Patients with orthopedic injuries and nontraumatic musculoskeletal disorders compose a large portion of the more than 100 million patients who come to U.S. emergency departments (EDs) annually. Although only rarely life-threatening, orthopedic injuries may threaten a limb or its function, and accurate early diagnosis and treatment can avert long-term complications. Many of these injuries can and should be treated definitively by the emergency physician. Consultation with an orthopedist should be sought for the treatment of most long bone fractures, open fractures, injuries with joint violation, and injuries with neurovascular compromise and for follow-up of certain patients initially treated in the ED.

Orthopedic injuries often occur as a result of accidents (industrial or otherwise) and frequently involve young, otherwise healthy, working individuals. Accurate initial diagnosis, treatment, and documentation assume great importance medically and economically. Many problems can be avoided if the following 10 general principles are kept in mind:

1. Most orthopedic injuries can be predicted by understanding the chief complaint, the age of the patient, the mechanism of injury, and an estimate of the amount of energy delivered.
2. A careful history and physical examination predict radiographic findings with a high degree of accuracy. A presumptive diagnosis before a radiographic study may prompt the physician to order special views necessary to correctly diagnose an injury. Many fractures were accurately described before the advent of roentgenology (Table 49-1).
3. If a fracture is suggested clinically, but radiographic films appear negative, the patient should initially be treated with immobilization as though a fracture were present.
4. Criteria for adequate radiographic studies exist; inadequate studies should not be accepted.
5. Radiographic studies should be performed before most reductions are attempted, except when a delay could be potentially harmful to the patient or in some field situations.
6. Neurovascular competence should be checked and recorded before and after all reductions and after application of immobilization.
7. Patients must be checked for the ability to safely ambulate before discharge from the ED and should not be discharged unless this can be established.
8. Patients should receive explicit aftercare instructions before leaving the ED, covering such areas as monitoring for signs of neurovascular compromise or increasing compartment pressure, cast care, weightbearing, crutch use, and an explicit plan and timing for follow-up.
9. In a patient with multiple trauma, noncritical orthopedic injuries should be diagnosed and treated only after more threatening injuries have been addressed.
10. All orthopedic injuries should be described precisely and according to established conventions. When communicating with an orthopedic consultant, this may affect decisions regarding disposition of a patient and operative versus nonoperative management.

FRACTURES

Fracture Nomenclature

Describing orthopedic injuries with precise language according to established convention enables accurate, clear communication with other parties. Terms commonly used to describe a fracture are listed in Box 49-1. A fracture is a break in the continuity of bone or cartilage. Clinically, a history of loss of function, pain, tenderness, swelling, abnormal motion, and deformity suggests a fracture. Radiographic studies are the mainstay of diagnosis and are usually, although not always, confirmatory. At times, use of special views, radionuclide bone scans, computed tomography (CT), or magnetic resonance imaging (MRI) is necessary to confirm a clinical impression. These studies should be considered when the clinical evidence is at odds with the findings of routine radiography.

General Descriptors

Description of a fracture should begin by stating whether the fracture is closed or open (less desirable terms are simple or compound). In a closed fracture the skin and soft tissue overlying the fracture site are intact. The fracture is open if it is exposed to the outside environment in any manner. This exposure may be as obscure as a puncture wound or as gross as splintered bone protruding through the skin. It is sometimes difficult to determine whether a small wound in proximity to a fracture actually communicates with that fracture. Some physicians advocate probing such a wound with a blunt sterile swab to establish a relationship; no study has established the safety, benefit, or accuracy of this maneuver. If doubt exists, an open fracture should be assumed to be present.

The next item that should be noted in the description of a fracture is the exact anatomic location, including the name of the bone, left or right, and standard reference points along the bone, for example, the humeral neck or posterior tibial tubercle. Long bones can be divided into thirds—proximal, middle, or
Table 49-1 Common Fracture Names and Their Origins

<table>
<thead>
<tr>
<th>FRACTURE EPONYM OR NAME</th>
<th>DESCRIPTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviator’s</td>
<td>Vertical fracture of the neck of the talus with subtalar dislocation and backward displacement of the body.</td>
<td>First described in flyers during World War I. Arises from forced dorsiflexion of the foot in flying accidents and in traffic accidents after a head-on collision.</td>
</tr>
<tr>
<td>Barton’s</td>
<td>Intra-articular fracture-dislocation of the wrist.</td>
<td>Considered complicated and unstable. Requires surgical reduction in most cases. Described by Barton in 1838 before the advent of radiography.</td>
</tr>
<tr>
<td>Dorsal Barton’s</td>
<td>Oblique intra-articular fracture of the dorsal rim of the distal radius with displacement of the carpus along with the fracture fragment.</td>
<td>Results from high-velocity impact across the articular surface of the radiocarpal joint, with the wrist in dorsiflexion at the moment of impact.</td>
</tr>
<tr>
<td>Volar Barton’s</td>
<td>Wedge-shaped articular fragment sheared off the volar surface of the radius (volar rim fracture), displaced volarly along with the carpus.</td>
<td>Similar mechanism as dorsal Barton’s but with wrist in volar flexion at time of injury. Also referred to as reverse Barton’s fracture. Much rarer than dorsal Barton’s fracture.</td>
</tr>
<tr>
<td>Bennett’s</td>
<td>Oblique fracture through base of the first metacarpal with dislocation of the radial portion of the articular surface.</td>
<td>Usually produced by direct force applied to the end of the metacarpal. Dorsal capsular structures disrupted by the dislocation. Marked tenderness along medial base of thumb.</td>
</tr>
<tr>
<td>Bosworth</td>
<td>Fracture-dislocation of the ankle resulting in the fibula being entrapped behind the tibia.</td>
<td>Rare injury, produced by a severe external rotation force applied to the foot. Physical examination reveals foot severely externally rotated in relation to the tibia.</td>
</tr>
<tr>
<td>Boxer’s</td>
<td>Fracture of the neck of the fourth or fifth metacarpal.</td>
<td>Results from striking a clenched fist into an unyielding object, usually during an altercation, or against a wall, out of frustration or anger.</td>
</tr>
<tr>
<td>Chance’s</td>
<td>Vertebral fracture, usually lumbar, involving the posterior spinous process, pedicles, and vertebral body.</td>
<td>Caused by simultaneous flexion and distraction forces on the spinal column, usually associated with use of lap seat belts. Anterior column fails in tension along with the middle and posterior columns. May be misdiagnosed as a compression fracture.</td>
</tr>
<tr>
<td>Chauffeur’s</td>
<td>Solitary fracture of radial styloid.</td>
<td>Occurs from tension forces sustained during ulnar deviation and supination of the wrist. Name derives from occurrence in chauffeurs who suffered violent, direct blows to the radius incurred while turning the crank on a car, only to have it snap back, during previous eras.</td>
</tr>
<tr>
<td>Clay shoveler’s</td>
<td>Fracture of the tip of the spinous process of the sixth or seventh cervical vertebra.</td>
<td>First described in Australian clay shoveler who sustained a fracture of the spinous process by traction as they lifted heavy loads of clay.</td>
</tr>
<tr>
<td>Colles’</td>
<td>Fracture of the distal radius with dorsal displacement and volar angulation, with or without an ulnar styloid fracture.</td>
<td>Most common wrist fracture in adults, especially in the elderly. Results from fall on an outstretched hand. Also known as silver fork deformity, which accurately describes the gross appearance in the lateral view. First described by Colles in 1814, before the advent of radiography.</td>
</tr>
<tr>
<td>Cotton’s</td>
<td>Trimalleolar fracture.</td>
<td>Fracture of the lateral malleolus, fracture of the posterior malleolus, and either a fracture of the medial malleolus or a disruption of the deltoid ligament with visible widening of the mortise on ankle radiograph.</td>
</tr>
<tr>
<td>Dashboard fracture</td>
<td>Fracture of the posterior rim of the acutabulum.</td>
<td>Named for mechanism of injury: a seated passenger striking the knee on a dashboard, driving the head of the femur into the acetabulum.</td>
</tr>
<tr>
<td>Dupuytren’s</td>
<td>Fracture-dislocation of the ankle.</td>
<td>Results from a similar mechanism as the better known Maisonneuve fracture (i.e., external rotation of the ankle), resulting in either deltoid ligament rupture or medial malleolus fracture, diastasis of the inferior tibiofibular joint, and indirect fracture of the fibular shaft. Maisonneuve was the student of Dupuytren.</td>
</tr>
<tr>
<td>Essex-Lopresti</td>
<td>Fracture of radial head with dislocation of distal radioulnar joint.</td>
<td>Results from longitudinal (axial) compression of the forearm.</td>
</tr>
<tr>
<td>Galeazzi’s</td>
<td>Fracture of the shaft of the radius with dislocation of the distal radioulnar joint. Ligaments of inferior radioulnar joint are ruptured and head of ulna displaced from ulnar notch of the radius.</td>
<td>Results from fall on outstretched hand, with the wrist in extension and the forearm forcibly pronated. Inherently unstable with tendency to redisplace after reduction.</td>
</tr>
<tr>
<td>Hangman’s</td>
<td>Fracture-dislocation of atlas and axis, specifically of pars interarticularis of C2 and disruption of C2-3 junction. Separation occurs between second and third vertebral bodies from anterior to posterior side.</td>
<td>Results from extreme hyperextension during abrupt deceleration. Most common cause is the forehead striking the windshield of a car during a collision. A bit of a misnomer in that hanging usually produces death by strangulation rather than cord damage.</td>
</tr>
</tbody>
</table>
### Table 49-1  Common Fracture Names and Their Origins—cont’d

