The amputated part should be thoroughly washed in isotonic solution (e.g., Ringer’s lactate) and wrapped in sterile gauze that has been soaked in aqueous penicillin (100,000 units in 50 mL of Ringer’s lactate solution). The amputated part is then wrapped in a similarly moistened sterile towel, placed in a plastic bag, and transported with the patient in an insulated cooling chest with crushed ice. Care must be taken not to freeze the amputated part.

**COMPARTMENT SYNDROME**

**Injury**

Compartment syndrome develops when the pressure within an osteofascial compartment of muscle causes ischemia and subsequent necrosis. This ischemia may be caused by an increase in compartment size (e.g., swelling secondary to revascularization of an ischemic extremity) or by decreasing the compartment size (e.g., a constrictive dressing). Compartment syndrome may occur in any site in which muscle is contained within a closed fascial space. (Remember, the skin also may act as a restricting membrane in certain circumstances.) Common areas for compartment syndrome include the lower leg, forearm, foot, hand, gluteal region, and thigh (Figure 8-4).

The end results of unchecked compartment syndrome are catastrophic. They include neurologic deficit, muscle necrosis, ischemic contracture, infection, delayed healing of a fracture, and possible amputation.

**Assessment**

Any injury to an extremity has the potential to cause a compartment syndrome. However, certain injuries are considered high risk, including:

- Tibial and forearm fractures
- Injuries immobilized in tight dressings or casts
- Severe crush injury to muscle
- Localized, prolonged external pressure to an extremity
- Increased capillary permeability secondary to reperfusion of ischemic muscle
- Burns
- Excessive exercise

The key to the successful treatment of acute compartment syndrome is early diagnosis. A high degree of awareness is important, especially if the patient has an altered mental sensorium and is unable to respond appropriately to pain. See Skill Station XII: Musculoskeletal Trauma: Assessment and Management, Skill XII-E: Compartment Syndrome: Assessment and Management.

The signs and symptoms of compartment syndrome include:

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**Figure 8-4** Compartment Syndrome. Develops when the pressure within an osteofascial compartment of muscle causes ischemia and subsequent necrosis. (A) Normal call. (B) Calf with compartment syndrome.
• Increasing pain greater than expected and out of proportion to the stimulus
• Palpable tenueness of the compartment
• Asymmetry of the muscle compartments
• Pain on passive stretch of the affected muscle
• Altered sensation

Absence of a palpable distal pulse usually is an uncommon finding and should not be relied upon to diagnose compartment syndrome. Weakness or paralysis of involved muscles and loss of pulses (because the compartment pressure exceeds the systolic pressure) in the affected limb are late signs of compartment syndrome.

Remember, changes in distal pulses or capillary refill times are not reliable in diagnosing compartment syndrome. Clinical diagnosis is based on the history of injury and physical signs, coupled with a high index of suspicion.

Intracompartmental pressure measurements may be helpful in diagnosing suspected compartment syndrome. Tissue pressures that are greater than 30 to 45 mm Hg suggest decreased capillary blood flow, which may result in increased muscle and nerve damage caused by anoxia. Systemic blood pressure is important: the lower the systemic pressure, the lower the compartment pressure that causes a compartment syndrome. Pressure measurement is indicated in all patients who have an altered response to pain.

Management

All constrictive dressings, casts, and splints applied over the affected extremity must be released. The patient must be carefully monitored and reassessed clinically for the next 30 to 60 minutes. If no significant changes occur, fasciotomy is required. Compartment syndrome is a time-dependent condition. The higher the compartment pressure and the longer it remains elevated, the greater the degree of resulting neuromuscular damage and functional deficit. Delay in performing a fasciotomy may result in myoglobinuria, which may cause decreased renal function. Surgical consultation for diagnosed or suspected compartment syndrome must be obtained early.

NEUROLOGIC INJURY SECONDARY TO FRACTURE-DISLOCATION

Injury

Fractures and particularly dislocations may cause significant neurologic injury because of the anatomic relationship and proximity of the nerve to the joint—for example, sciatic nerve compression from posterior hip dislocation or axillary nerve injury from anterior shoulder dislocation. Optimal functional outcome is jeopardized unless this injury is recognized and treated early.

