg, reduction of a dislocated shoulder, small amounts of carefully monitored sedation (eg, a short-acting benzodiazepine) may be required in addition to an intravenous narcotic.

IV. Principles of Immobilization

Splinting of extremity injuries must be deferred until life-threatening problems are identified and managed. However, all such injuries must be splinted before patient transport. Specific types of splints can be applied for specific fracture needs. The pneumatic antishock garment (PASG) has not proved to be an effective or safe splint for extremity injuries, although it may be helpful temporarily for patients with life-threatening hemorrhage from pelvic injuries. A long spine board provides a "total body splint" for multiple injured patients with possible or definite unstable spine injuries. However, its hard, unpadded surface may cause pressure sores on the patient's occiput, scapulae, sacrum, and heels. Therefore, as soon as possible, the patient should be moved carefully to an equally supportive padded surface, using a scoop-style stretcher to facilitate the transfer. The patient should be fully immobilized and an adequate number of personnel should be available during this transfer. (See Chapter 7, Spine and Spinal Cord Trauma and Skill Station XI, Immobilization Techniques for Neck and Spinal Trauma.)
A. Femoral Fractures

Femoral fractures are best provisionally immobilized with traction splints. The traction splint's force is applied distally at the ankle. Proximally, the splint is secured to the thigh and hip area. Traction splints may be used for ipsilateral femoral and tibial fractures. Excess traction may cause skin damage to the foot or ankle, perineal injury, and neurovascular compromise from pressure stretching of anatomic structures. Hip fractures can be similarly immobilized with a traction splint, especially if the leg is shortened and malrotated. Alternatively, the injured leg is merely secured to the other leg and/or the stretcher. Hip dislocations may produce a fixed deformity. If gentle realignment of the limb with manual traction is not possible, pillows or other bulky padding and tape may be used to support the limb in the most comfortable position.

B. Knee Injuries

A long-leg splint, a traction-type splint applied with minimal traction, or a commercial knee-immobilizator may be used to support the injured knee. Additional stability is provided by splinting the opposite leg. Padding may be needed to maintain some knee flexion.

C. Tibia Fractures

Tibia fractures are best immobilized with a well-padded board or metal gutter, long-leg splint. A gently inflated pneumatic splint also is good. For proximal fractures, a traction-type splint can be used, but beware of excessive traction. When aligning a tibial fracture in a splint, make sure that rotation is correct.

D. Ankle Fractures

Ankle fractures may be immobilized with a pillow splint or padded-board splint, avoiding pressure over bony prominences. Assess the neurovascular status before and after the splint is applied.

E. Upper Extremity and Hand Injuries

The hand can be temporarily splinted in an anatomic, functional position, with the wrist slightly dorsiflexed and the fingers gently flexed. This position usually can be achieved by gently immobilizing the hand over a large role of gauze, and using a short arm splint as well.

The forearm and wrist are immobilized flat on padded or pillow splints.

The elbow is splinted in a flexed position, either by using padded splints or by direct immobilization to the body with a sling and swath device.

The arm is immobilized by splinting to the body or simple application of a sling or swath, which can be augmented with splints for unstable fractures.
Shoulder injuries are managed similarly, using bulky padding as necessary.

Circumferential bandages, used to apply molded and padded, splints, can have a tourniquet effect. The extremity must be monitored frequently for vascular compromise. All splints must be padded over bony prominences.

All jewelry, including rings, bracelets, etc, must be removed before splinting any extremity injury to prevent pressure on the area and circulatory embarrassment.
V. Summary

The initial assessment and management of extremity trauma are part of the secondary survey in the management of the multiply injured patient. Life-threatening situations must be properly assessed and managed before attention is directed to the injured extremity. The extremity can sustain a variety of injuries, from sprains and fractures to traumatic amputation. It is essential to recognize arterial injuries, compartment syndromes, open fractures, and crush or other severe injuries promptly to assure timely treatment.