<table>
<thead>
<tr>
<th>FRACTURE EPONYM OR NAME</th>
<th>DESCRIPTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hume’s</td>
<td>Fracture of the proximal ulna associated with forward dislocation of the head of the radius.</td>
<td>Essentially high Monteggia's injury.</td>
</tr>
<tr>
<td>Jefferson’s</td>
<td>Burst fracture of ring of C1, or atlas.</td>
<td>Axial loading results in a shattering of the ring of the atlas. Decompressive type of injury. Associated with disruption of transverse ligament; an unstable injury.</td>
</tr>
<tr>
<td>Jones</td>
<td>Transverse fracture of the metatarsal base, occurring at least 15 mm distal to the proximal end of the bone, distal to the insertion of the peroneus brevis.</td>
<td>Should not be confused with the more common avulsion fracture of fifth metatarsal styloid, produced by avulsion at the insertion of the peroneus brevis. Jones described the fracture that bears his name in 1902, after sustaining the injury himself while dancing.</td>
</tr>
<tr>
<td>Le Fort</td>
<td>Maxillary fracture.</td>
<td>Types I, II, and III (see Chapter 42).</td>
</tr>
<tr>
<td>Le Fort-Wagstaffe</td>
<td>Avulsion fracture of the anterior cortex of the lateral malleolus.</td>
<td>Rare pull-off injury of the fibular attachment of the anterior tibiotalar ligament.</td>
</tr>
<tr>
<td>Lisfranc’s</td>
<td>Fracture located around the tarsometatarsal (Lisfranc’s) joint, usually associated with dislocation of this joint.</td>
<td>Lisfranc, a field surgeon in Napoleon's army, described an amputation performed through the tarsometatarsal joint in a soldier who caught his foot in a stirrup when he fell off his horse. Since then, the joint has borne his name.</td>
</tr>
<tr>
<td>Maisonneuve</td>
<td>Fracture of proximal third of fibula associated with rupture of the deltoid ligament or fracture of the medial malleolus and disruption of the syndesmosis.</td>
<td>Results from external rotation of the ankle with transmission of forces through the syndesmosis; proximally the force is relieved by fracture of the fibula. Described experimentally in 1840, before radiography.</td>
</tr>
<tr>
<td>Malgaigne’s</td>
<td>Fracture of the ilium near the sacroiliac joint with displacement of the symphysis, or a dislocation of the sacroiliac joint with fracture of both ipsilateral pubic rami.</td>
<td>Resultant pelvic injury is unstable. Described by Malgaigne, based on clinical findings, in 1847.</td>
</tr>
<tr>
<td>March</td>
<td>Fatigue, or stress, fracture of the metatarsal.</td>
<td>Arises from long marches or other repetitive use trauma (e.g., marathon running) or less commonly from single stumbling movements.</td>
</tr>
<tr>
<td>Monteggia’s</td>
<td>Fracture of the junction of the proximal and middle thirds of the ulna associated with anterior dislocation of the radial head.</td>
<td>Usually caused by fall on outstretched hand along with forced pronation of forearm or by a direct blow on the posterior aspect of the ulna. Reported by Monteggia in 1814.</td>
</tr>
<tr>
<td>Nightstick</td>
<td>Fracture of either ulna or radius, or both.</td>
<td>Name derived from a citizen's attempt to protect himself from a police officer's baton or &quot;nightstick&quot; by offering the forearm.</td>
</tr>
<tr>
<td>Pott’s</td>
<td>Definitions vary (see comment); most commonly a bimalleolar fracture or a fracture of the distal fibula, 4-7 cm above the lateral malleolus.</td>
<td>The exact fracture Pott described in 1769 is uncertain; clearly it referred to a fracture of the lower fibula, usually associated with other fractures or dislocations about the ankle.</td>
</tr>
<tr>
<td>Rolando’s</td>
<td>Intra-articular fracture at base of metacarpal. Frequently Y- or T-shaped, or may be severely comminuted.</td>
<td>Produced by an axial load with the metacarpal in partial flexion. Worse prognosis than a Bennett's fracture and, fortunately, rarer.</td>
</tr>
<tr>
<td>Salter-Harris</td>
<td>An epiphyseal fracture occurring in children or adolescents.</td>
<td>Graded I-V, depending on degree of involvement and/or displacement of epiphysis and metaphysis (see text dealing with Salter-Harris fractures and also Figure 46-1).</td>
</tr>
<tr>
<td>Smith’s</td>
<td>Extra-articular fracture of the distal radius with volar displacement of distal fragment.</td>
<td>Reverse of the Colles' fracture but much more uncommon. Sometimes referred to as a &quot;garden spade&quot; deformity. Usually results from fall with force to back of hand. First described by Smith in 1847.</td>
</tr>
<tr>
<td>Stener</td>
<td>Avulsion of the ulnar corner of the base of the proximal phalanx of the thumb.</td>
<td>Bony equivalent of rupture of the ulnar collateral ligament, or &quot;gamekeeper's thumb.&quot;</td>
</tr>
<tr>
<td>Teardrop</td>
<td>Wedge-shaped fracture of the anteroinferior portion of the vertebral body, displaced anteriorly.</td>
<td>Commonly involves a ligamentous injury and may produce neurologic injury.</td>
</tr>
<tr>
<td>Thurston Holland’s fragment</td>
<td>Triangular metaphyseal fragment that accompanies the epiphysis in Salter-Harris type II fractures.</td>
<td>Described by Thurston Holland in 1929. The name is commonly hyphenated, although technically it should not be.</td>
</tr>
<tr>
<td>Tillaux</td>
<td>Isolated avulsion fracture of the anterolateral aspect of the distal tibial epiphysis.</td>
<td>Occurs in older adolescents (12-15 years) after the medial parts of the epiphyseal plates close but before the lateral part closes. External rotation force places stress on anterior talofibular ligament. Described by Tillaux in 1872.</td>
</tr>
</tbody>
</table>
Box 49-1 Fracture Description