Assessment

A thorough examination of the neurologic system is essential in patients with musculoskeletal injury. Determination of neurologic impairment is important, and progressive changes must be documented.

Assessment usually demonstrates a deformity of the extremity. Assessment of nerve function usually requires a cooperative patient. For each significant peripheral nerve, voluntary motor function and sensation must be confirmed systematically (Tables 8-2 and 8-3). Muscle testing must include palpation of the contracting muscle.

In most patients with multiple injuries, it is difficult to initially assess nerve function. However, assessment must be repeated on an ongoing basis, especially after the patient is stabilized. Progression of neurologic findings is indicative of continued nerve compression. The most important aspect of any neurologic assessment is the documentation of progression of neurologic findings. It also is an important aspect of surgical decision making.

Management

The injured extremity should be immobilized in the dislocated position, and surgical consultation obtained immediately. If indicated and if the treating doctor is knowledgeable, a careful reduction of the dislocation may be attempted. After reducing a dislocation, neurologic function should be reevaluated and the limb splinted.

Other Extremity Injuries

Other significant extremity injuries include contusions and lacerations, joint injuries, and fractures.

CONTUSIONS AND LACERATIONS

Simple contusions and/or lacerations should be assessed to rule out vascular and/or neurologic injury. In general, lacerations require debridement and closure. If a laceration extends below the fascial level, it requires operative
TABLE 8-2  Peripheral Nerve Assessment of Upper Extremities

<table>
<thead>
<tr>
<th>NERVE</th>
<th>MOTOR</th>
<th>SENSATION</th>
<th>INJURY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulnar</td>
<td>Index finger abduction</td>
<td>Little finger</td>
<td>Elbow injury</td>
</tr>
<tr>
<td>Median distal</td>
<td>Thenar contraction with opposition</td>
<td>Index finger</td>
<td>Wrist dislocation</td>
</tr>
<tr>
<td>Median, anterior interosseous</td>
<td>Index tip flexion</td>
<td>Supracondylar fracture of humerus (children)</td>
<td></td>
</tr>
<tr>
<td>Musculocutaneous</td>
<td>Elbow flexion</td>
<td>Lateral forearm</td>
<td>Anterior shoulder dislocation</td>
</tr>
<tr>
<td>Radial</td>
<td>Thumb, finger metacarpophalangeal extension</td>
<td>First dorsal web space</td>
<td>Distal humeral shaft, anterior shoulder dislocation</td>
</tr>
<tr>
<td>Axillary</td>
<td>Deltoid</td>
<td>Lateral shoulder</td>
<td>Anterior shoulder dislocation, proximal humerus fracture</td>
</tr>
</tbody>
</table>

TABLE 8-3  Peripheral Nerve Assessment of Lower Extremities

<table>
<thead>
<tr>
<th>NERVE</th>
<th>MOTOR</th>
<th>SENSATION</th>
<th>INJURY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral</td>
<td>Knee extension</td>
<td>Anterior knee</td>
<td>Pubic ramus fractures</td>
</tr>
<tr>
<td>Obturator</td>
<td>Hip adduction</td>
<td>Medial thigh</td>
<td>Obturator ring fractures</td>
</tr>
<tr>
<td>Posterior tibial</td>
<td>Toe flexion</td>
<td>Sole of foot</td>
<td>Knee dislocation</td>
</tr>
<tr>
<td>Superficial peroneal</td>
<td>Ankle eversion</td>
<td>Lateral dorsum of foot</td>
<td>Fibular neck fracture, knee dislocation</td>
</tr>
<tr>
<td>Deep peroneal</td>
<td>Ankle/foot dorsiflexion</td>
<td>Dorsal first to second web space</td>
<td>Fibular neck fracture, compartment syndrome</td>
</tr>
<tr>
<td>Sciatic nerve</td>
<td>Plantar dorsiflexion</td>
<td>Foot</td>
<td>Posterior hip dislocation</td>
</tr>
<tr>
<td>Superior gluteal</td>
<td>Hip abduction</td>
<td></td>
<td>Acetabular fracture</td>
</tr>
<tr>
<td>Inferior gluteal</td>
<td>Gluteus maximus hip extension</td>
<td></td>
<td>Acetabular fracture</td>
</tr>
</tbody>
</table>

intervention to more completely debride the wound and assess for damage to underlying structures.