A knowledge of the mechanism of injury and history of the injury-producing event enables the physician to diagnose and properly manage the injured extremity. Early alignment of fractures and dislocations and proper splinting techniques can prevent serious complications and late sequelae of extremity trauma. In addition, an awareness of the patient's tetanus immunization status, particularly in cases of open fractures, can prevent serious complications. The astute physician, armed with the proper knowledge and skills, can satisfactorily provide the initial management for most extremity trauma.

In the multiply injured patient with extremity trauma, urgent operative fixation of fractures within the first 24 hours may reduce mortality and morbidity. It is essential to obtain orthopedic consultation early in the patient's management.
Skill Station XII: Principles and Techniques of Immobilization for Extremity Trauma

Resources and Equipment

This list is the recommended equipment to conduct this skill session in accordance with the stated objectives for and intent of the procedures outlined. Additional equipment may be used providing it does not detract from the stated objectives and intent of this skill, or from performing the procedure in a safe method as described and recommended by the ACS Committee on Trauma.

1. Live patient model.
2. Leg traction splint (type used in individual locale).

Objectives

Upon completion of this station, the participant will be able to:

1. Discuss principles associated with immobilizing extremity injuries.
2. Demonstrate the technique for properly applying a leg traction splint.
3. Identify when the patient's injured extremity has been properly immobilized in accordance with the principles and techniques outlined in this skill station.
Skill Procedure: Principles and Techniques of Immobilization for Extremity Trauma

Note: Universal precautions are required whenever caring for the trauma patient.

Goal of Splinting: Prevent further injury, and control pain and bleeding.

I. Principles of Extremity Immobilization

A. Assess the ABCs and treat life-threatening situations first.

B. Remove and/or cut open all clothing on the extremity. Remove watches, rings, bracelets, and potentially constricting devices.

C. Assess the neurovascular status of the extremity before applying the splint. Assess for pulses, external hemorrhage, and if possible, motor and sensory function. (See Tables 1 and 2 in this chapter.)

D. Dress any open wounds.

E. Select the appropriate size and type of splint for the injured extremity. The device should extend one joint above and one joint below the injured site.

F. Apply padding over bony prominences that will be covered by the splint.

G. Apply gentle distal and proximal traction to align the extremity before and during application of the splint. Gentle traction should be maintained until the splinting device is secured.

H. Continue to monitor the neurovascular status of the injured extremity.

I. Do not force realignment of deformities near a joint.

J. Obtain orthopedic consultation, especially for fracture-dislocations of the joints.
II. Application of the Leg Traction Splint

A. One person should handle the injured extremity, and another should handle the application of the splint.

B. Measure the unaffected leg with the traction splint.

1. The upper cushioned ring should be placed right under the buttocks and adjacent to the ischial tuberosity.

2. Two support straps should be above the knee and two below the knee.

C. Cut away clothing (including all foot wear) to expose the injured site. Dress any open wounds.

D. The first assistant supports the leg, while the second assistant removes the shoe and sock to assess distal circulation and pedal pulses.

E. The first assistant applies manual traction to the leg, while maintaining support under the fracture site and the calf.

F. Reassess the distal pulse after applying manual traction.

G. While the first assistant maintains manual traction on the leg, the second assistant applies the ankle hitch around the patient's ankle and upper foot. The bottom strap should be the same length or preferably shorted than the two upper cross straps.

H. Gently lift the fractured limb, while maintaining support and traction. Slide the splint under the affected leg, placing the padded upper ring snugly against the ischial tuberosity.

I. Gently lay the leg on the splint, and extend the leg elevator. Snugly attach the top strap first.

J. While continuing to support the leg and maintain traction, attach the ankle hitch to the traction hook.

K. Apply traction gently to the leg by turning the windlass know until the extremity appears stable, or in the conscious patient, until pain and spasm are relieved.

L. Reassess the distal, pedal pulses.

M. Secure the remaining straps, making sure they are not too tight.

N. Continually reassess the circulation of the affected limb.