**Identification**
- Open versus closed
- Exact anatomic location
- Direction of fracture line
- Simple, comminuted
- Position (displacement, alignment)

**Additional Modifiers**
- Complete versus incomplete
- Involvement of articular surface (%)
- Avulsion
- Impaction
- Depression
- Compression

**Special Situations**
- Pathologic
- Stress

---

distal—and these thirds or the junction of any two of them (e.g., the junction of the middle and distal third of the tibia) are used to describe fractures. The most descriptive language possible should be used. It is better to say “closed fracture of the right ulnar styloid” than “closed fracture of the right distal ulna” because the former conveys more precise anatomic information.

An additional modifier describes the direction of the fracture line in relation to the long axis of the bone in question. A transverse fracture occurs at a right angle to the long axis of the bone (Fig. 49-1A), whereas an oblique fracture runs oblique to the long axis of the bone (Fig. 49-1B). A spiral fracture results from a rotational force and encircles the shaft of a long bone in a spiral fashion (Fig. 49-1C). A fracture with more than two fragments is termed comminuted (Fig. 49-1D).

The position and alignment of the fracture fragments (i.e., their relationship to one another) should be described. Fragments are described relative to their normal position, and any deviation from normal is termed displacement. By convention, the position of the distal fragment is described relative to the proximal one. Displacement may be described as a quantitative measurement (i.e., in millimeters) or as a percentage of the bone width. Figure 49-2 shows a dorsal displacement of the fractured radius, and Figure 49-3 shows lateral, or valgus, displacement of the distal tibia and fibula.

The terms valgus and varus are sometimes confusing. Valgus denotes a deformity in which the described part is angled away from the midline of the body. Conversely, varus denotes a deformity in which the angulation of the part is toward the midline. Alignment refers to the relationship of the longitudinal axis of one fragment to another; deviation from the normal alignment is termed angulation. The direction of angulation is determined by the direction of the apex of an angle formed by the two fracture fragments (Fig. 49-4). This angle is opposite to the direction of displacement of the distal fragment. The relative position or angulation of the distal fragment of a fracture may also be described with terms such as radial or ulnar, dorsal or volar, anterior or posterior, and lateral or medial. One should also be aware of rotational deformity, present when the distal fragment of a fracture is rotated to some degree along the axis of the bone itself. Especially in the digits of the hand, radial or ulnar deviation of a flexed finger can occur, and radiographs often underestimate the degree of clinical deformity and rotation present.

### Descriptive Modifiers

A fracture is termed complete if it interrupts both cortices of the bone and incomplete if it involves only one. It should be noted whether a fracture extends into and involves an articular surface. Frequently the percentage of articular surface involved can only be estimated; in some cases the percentage that is actually involved dictates the need to perform a surgical reduction. In general, it is important that the articular surface be restored to anatomic integrity to prevent consequent traumatic arthropathy.

Avulsion fracture refers to a bone fragment that is pulled away from its normal position by either the forceful contraction of a muscle (Fig. 49-5A) or the resistance of a tendon or ligament to a force in the opposite direction (Fig. 49-5B). Impaction refers to the

---

**Figure 49-1.** Types of fractures. A, Transverse. B, Oblique. C, Spiral. D, Comminuted.

**Figure 49-2.** Dorsal displacement of distal radius.
forceful collapse of one fragment of bone into or onto another. In the proximal humerus, this collapse typically occurs in a telescoping manner, particularly in elderly patients, whose bones are soft and brittle. In the tibial plateau, impaction occurs frequently in the form of a depression (Fig. 49-6A and B), and in the vertebral bodies, impaction frequently occurs in the form of compression (Fig. 49-6C).

A fracture that occurs through abnormal bone is termed pathologic. A pathologic fracture is suggested whenever a fracture occurs from seemingly trivial trauma. Diseases that cause structural weakness predisposing to injury include primary or metastatic malignancies, cysts, enchondromata, and giant-cell tumors. In addition, osteomalacia, osteogenesis imperfecta, scurvy, rickets, and Paget’s disease all weaken bones, making them susceptible to fracture. The term pathologic also is applied to fractures through osteoporotic bone when the demineralization is a result of disease, as in polio. Fractures through osteoporotic bone of the elderly usually are not described as pathologic. When fractures occur in normal bones and a history of “trivial trauma” is elicited, violence or battering should be suspected. Repeated low-intensity forces may lead to resorption of normal bone, resulting in a stress fracture. Other names for this condition are fatigue fracture and march fracture (see Table 49-1). Most stress fractures occur in the lower extremities and commonly affect individuals involved in activities such as running, basketball, aerobics, and dancing. Extrinsic factors such as training regimens, type of equipment used, and nutrition habits, as well as intrinsic factors such as anatomic variation, muscle endurance, and hormonal factors have all been associated with stress fractures. These injuries may not be recognizable on initial plain films; therefore management should be based on clinical diagnosis. The tibia, fibula, metatarsals, navicular, cuneiform, calcaneus, femoral neck, or femoral shaft may be involved.

Fracture Eponyms

Many fractures were described before the advent of radiography and are described by an eponym rather than the exact bony injury. These eponyms reflect the rich history of orthopedic care and, despite the objections of some, are still commonly used to describe orthopedic injuries (see Table 49-1).

Fracture Healing

Specific fractures are discussed in subsequent chapters. In general, the goal is to realign bony fragments so that healing or union can take place and normal function is restored. The process from fracture to union begins with a hematoma, caused by rupture of vessels crossing the fracture line. The hematoma bridges the fragments and is followed by an inflammatory phase when granulation tissue forms on the fracture surfaces. Resorption of the hematoma provides the first continuity between the fragments; however, this procallus provides no structural rigidity for bearing stress. With remodeling, callus subsequently is formed on the periosteal and endosteal surfaces of the bone, acting as a biologic splint. This area first becomes mineralized by deposition of calcium phosphate and then undergoes osseous metaplasia. Callus is resorbed as the original fracture surfaces develop firm bony union. In some bones, such as the skull and the neck of the femur, where periosteum is deficient, there may be virtually no callus formation.

Radiographic studies conducted 10 to 14 days after injury show the bone surrounding the fracture line becoming less dense because of localized bone resorption and hyperemia associated with the formation of granulation tissue. As a result, the fracture becomes considerably easier to visualize radiographically about 10 days after injury. After 2 to 3 weeks, soft tissue swelling has regressed, and callus first becomes visible, initially in a mottled pattern and then taking on a dense appearance. The callus undergoes organization, with peripheral margins becoming smooth as physically unstressed portions are resorbed.
Figure 49-5. Avulsion fractures. A, Musculotendinous avulsions of small bone fragments from the head of the humerus. B, Extensor tendon avulsion of bone from the base of the middle phalanx.