Contusions usually are recognized by pain in the area and decreased function of the extremity. Palpation confirms localized swelling and tenderness. The patient usually cannot use the muscle or experiences decreased function because of pain in the affected extremity. If the patient is seen early, contusions are treated by limiting function of the injured part and applying cold packs.

Small wounds, especially those resulting from crush injuries, may be significant. When a very strong force is applied very slowly over an extremity, significant devascularization and crushing of muscle may occur with only a small skin wound. Crush and degloving injuries can be very subtle and must be suspected based on the mechanism of injury.

The risk of tetanus is increased with wounds that: (1) are more than 6 hours old, (2) are contused and/or abraded,
JOINT INJURIES

Injury
Joint injuries that are not dislocated (ie, the joint is within its normal anatomic configuration but has sustained significant ligamentous injury) usually are not limb-threatening. However, such joint injuries may decrease the function of the limb.

Assessment
With joint injuries, the patient usually reports some form of abnormal stress to the joint—for example, impact to the anterior tibia that pushed the knee back, impact to the lateral aspect of the leg that resulted in a valgus strain to the knee, or a fall onto an outstretched arm that caused a hyperflexion injury to the elbow.

Physical examination reveals tenderness throughout the affected ligament. A hematoma usually is present unless the joint capsule is disrupted and the bleeding diffuses into the soft tissues. Passive ligamentous testing of the affected joint reveals instability. X-ray examination usually reveals no significant injury. However, some small avulsion fractures from ligamentous insertions or origins may be present radiographically.

Management
Joint injuries should be immobilized. The vascular and neurologic status of the limb distal to the injury should be reassessed. Surgical consultation usually is warranted.

FRACTURES

Injury
Fractures are defined as a break in the continuity of the bone cortex. They may be associated with abnormal motion, some form of soft tissue injury, crepitus, and pain. A fracture can be open or closed.

Assessment
Examination of the extremity demonstrates pain, swelling, deformity, tenderness, crepitus, and abnormal motion at the fracture site. The evaluation for crepitus and abnormal motion at the fracture site may occasionally be necessary to make the diagnosis, but this is painful and may potentially increase soft tissue damage. These diagnostic tests must not be done routinely or repetitively. Usually the swelling, tenderness, and deformity are sufficient to confirm a fracture. It is important to periodically reassess the neurovascular status of a limb, especially if a splint is in place.

Principles of Immobilization

Splinting of extremity injuries, unless associated with life-threatening injuries, usually can be accomplished during the secondary survey. However, all such injuries must be splinted before a patient is transported. Assess the limb's neurovascular status after applying splints or realigning a fracture.

Specific types of splints can be applied for specific fracture needs. The pneumatic antishock garment (PASG) is not generally recommended as a lower-extremity splint. However, it may be temporarily useful for patients with life-threatening hemorrhage from pelvic injuries or severe lower-extremity injuries with soft tissue injury. Prolonged inflation (>2 hours) of the leg components in patients with hypotension may lead to compartment syndrome.

A long spine board provides a total body splint for patients with multiple injuries who have possible or confirmed 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 or an appropriate logrolling maneuver to facilitate the transfer. The patient should be fully immobilized, and an adequate number of personnel should be available during this transfer. See Skill Station XII: Spinal Cord Injury: Assessment and Management, and Skill Station XII: Musculoskeletal Trauma: Assessment and Management, Skill XII-B: Principles of Extremity Immobilization.