Figure 49-6. A and B, Tibial plateau fracture. C, Vertebral body compression fracture.
In a healthy adult the whole process from injury to consolidation takes about 2 months for the humerus and about 4 months for a large bone such as the femur. Oblique fractures tend to heal more quickly than transverse fractures. Healing is quicker in children and slower in the elderly. The rate of fracture healing is affected by many factors, including the type of bone (cancellous bone heals faster than cortical bone); degree of fracture and opposition; and systemic states, such as hyperthyroidism or illness requiring ongoing corticosteroid treatment. Exercise speeds healing, whereas chronic hypoxia has been known to slow repair.

The presence of abundant callus seen on radiograph that is beginning to organize is usually associated with clinical union. If any suggestion of movement at the fracture site is noted on clinical examination, union is regarded as inadequate. Several terms are used to denote abnormal union. Delayed union is union that takes longer than usual for a particular fracture location. Malunion occurs when a residual deformity exists. Nonunion is the failure of a fracture to unite. When nonunion results in a false joint, it is termed a pseudarthrosis.

If the ends of the bone have remained constant on serial films and an adequate surrounding sheath of organizing callus can be seen, it is permissible for the patient to return to limited active use, even if the original fracture remains visible. The final process of consolidation develops later.

**Fractures in Children**

Certain features of children’s bones distinguish pediatric fractures from adult fractures. Bones of children are necessarily soft and resilient and sustain numerous incomplete fractures. Greenstick fractures are incomplete angulated fractures of long bones. The resultant bowing of the bone causes an appearance resembling a moist, immature branch that breaks in a similar fashion when bent (Fig. 49-7A). A torus fracture is another form of incomplete fracture, characterized by a wrinkling or buckling of the cortex. In Greek architecture a torus is a bump at the base of a column, and these fractures, occurring at the end of long bones, take on such an appearance. These fractures may be extremely subtle on radiographs (Fig. 49-7B).

Another feature of growing long bones that is a frequent source of trouble and confusion is the presence of epiphyses, cartilaginous centers at or near the ends of bone that give rise to growth of the bone. Figure 49-8 is a schematic review of the anatomy of a growing bone. Because cartilage is radiolucent, the cartilaginous portion of an epiphysis is not visualized on radiographs. A tendency exists to consider only the ossified nucleus and to ignore the cartilaginous structure that bridges to the metaphysis. Exercise speeds healing, whereas chronic hypoxia has been known to slow repair.

The presence of abundant callus seen on radiograph that is beginning to organize is usually associated with clinical union. If any suggestion of movement at the fracture site is noted on clinical examination, union is regarded as inadequate. Several terms are used to denote abnormal union. Delayed union is union that takes longer than usual for a particular fracture location. Malunion occurs when a residual deformity exists. Nonunion is the failure of a fracture to unite. When nonunion results in a false joint, it is termed a pseudarthrosis.

If the ends of the bone have remained constant on serial films and an adequate surrounding sheath of organizing callus can be seen, it is permissible for the patient to return to limited active use, even if the original fracture remains visible. The final process of consolidation develops later.

**Fractures in Children**

Certain features of children’s bones distinguish pediatric fractures from adult fractures. Bones of children are necessarily soft and resilient and sustain numerous incomplete fractures. Greenstick fractures are incomplete angulated fractures of long bones. The resultant bowing of the bone causes an appearance resembling a moist, immature branch that breaks in a similar fashion when bent (Fig. 49-7A). A torus fracture is another form of incomplete fracture, characterized by a wrinkling or buckling of the cortex. In Greek architecture a torus is a bump at the base of a column, and these fractures, occurring at the end of long bones, take on such an appearance. These fractures may be extremely subtle on radiographs (Fig. 49-7B).

Another feature of growing long bones that is a frequent source of trouble and confusion is the presence of epiphyses, cartilaginous centers at or near the ends of bone that give rise to growth of the bone. Figure 49-8 is a schematic review of the anatomy of a growing bone. Because cartilage is radiolucent, the cartilaginous portion of an epiphysis is not visualized on radiographs. A tendency exists to consider only the ossified nucleus and to ignore the cartilaginous structure that bridges to the metaphysis. Exercise speeds healing, whereas chronic hypoxia has been known to slow repair.

The presence of abundant callus seen on radiograph that is beginning to organize is usually associated with clinical union. If any suggestion of movement at the fracture site is noted on clinical examination, union is regarded as inadequate. Several terms are used to denote abnormal union. Delayed union is union that takes longer than usual for a particular fracture location. Malunion occurs when a residual deformity exists. Nonunion is the failure of a fracture to unite. When nonunion results in a false joint, it is termed a pseudarthrosis.

If the ends of the bone have remained constant on serial films and an adequate surrounding sheath of organizing callus can be seen, it is permissible for the patient to return to limited active use, even if the original fracture remains visible. The final process of consolidation develops later.

**Fractures in Children**

Certain features of children’s bones distinguish pediatric fractures from adult fractures. Bones of children are necessarily soft and resilient and sustain numerous incomplete fractures. Greenstick fractures are incomplete angulated fractures of long bones. The resultant bowing of the bone causes an appearance resembling a moist, immature branch that breaks in a similar fashion when bent (Fig. 49-7A). A torus fracture is another form of incomplete fracture, characterized by a wrinkling or buckling of the cortex. In Greek architecture a torus is a bump at the base of a column, and these fractures, occurring at the end of long bones, take on such an appearance. These fractures may be extremely subtle on radiographs (Fig. 49-7B).

Another feature of growing long bones that is a frequent source of trouble and confusion is the presence of epiphyses, cartilaginous centers at or near the ends of bone that give rise to growth of the bone. Figure 49-8 is a schematic review of the anatomy of a growing bone. Because cartilage is radiolucent, the cartilaginous portion of an epiphysis is not visualized on radiographs. A tendency exists to consider only the ossified nucleus and to ignore the cartilaginous structure that bridges to the metaphysis. Exercise speeds healing, whereas chronic hypoxia has been known to slow repair.

The presence of abundant callus seen on radiograph that is beginning to organize is usually associated with clinical union. If any suggestion of movement at the fracture site is noted on clinical examination, union is regarded as inadequate. Several terms are used to denote abnormal union. Delayed union is union that takes longer than usual for a particular fracture location. Malunion occurs when a residual deformity exists. Nonunion is the failure of a fracture to unite. When nonunion results in a false joint, it is termed a pseudarthrosis.

If the ends of the bone have remained constant on serial films and an adequate surrounding sheath of organizing callus can be seen, it is permissible for the patient to return to limited active use, even if the original fracture remains visible. The final process of consolidation develops later.
ankle because of the relative weakness of the cartilaginous growth zone, which separates before stronger ligaments and bones are torn or broken. Epiphyseal injuries should be described according to the Salter-Harris classification (Table 49-2).

Type I injuries involve only a slip of the zone of provisional calcification. Comparison radiographs are usually necessary to detect small slips. Swelling and tenderness over an epiphysis (e.g., of the lateral ankle) and a negative radiograph suggest an epiphyseal injury rather than a sprain, because the epiphysis is weaker than the overlying ligaments.

Type II injuries are similar to type I injuries, with a fracture extending into the metaphysis. The triangular metaphyseal fragment sometimes is referred to as the Thurston Holland sign (see Table 49-1). Type II injuries account for approximately three fourths of all epiphyseal fractures. Because the germinal layer is not involved, growth disturbance usually does not occur with type I and II injuries. These injuries are amenable to closed reduction and immobilization without internal fixation.

Type III injuries are composed of a slip of the growth plate plus a fracture through the epiphysis, involving the articular surface. Because this fracture involves the germinal layer, growth may be disrupted. Anatomic reduction does not eliminate the possibility of growth disturbance. Type IV fractures are similar to type III fractures, with the additional involvement of a metaphyseal fracture. Open reduction and internal fixation are usually required to obtain anatomic alignment of the physeal and articular surface. Growth disturbance occurs in a high proportion of patients.

Type V fractures are crush injuries of the epiphysial plate, usually produced by a compressive force. This type of injury usually occurs in joints that move in one plane, most commonly the knee and ankle. Because this injury occurs in a radiolucent area, the injury may be difficult to diagnose on radiograph, but it is suggested by mechanism of injury and pain over the epiphysis. The diagnosis can be established by MRI if hemorrhage or a hematoma is identified within the growth plate immediately after injury. Also reported is loss of MRI signal from the cartilage.

Physeal injuries occur twice as often in boys as in girls and are most common in boys aged 12 to 15 years and in girls aged 9 to 12 years. Distal physes are injured more often than proximal physes, and the most common anatomic locations include the distal radius, phalanges, and distal tibia. Distal radius fractures account for two thirds of fractures in pediatric patients in the ED. The incidence of these fractures has increased by 40% over the past three decades, possibly because of a change in recreational activities, such as increased skiing and skating among boys and increased basketball, soccer, and skating among girls. Most distal radius type I and II fractures can be treated through closed reduction, though this may be more technically difficult with completely displaced both-bone fractures. Similar practice has been applied to distal tibia type I and II fractures, though the incidence of premature physeal closure was shown to be 3.5 times higher if the residual fracture displacement was greater than 3 mm in postreduction radiographs. Growth arrest as a complication of physeal fracture is most likely to be seen at the distal femur, distal and proximal tibia, and distal radius.

**Diagnostic Modalities for Fracture Diagnosis**

**Plain Radiography**

Conventional radiography is the mainstay in diagnosing fractures. In addition to confirming or excluding fractures, it can identify other pathologic conditions. With penetrating trauma, foreign bodies, air, and gas also may be detected. With minor trauma and when good follow-up monitoring is ensured, it is acceptable to delay radiography. Delay cannot be permitted, however, when the suggested injury is one that might be made worse by delayed diagnosis, such as a nondisplaced hip fracture.

Biplanar radiographs of an injured extremity should be obtained to fully delineate the bony injury. Conventional radiographic evaluation of long bones include at least two orthogonal views, and an oblique view is also usually obtained. In certain locations, such as the phalanges, oblique views are necessary. If doubt still exists, the clinician should ask for more views in various degrees of obliquity to the other films. A fracture line is most visible when it is parallel to the x-ray beam and is invisible when it is exactly 90 degrees to the beam. The clinician should never accept a study that examines the bone in only one plane. When a long bone is found to be fractured, it is imperative that the bone be viewed radiographically in its entire length.

Each film is examined to ensure that proper technique has been used and that no important area is omitted from the film. Overexposed films may fail to reveal an abnormality. Although some fine detail is lost on portable films, these are acceptable in unstable patients, in whom the risk of moving the patient does not outweigh the benefit of the more detailed study. Even with good technique, some fractures are not visible initially and do not appear until the margins of the fracture absorb. Absorption widens the radiolucent line, and a defect appears in 7 to 10 days. At that time, new bone produced beneath the periosteum at the margins of the fracture accentuates the fracture. Accordingly, if a fracture is suggested but not visible at the initial visit, the injury should be treated as a fracture and reexamined clinically and radiographically in 7 to 10 days, and the patient should be informed of the rationale for this regimen.

**Stress views** of joints are used in some instances to evaluate the degree of ligamentous injury. Some authors argue against the use of stress views, citing a risk of further injuring an already traumatized structure, additional radiation exposure to the patient and
the technologist, and the possibility that pain may not allow sufficient stress to be applied. For these reasons, stress views should be used judiciously in circumstances when other methods of evaluating ligamentous injuries are not available. Comparison views are useful in selected situations but should not routinely be performed in all pediatric examinations.11 If a fracture is definitely present on the affected side, the comparison view exposes the child to radiation and adds expense with no benefit. Similarly, an experienced physician generally is able to read a normal film with reasonable certainty. It is reasonable to use comparison views in instances when radiographs are inconclusive and when the confusion arises specifically out of the need to distinguish between a possible fracture and normal developmental anatomy. Obtaining a wide field of the affected extremity is more useful than routine comparison views for a young child because the child often does not localize the pain well; this is especially true with regard to complaints of knee pain in cases of hip injury or wrist complaints in forearm and elbow injury. Comparison views sometimes are helpful in adults when a question of accessory ossicles or nonfused bones (e.g., bipartite patella) exists because these anomalies are usually bilateral. The bleeding that inevitably accompanies fractures may produce soft tissue swelling, which may impinge on or obliterate overlying muscle planes. Fat pads, such as in the elbow, may be displaced. Another useful sign is the fat-fluid level, which may accompany fractures extending into the knee joint. The fat-fluid level is visible, however, only if the cross-table technique is used.

The bones themselves should be examined systematically. Normal adult bones possess a smooth unbroken contour. A distinct angle is highly suggestive of a fracture. In an adult the typical fracture is represented by a lucent line that interrupts the smooth contour and usually extends to the opposite side. Nutrient arteries may be confused with fractures but have different radiographic characteristics: They are fine, are sharply marginated, extend obliquely through the cortex, and are less radiolucent than fractures. Pseudofractures can be created by soft tissue folds, bandages or other overlying material, or a radiographic artifact called the Mach effect. If lucencies extend beyond the bones, the line is highly unlikely to represent a fracture. Anomalous bones and calcified soft tissue likewise may be mistaken for fractures. Avulsions and small fracture fragments have an irregular surface that lacks well-corticated margins and a defect in the adjacent bone is present, whereas anomalous ossification centers (accessory ossicles) and sesamoids are characterized by smooth cortical margins. Reference texts are useful in identifying and confirming these anomalies because they tend to occur in predictable locations.12 Compression fractures are represented by increased density rather than a lucency. Finally, the most commonly missed fracture is the second fracture. One should be diligent in searching for additional fractures after discovering the first fracture on a study. In particular, certain paired fractures, such as the distal tibia and proximal fibula, should be sought out.

Special Imaging Techniques

Radionuclide Bone Scanning. In the past, radionuclide bone scanning was used to detect skeletal abnormalities not radiographically evident in children and adults.13 Occult lesions, especially stress fractures, acute osteomyelitis, and tumors, can be detected on these scans, although there are problems with specificity and sensitivity. This modality has been largely supplanted by CT and MRI and now is seldom used.

Computed Tomography. Computed (digital) radiography is now in widespread use. Although conventional radiography remains the initial imaging study of choice for skeletal trauma, CT offers a more detailed and diagnostically sensitive evaluation of bones and joints. With improved resolution and speed, multidetector-row CT captures large volumetric data sets from which two- and three-dimensional images can be created.14,15 Workstation post-processing has become an integral part of the examination. Two-dimensional multiplanar reconstruction in any chosen plane, and three-dimensional surface rendering techniques provide images with unprecedented quality, even in the presence of metallic implants or fixation devices.16

CT is used to confirm possible fractures or to better define displacement, alignment, or fragmentation of fractures. It is also useful in trauma to rule out cervical spine fracture when plain films are equivocal and in noncompressive vertebral fractures to assess the number of fragments and their spatial relationship to the spinal canal. CT is used frequently to define the integrity of articular surfaces in the acetabulum, knee, wrist, or ankle and in Salter-Harris type IV fractures.7 In the multiple trauma patient requiring thoracic, abdominal, and pelvic CT imaging to rule out visceral injury, the soft tissue protocols may be adapted to acquire diagnostic bone images, as well.17 During imaging of the chest, abdomen, or pelvis, data sets are created from which the thoracolumbar spine and bony pelvis can be derived.