FEMORAL FRACTURES

Femoral fractures are immobilized temporarily with traction splints (Figure 8-5). The traction splint's force is applied distally at the ankle or through the skin. Proximally, the splint is pushed into the thigh and hip areas by a ring that applies pressure to the buttocks, perineum, and groin. Excessive traction can cause skin damage to the foot, ankle, or perineum. Neurovascular compromise can result from stretching the peripheral nerves. Hip fractures can be similarly immobilized with a traction splint, but are more suit-
KNEE INJURIES

The use of commercially available knee immobilizers or the application of a long-leg plaster splint is very helpful in maintaining comfort and stability. The leg should not be immobilized in complete extension, but should be immobilized with about 10 degrees of flexion to take pressure off the neurovascular structures.

TIBIA FRACTURES

Tibia fractures are best immobilized with a well-padded cardboard or metal gutter long-leg splint. If readily available, plaster splints immobilizing the lower leg, the knee, and the ankle may be used.

ANKLE FRACTURES

Ankle fractures may be immobilized with a pillow splint or padded cardboard splint, thereby avoiding pressure over bony prominences.

UPPER-EXTREMITY AND HAND INJURIES

The hand may be temporarily splinted in an anatomic, functional position, with the wrist slightly dorsiflexed and the fingers gently flexed 45 degrees at the metacarpophalangeal joints. This position can be achieved by gently immobilizing the hand over a large roll of gauze and using a short-arm splint.

The forearm and wrist are immobilized flat on padded or pillow splints. The elbow usually is immobilized in a flexed position, either by using padded splints or by direct immobilization with respect to the body using a sling and swath device. The upper arm usually is immobilized by splinting it to the body or applying a sling or swath, which can be augmented by a thoracobrachial bandage. Shoulder injuries are managed by a sling-and-swath device or a Velcro-type of dressing.

Pain Control

Analgesics are generally indicated for joint injuries and fractures. However, the administration of pain medications must be tempered by the patient's clinical situation. The appropriate use of splints significantly decreases the patient's discomfort by controlling the amount of motion that occurs at the injured site.

Patients who do not appear to have significant pain and discomfort from a major fracture may have other associated injuries—for example, intracranial lesions or hypoxia—or may be under the influence of alcohol and/or other drugs.

Effective pain relief usually requires the administration of narcotics, which should be given in small doses intravenously and repeated as needed. Muscle relaxants and sedatives should be administered cautiously in patients with isolated extremity injuries—for example, reduction of a dislocation. Regional nerve blocks have a role in pain relief and the reduction of appropriate fractures. It is essential to assess and document any peripheral nerve injury before administering a nerve block.

Whenever analgesics, muscle relaxants, or sedatives are administered to an injured patient, the potential exists for respiratory arrest. Consequently, appropriate resuscitative equipment must be immediately available.
**Associated Injuries**

Certain musculoskeletal injuries, because of their common mechanism of injury, are often associated with second injuries that are not immediately apparent or may be missed (see Table 8-4). Steps to ensure recognition and management of these injuries include:

1. Review the injury history, especially the mechanism of injury, to determine whether another injury is present.
2. Thoroughly reexamine all extremities, placing special emphasis on the hands, wrists, feet, and the joint above and below a fracture or dislocation.
3. Visually examine the patient's dorsum, including the spine and pelvis. Open injuries and closed soft tissue injuries that may be indicative of an unstable injury must be documented.
4. Review the x-rays obtained in the secondary survey to identify subtle injuries that may be associated with more obvious trauma.

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**Occult Skeletal Injuries**

Remember, not all injuries can be diagnosed during the initial assessment and management of injury. Joints or bones that are covered or well padded within muscular areas may contain occult injuries. It can be difficult to identify nondisplaced fractures or joint ligamentous injuries, especially if the patient is unresponsive or there are other severe injuries. It is important to recognize that injuries are commonly discovered days after the injury incident—for example, when the patient is being mobilized. Therefore, it is important to reassess the patient routinely and to relate this possibility to other members of the trauma team and the patient's family.

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**PITFALL**

Despite a thorough examination, occult associated injuries may not be appreciated during the initial evaluation. It is imperative to repeatedly reevaluate the patient to assess for these injuries.

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**TABLE 8-4 Injuries Associated with Musculoskeletal Injuries**

<table>
<thead>
<tr>
<th>INJURY</th>
<th>MISSED/ASSOCIATED INJURY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clavicular fracture</td>
<td>Major thoracic injury, especially pulmonary contusion and rib fractures</td>
</tr>
<tr>
<td>Scapular fracture</td>
<td></td>
</tr>
<tr>
<td>Fracture and/or dislocation of shoulder</td>
<td></td>
</tr>
<tr>
<td>Displaced thoracic spine fracture</td>
<td>Thoracic aortic rupture</td>
</tr>
<tr>
<td>Spine fracture</td>
<td>Intraabdominal injury</td>
</tr>
<tr>
<td>Fracture/dislocation of elbow</td>
<td>Brachial artery injury, Median, ulnar, and radial nerve injury</td>
</tr>
<tr>
<td>Major pelvic disruption (motor vehicle occupant)</td>
<td>Abdominal, thoracic, or head injury</td>
</tr>
<tr>
<td>Major pelvic disruption (motorcyclist or pedestrian)</td>
<td>Pelvic vascular hemorrhage</td>
</tr>
<tr>
<td>Femur fracture</td>
<td>Femoral neck fracture, Posterior hip dislocation</td>
</tr>
<tr>
<td>Posterior knee dislocation</td>
<td>Femoral fracture, Posterior hip dislocation</td>
</tr>
<tr>
<td>Knee dislocation or displaced tibial plateau fracture</td>
<td>Popliteal artery and nerve injuries</td>
</tr>
<tr>
<td>Calcaneal fracture</td>
<td>Spine injury or fracture, Fracture-dislocation of hindfoot, Tibial plateau fracture</td>
</tr>
<tr>
<td>Open fracture</td>
<td>70% incidence of associated nonskeletal injury</td>
</tr>
</tbody>
</table>
CHAPTER SUMMARY

1. Musculoskeletal injuries, while generally not life-threatening may pose delayed threats to life and limb.

2. The goal of the initial assessment of musculoskeletal trauma is to identify injuries that pose a threat to life and/or limb. Although uncommon, life-threatening musculoskeletal injuries must be properly assessed and managed. Most extremity injuries are appropriately diagnosed and managed during the secondary survey.

3. It is essential to recognize and manage in a timely manner pelvic fractures, arterial injuries, compartment syndrome, open fractures, crush injuries, and fracture-dislocations. Knowledge of the mechanism of injury and history of the injury-producing event enables the doctor to be aware of what associated conditions potentially exist with the incurred extremity. Early splitting of fractures and dislocations may prevent serious complications and late sequelae. In addition, an awareness of the patient’s tetanus immunization status, particularly in cases of open fractures or significantly contaminated wounds, may prevent serious complications. Armed with the proper knowledge and skills, as outlined in this chapter, the doctor can satisfactorily provide the initial management for most musculoskeletal trauma.

Bibliography


PELVIC FRACTURES AND ASSOCIATED INJURIES

How do I treat patients with pelvic fractures?

The sacrum and innominate bones (ilium, ischium, and pubis), along with many ligamentous complexes, comprise the pelvis. Fractures and ligamentous disruptions of the pelvis suggest that major forces were applied to the patient. Such injuries usually result from auto–pedestrian, motor vehicle, and motorcycle crashes. Pelvic fractures have a significant association with injuries to intraperitoneal and retroperitoneal visceral and vascular structures. The incidence of tears of the thoracic aorta also appears to be significantly increased in patients with pelvic fractures, especially anteroposterior fractures. Therefore, hypotension may or may not be related to the pelvic fracture itself when blunt trauma is the mechanism of injury.

Patients with hemorrhagic shock and unstable pelvic fractures have four potential sources of blood loss: (1) fractured bone surfaces, (2) pelvic venous plexus, (3) pelvic arterial injury, and (4) extrapelvic sources. The pelvis should be temporarily stabilized or “closed” using an available commercial compression device or sheet to decrease bleeding. Intraabdominal sources of hemorrhage must be excluded or treated operatively. Further decisions to control ongoing pelvic bleeding include angiographic embolization, surgical stabilization, and direct surgical control (see Figure 5-6).