Magnetic Resonance Imaging. MRI constitutes the most advanced noninvasive examination of orthopedic structures, delineating lesions of bone, cartilage, ligaments, and other structures, such as menisci, disks, and epiphyseal structures. MRI is expensive and time-consuming and should be reserved for instances in which the diagnosis is in doubt and specific findings would alter the treatment.

Ultrasound Imaging. Point-of-care ultrasound may be an effective tool for the diagnosis of fractures when conventional radiography is unavailable. Through use of bedside ultrasonography, fractures are visualized as an interruption of the linear bony cortex and may be clinically correlated during the physical examination of the affected area. Ultrasound can be effective in the diagnosis of long bone fractures, orbital floor fractures, rib fractures, and occult fractures of the foot and ankle.18 Ultrasound can be used in “real-time” during fracture reduction to confirm proper reduction and alignment of bony fragments.19

Complications of Fractures

Infection (Osteomyelitis)

Any fracture communicating with the surface of the skin is termed an open fracture. Open fractures are treated as true orthopedic emergencies because of the risk of infection; the dreadful nature of the complication of osteomyelitis dictates that no time should be wasted in initiating therapy (Box 49-2). Wounds should be irrigated of gross debris and covered with a sterile dressing, and parenteral antibiotics should be instituted as early as possible.20

Currently, suggested therapy includes a first-generation cephalosporin, such as cefazolin, for all open fractures, with the addition of an aminoglycoside for grade II or III fractures.21,22 Early versus delayed treatment of open fractures and its subsequent effect on rates of infection has been a source of debate. Historic guidelines recommending débridement of open fracture wounds within 6 hours of injury were based on animal experiments conducted in the 1890s.23 Current human studies suggest no clear advantage to performing surgical débridement within 6 hours of injury. The timing of débridement—less than 6 hours versus more than 6 hours after injury—had no effect on clinical or functional outcome in a prospective multicenter study of severe lower-extremity fractures.24 Other retrospective studies and literature reviews advocate early débridement and irrigation of the wound within the first 24 hours of injury to prevent infection.25

Certain open fractures of the finger present a notable exception to the previous recommendation. Such injuries, especially an open distal tuft fracture, are common when the phalanx of a finger is...
subject to crush injury (e.g., by a door) and there exists a skin defect overlying a fractured bone. In a prospective, placebo-controlled study of 193 patients with open fracture of the finger, flucloxacillin or placebo was administered to randomized patients with open phalangeal fractures, and both groups were treated with aggressive surgical irrigation and debridement. No significant difference was found in the infection rate between the groups, and no patient developed osteomyelitis. The data suggest that vigorous irrigation and debridement are adequate primary treatment for open phalangeal fractures in fingers with intact digital arteries. Such injuries might be repaired by the emergency physician without consultation.

Hemorrhage

Because of the rich blood supply to the skeleton, fractures can result in large amounts of blood loss, shock, and death from exanguination. In particular, certain pelvic fractures can cause great blood loss as adequate tamponade is not possible. In adults, blood loss can range from 100 mL from a forearm fracture to 3 L from a pelvic fracture (Table 49-3).

Vascular Injuries

Vascular injuries characteristically are associated with certain fractures and may be limb-threatening. Fractures and dislocations (at the femorotibial articulation) of the knee result from tremendous force that often injures the popliteal artery. Fracture of the femoral neck requires emergent reduction and fixation to protect the blood supply to the femoral head. In the extremities, assessment of vascular injuries may be difficult. The initial survey should note the presence or absence of pulses and the state of capillary filling. If an end artery is completely disrupted, the tissue distal to the injury may exhibit the classic five Ps: pain, pallor, pulselessness, paresthesias, and paralysis. Incomplete and subclinical injuries occasionally occur that initially may be asymptomatic and undetectable. Likewise, in an unconscious, multiply injured patient, major vascular injuries may not be obvious. The mechanism of injury and anatomy dictate the need to assess the possibility of an injured vessel. If pulses cannot be palpated, a Doppler stethoscope should be used to listen for blood flow. Even palpable pulses may be misleading, however, because it has been shown that in 10 to 20% of significant arterial injuries, distal pulses may initially be normal. When pulses are present but the mechanism of injury suggests the possibility of vascular injury, additional diagnostic studies or surgical exploration may be necessary. If a limb is clearly not perfused, operative vascular exploration and repair should take place promptly. Late complications of undiagnosed vascular injuries include thrombosis, arteriovenous fistulae, aneurysm, false aneurysm, and tissue ischemia with limb dysfunction. Delay of vascular injury repair is a risk factor for consequent amputation.

Traditionally, conventional arteriography has been the diagnostic modality of choice in evaluating vascular injuries; however, it is invasive and costly. Alternative methods of vascular assessment include arterial pressure indices and serial physical examinations. Recent advances in computed tomographic angiography have proven it an effective alternative to conventional arteriography, and its advantages include immediate availability and noninvasiveness.

Nerve Injuries

Nerves can be injured by either blunt or penetrating trauma. Neuropraxia is the contusion of a nerve, with disruption of the ability to transmit impulses. Paralysis, if present, is transient, and sensory loss is slight. Normal function usually returns to a neuropraxic nerve in weeks to months. Axonotmesis is a more severe crush injury to a nerve. The injury to nerve fibers occurs within their sheaths. Because the Schwann tubes remain in continuity, spontaneous healing is possible but slow. Neurotmesis is the severing of a nerve, usually requiring surgical repair. Age, site, injured nerve, and delay between injury and repair have all been shown to influence prognosis after microsurgical repair. Because of proximity, specific nerve injuries characteristically accompany certain fractures (Table 49-4). For example, in the upper extremity,

**Box 49-2 Classification and Emergency Management of Open Fractures**

**Grades**

- Grade I: Wound less than 1 cm long, punctured from below
- Grade II: Laceration 5 cm long; no contamination or crush; no excessive soft tissue loss, flaps, or avulsion
- Grade III: Large laceration, associated contamination or crush; frequently includes a segmental fracture
  - IIIA: Involves extensive soft tissue stripping of bone
  - IIIB: Periosteal stripping has occurred
  - IIC: Major vascular injury present

**Management**

1. Control hemorrhage in field with sterile pressure dressing after carefully removing gross debris (e.g., wood, clothing, leaves).
2. Splint without reduction, unless vascular compromise is present.
3. Irrigate with saline and cover with saline-soaked sponges after arrival in the emergency department.
4. Begin intravenous antibiotic prophylaxis, usually a first-generation cephalosporin for grade I, with the addition of an aminoglycoside for grades II and III.
5. Administer tetanus prophylaxis, including tetanus immune globulin, for large crush wounds.