Mechanism of Injury/Classification

The four patterns of force leading to pelvic fractures are the following: (1) AP compression, (2) lateral compression, (3) vertical shear, and (4) complex (combination) pattern.

An AP compression injury may be caused by an auto–pedestrian collision or motorcycle crash, a direct crushing injury to the pelvis, or a fall from a height greater than 12 feet (3.6 meters). With disruption of the symphysis pubis, there often is tearing of the posterior osseous ligamentous complex (sacroiliac, sacrospinous, sacrotuberous, and fibromuscular pelvic floor) represented by a sacroiliac fracture and/or dislocation or sacral fracture. With opening of the pelvic ring, there may be hemorrhage from the posterior pelvic venous complex and, occasionally, branches of the internal iliac artery. Figure 5-6 shows an “open book” fracture.

Lateral compression injuries often result from motor vehicle crashes and lead to internal rotation of the involved hemipelvis. This rotation drives the pubis into the lower genitourinary system, injuring the bladder and/or urethra. The pelvic volume is actually compressed in such an injury, so life-threatening hemorrhage is not common. Figure 5-7 shows a “closed” fracture.

A high-energy shear force applied in a vertical plane across the anterior and posterior aspects of the ring disrupts

![Figure 5-7 Closed Fracture.](image)

![Figure 5-8 Open Book Fracture.](image)

![Figure 5-9 Vertical Shear Fracture.](image)
PITFALL

Delay in stabilization of the pelvis allows continued hemorrhage.

the sacrospinous and sacrotuberal ligaments and leads to a major pelvic instability. Figure 5-9 shows a vertical shear fracture.

In some cases of severe injury, combinations of compression and shear forces result in complex combination patterns. These injuries are associated with major bleeding.

Assessment

The flank, scrotum, and perianal area should be inspected quickly for blood at the urethral meatus; swelling or bruising; or laceration in the perineum, vagina, rectum, or buttocks, which is suggestive of an open pelvic fracture. Palpation of a high-riding prostate gland also is a sign of a significant pelvic fracture.

Mechanical instability of the pelvic ring can be quickly ascertained during physical examination of the pelvis. Once instability has been verified, a source of hemorrhage has been suggested; no further maneuvers to demonstrate instability are necessary. A rapidly available x-ray may avoid the pain and potential hemorrhage associated with manipulating the pelvis.

The first indication of mechanical instability is seen on inspection for leg-length discrepancy or rotational deformity (usually external) without a fracture of that extremity. Because the unstable pelvis is able to rotate externally, the pelvis can be closed by pushing on the iliac crests at the level of the anterior superior iliac spine. Motion can be felt if the iliac crests are grasped and the unstable hemipelvis is pushed inward and then outward (compression distraction maneuver). With posterior disruption, the involved hemipelvis can be pushed cephalad as well as pulled caudally. This translational motion can be felt by palpating the posterior iliac spine and tubercle while pushing or pulling the unstable hemipelvis. When appropriate, an AP x-ray film of the pelvis confirms the clinical examination. When time, availability, and patient condition permit, the x-ray may be used in lieu of manipulation to make the diagnosis. See Chapter 3: Shock; and Skill Station IV: Shock Assessment and Management.

Management

Simple techniques may be used to splint unstable pelvix and close the increased pelvic volume prior to transfer and during the resuscitation with crystalloids and blood. These techniques include: (1) a sheet around the pelvis as a sling, causing internal rotation of the lower limbs, (2) commercially available pelvic splints, (3) other pelvic-stabilizing devices (Figure 5-10).

Reduction of an acetabular fracture by long traction of the lower extremity also can be useful. A definitive management of pelvic fractures varies, depending on the hemodynamic status of the patient in emergency situations as shown in Figure 5-10. Management of Pelvic Fractures. Since significant shock is required to care for patients with severe pelvic fractures, early consideration of transfer to a trauma center is essential.

Figure 5-10 Pelvic Stabilization. Pelvic bind (A) and pelvic stabilization using a sheet (B).