**Table 49-3 Blood Loss Associated with Fracture in Adults**

<table>
<thead>
<tr>
<th>Fracture Site</th>
<th>Amount of Blood Loss (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius and ulna</td>
<td>150-250</td>
</tr>
<tr>
<td>Humerus</td>
<td>250</td>
</tr>
<tr>
<td>Tibia and fibula</td>
<td>500</td>
</tr>
<tr>
<td>Femur</td>
<td>1000</td>
</tr>
<tr>
<td>Pelvis</td>
<td>1500-3000</td>
</tr>
</tbody>
</table>

**Table 49-4 Nerve Injuries Accompanying Orthopedic Injuries**

<table>
<thead>
<tr>
<th>Orthopedic Injury</th>
<th>Nerve Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal radius</td>
<td>Median nerve</td>
</tr>
<tr>
<td>Elbow injury</td>
<td>Median or ulnar</td>
</tr>
<tr>
<td>Shoulder dislocation</td>
<td>Axillary</td>
</tr>
<tr>
<td>Sacral fracture</td>
<td>Cauda equina</td>
</tr>
<tr>
<td>Acetabulum fracture</td>
<td>Sciatic</td>
</tr>
<tr>
<td>Hip dislocation</td>
<td>Femoral nerve</td>
</tr>
<tr>
<td>Femoral shaft fracture</td>
<td>Peroneal</td>
</tr>
<tr>
<td>Knee dislocation</td>
<td>Tibial or peroneal</td>
</tr>
<tr>
<td>Lateral tibial plateau fracture</td>
<td>Peroneal</td>
</tr>
</tbody>
</table>
a distal radius fracture caused by a high-energy insult can be associated with acute dysfunction of the median nerve. Deteriorating neurologic function may necessitate temporary or definitive stabilization of a fracture.

When the nerve is completely severed, all functions are absent, including superficial sensation to touch, pain, and temperature; deep sensation to muscle and joint movements, position, deep pressure, and vibration; motor supply and deep tendon reflexes (to distally innervated muscle groups); and response to electrical stimulation. For less severe injuries, any subjective change in sensation should be noted. Light touch is a good screening test. Two-point discrimination is a more sensitive examination and should be used routinely in evaluating digital nerves. Separating the ends of a paper clip a few millimeters apart and asking the patient to discriminate between one or two points may easily accomplish this. The discrimination on the injured digit is then compared with the uninjured ones. Two-point discrimination may be of limited value in children in whom a subjective response may be misleading; this is also true in patients with calloused fingertips.

The discrimination on the injured digit is then compared with the uninjured ones. Two-point discrimination may be of limited value in children in whom a subjective response may be misleading; this is also true in patients with calloused fingertips and in patients who are uncooperative, comatose, in severe pain, intoxicated. Testing for sympathetic nerve function with the Ninhydrin test, another sudomotor test used to assess peripheral nerve integrity, is reportedly more reliable than the O’Riain wrinkle test but is not practical to perform in the ED.

Compartment Syndrome

Compartment syndrome is a serious acute emergency complication that should be considered whenever pain and paresthesias occur in an extremity after a fracture within an enclosed osseofascial space (Table 49-5). The immediate threat is to the viability of nerve and muscle tissue within the involved compartment, but infection, gangrene, myoglobinuria, and renal failure also may ensue. Compartment syndrome is associated most commonly with a closed long bone fracture of the tibia, but it also is well described in the thigh, forearm, arm, hand, and foot.11-35 In addition, compartment syndrome can occur with soft tissue trauma alone and even with open fractures. It also has been described in a host of unusual situations, including prolonged procedures in the lithotomy position, the tuck position (knees tucked to the chest for lumbar surgery), coma, spontaneous hemorrhage, intraoperative injections, and the application of excessive traction in treatment of a fracture.36,37 Acute surgical stabilization of a fracture is also associated with higher rates of compartment syndrome in the postoperative period.38

Pathophysiology. Increased pressure in a closed nonexpandable compartment essentially represents a mismatch between the volume of that space and its contents. As such, it may arise from one of three circumstances: (1) increased compartment contents, (2) decreased compartment volume, or (3) external pressure (Box 49-3). As tissue pressure increases, so does venous pressure, resulting in compromise of the local circulation and tissue hypoxia; this is believed to occur at pressures that are above normal diastolic pressure but below systemic arterial pressure because of a reduced arteriovenous gradient at the tissue level. The body responds by releasing histamine in an attempt to dilate capillaries and increase blood flow to the affected area. Histamine also increases capillary membrane permeability, resulting in a leak of proteins and fluid into the surrounding tissue, further increasing compartment pressure.

### Table 49-5  Life-Threatening or Limb-Threatening Emergencies

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>POSSIBLE ADVERSE OUTCOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open fracture</td>
<td>Osteomyelitis</td>
</tr>
<tr>
<td>Fracture or dislocation with major vascular disruption (especially popliteal)</td>
<td>Amputation</td>
</tr>
<tr>
<td>Major pelvic fracture</td>
<td>Exsanguination</td>
</tr>
<tr>
<td>Hip dislocation</td>
<td>Avascular necrosis of femoral head</td>
</tr>
<tr>
<td>Compartment syndrome</td>
<td>Ischemic contracture; myoglobinuria, renal failure</td>
</tr>
</tbody>
</table>

### Box 49-3  Causes of Compartment Syndrome

#### Increased Compartment Content
- Bleeding
- Major vascular injury
- Coagulation disorder
- Anticoagulant therapy
- Increased capillary filtration
- Reperpfusion after ischemia
- Arterial bypass grafting
- Embolectomy
- Ergotamine ingestion
- Cardiac catheterization
- Lying on limb
- Trauma
  - Fracture
  - Convulsion
- Intensive use of muscle
  - Exercise
  - Seizures
  - Eclampsia
  - Tetany
  - Burns
  - Thermal
  - Electrical
- Intra-arterial drug injection
- Orthopedic surgery
  - Tibial osteotomy
  - Hauser’s procedure
- Reduction and internal fixation of fractures
- Snakebite
- Increased capillary pressure
- Intensive use of muscles
- Venous obstruction
  - Phlebitis rheumatica dolens (i.e., acute inflammation and edema of the legs)
  - Ill-fitting leg brace
  - Venous ligation
- Diminished serum osmolarity (i.e., nephrotic syndrome)

#### Decreased Compartment Volume
- Closure of fascial defects
- Excessive traction on fractured limbs

#### Miscellaneous
- Infiltrated infusion
- Pressure transfusion
- Leaky dialysis cannula
- Muscle hypertrophy
- Popliteal cyst

#### External Pressure
- Tight casts, dressings, or air splints
- Lying on limb

As tissue pressure continues to increase, venous blood flow is impaired as capillary perfusion pressure is exceeded. Finally, arterial capillary blood flow falls to a point at which the basic metabolic needs are no longer met, leading to ischemic necrosis of muscles and nerves within the compartment. An important concept in the management of compartment syndrome is that because local venous pressure cannot be significantly below local tissue pressure, and because elevation of a dependent limb decreases local arterial pressure by 0.8 mm Hg for each 1 cm of limb elevation, elevation of a limb with resultant reduction in the local arteriovenous gradient may be counterproductive and may exacerbate compartment syndrome. Vascular spasm seems to play an insignificant or minimal role in the development of compartment syndrome, as evidenced angiographically, where spasm has never been shown, and clinically, where it is observed that distal pulses usually are maintained until late in the course.

Normal compartment pressure is 0 mm Hg. Microcirculation generally is impaired when tissue pressures reach 30 mm Hg or more; however, some patients can tolerate much higher compartment pressures without development of compartment syndrome. Controversy exists over attempts to define compartment syndromes on the basis of specific tissue pressure. The tolerance to tissue ischemia varies among individuals because of shock, compensatory hypertension, altered tone in resistance vessels, preexisting vascular disease, and other unknown factors. Inadequate perfusion and relative ischemia begin when tissue pressure within a closed compartment increases to within 20 mm Hg of a patient’s diastolic pressure or, more accurately, within 30 mm Hg of the mean arterial pressure. When tissue pressure equals or exceeds the patient’s diastolic pressure, tissue perfusion effectively ceases. The development of muscle ischemia depends not only on the magnitude but also on the duration of elevated pressure. Intracompartmental pressures do not measure muscle and nerve ischemia but rather suggest the existence of the proper setting for compartment syndrome.

Anatomic Considerations and Risk Factors. Compartment syndrome theoretically can develop in any location where neuromuscular tissue is contained in a limiting envelope. The condition has been reported in the leg, thigh, buttock, arm, forearm, and hand (Box 49-4). By virtue of its location and higher likelihood of sustaining high-energy trauma, the leg, particularly the anterior compartment, is most commonly involved. Higher rates of compartment syndrome are seen with open fractures than with closed fractures, despite the fascial rents that accompany open fractures. The higher energy of injury observed with open fractures, with resultant tissue trauma, swelling, and bleeding, may account for this observation.

In a study of 164 patients treated over an 8-year period in the United Kingdom, a fracture was present in 69%, and half of these involved the tibial shaft. Perhaps more significant is that 31% of patients had only soft tissue injury without fracture. Most patients were men younger than age 35. Ten percent of patients either had a bleeding disorder or were taking anticoagulants. Traffic accidents and sports activities were the most common mechanisms of injury.

Clinical Presentation. Compartment syndrome is a clinical diagnosis. In a conscious and fully oriented patient, pain that is disproportionate to the injury or physical findings is a hallmark finding in compartment syndrome. Pain often is characterized as deep, burning, and unreleenting and is difficult to localize. The need for increasing amounts of analgesics should not lead the clinician automatically to the conclusion that the patient is drugseeking; rather, it should serve as a prompt to the possibility that a compartment syndrome is developing or is present.

Pain on passive stretching of the muscle groups in the suggestive compartment is an important finding. In addition, active flexion of involved muscles may produce pain. Other reliable suggestive signs and symptoms are hypoesthesias and paresthesias in the distribution of nerves crossing the compartment or tenderness, tenseness, or the sensation of tightness of the compartment.

Skin color, temperature, capillary refill, and distal pulses all are unreliable monitors for compartment syndrome because the pressure necessary to produce compartment syndrome is well below arterial pressure. Pallor and loss of pulses are late and ominous signs. Diminished pulses should suggest concomitant pathologic conditions responsible for reduced arterial flow. Although it is still frequently taught that the five Ps (pain, pallor, pulselessness, paresthesias, and paralysis) are signs and symptoms of compartment syndrome, this is generally not true. Rather, they are the signs of acute disruption of arterial flow. Subjective complaints are an important indicator of compartment syndrome. Patients who are not fully alert or cooperative are assessed with particular care.

Diagnostic Tests. If the history and examination suggest compartment syndrome, compartment pressures should be measured with any of the commercially available monitors (Fig. 49-9). The two most common methods of determining compartment pressures are the slit-catheter techniques and the side-port needle. The Stryker Intra-Compartmental Pressure Monitor system is a hand-held digital device that is easy to use with minimal training. Care should be taken to zero the monitor in on the plane in which it will be inserted to account for the effects of gravity. It is also paramount that the appropriate compartment be measured. Pressures of less than 30 mm Hg generally do not produce compartment syndrome. Pressures exceeding 30 mm Hg or within 30 mm Hg of the patient’s mean arterial pressure are an indication for fasciotomy. Serial or continuous pressure measurements should be performed in cases that are not clear-cut. A rising or sustained elevated compartment pressure is superior to a single measurement as an indicator of acute compartment syndrome or the need for fasciotomy. Compartment syndrome can occur at pressures significantly below systemic pressure. Doppler ultrasound is not useful in evaluating these patients because excellent arterial blood flow may be documented even in the presence of a significant compartment syndrome. Newer devices based on near-infrared spectroscopy (NIRS) measurement of tissue oxygenation have proven effective experimentally in detecting compartment syndrome but will require validation in the clinical setting before widespread application.

### Box 49-4: Reported Anatomical Locations of Compartment Syndromes

<table>
<thead>
<tr>
<th>Lower Extremity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leg</strong></td>
<td></td>
</tr>
<tr>
<td>Anterior compartment</td>
<td></td>
</tr>
<tr>
<td>Lateral compartment</td>
<td></td>
</tr>
<tr>
<td>Deep posterior compartment</td>
<td></td>
</tr>
<tr>
<td>Superficial posterior compartment</td>
<td></td>
</tr>
<tr>
<td><strong>Thigh</strong></td>
<td></td>
</tr>
<tr>
<td>Quadriceps compartment</td>
<td></td>
</tr>
<tr>
<td><strong>Buttock</strong></td>
<td></td>
</tr>
<tr>
<td>Gluteal compartment</td>
<td></td>
</tr>
<tr>
<td><strong>Upper Extremity</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Hand</strong></td>
<td></td>
</tr>
<tr>
<td>Interosseous compartment</td>
<td></td>
</tr>
<tr>
<td><strong>Forearm</strong></td>
<td></td>
</tr>
<tr>
<td>Dorsal compartment</td>
<td></td>
</tr>
<tr>
<td>Volar compartment</td>
<td></td>
</tr>
<tr>
<td><strong>Arm</strong></td>
<td></td>
</tr>
<tr>
<td>Deltoid compartment</td>
<td></td>
</tr>
<tr>
<td>Biceps compartment</td>
<td></td>
</tr>
</tbody>
</table>
Complex Regional Pain Syndromes (Reflex Sympathetic Dystrophy and Causalgia)

Definitions. The terms reflex sympathetic dystrophy (RSD) and causalgia have been used to describe pain syndromes that sometimes follow fractures, orthopedic surgery, soft tissue injuries, and other unrecognized trauma to the limbs and their appendages. Other names previously used for this spectrum of post-traumatic injuries include Sudeck’s atrophy, shoulder-hand syndrome, and postinfarction sclerodactyly. In an attempt to reduce misunderstanding about their etiology and treatment, the International Association for the Study of Pain (IASP) issued a consensus statement renaming the syndromes formerly called reflex sympathetic dystrophy and causalgia. Complex regional pain syndrome type 1 (CRPS-1), replacing the term reflex sympathetic dystrophy, is a pain syndrome that develops after an initiating noxious event, extends beyond the distribution of a single peripheral nerve, and is usually disproportionate to the inciting event. The site is most often the distal end of the affected extremity, with a distal-to-proximal gradient. It is associated with edema, changes in blood flow to the skin, abnormal sudomotor activity in the region of the pain, allodynia (pain resulting from non-noxious stimulation to the skin), hyperpathia (pain persisting or increasing after mild or light pressure), or hyperalgesia. The presence of a condition that otherwise would explain the degree of pain and dysfunction excludes the diagnosis of CRPS-1. Because so much of the literature still refers to RSD, this chapter still uses the terms RSD and CRPS-1 interchangeably. The definition of CRPS-2 is the same as for CRPS-1 except that there is demonstrable peripheral nerve injury. This term replaces causalgia under the IASP taxonomy.

Pathogenesis and Etiology. The pathogenesis of CRPS-1 has not been elucidated. Current research suggests that central and peripheral sensitization after a noxious event, inflammation, alteration of sympathetic and catecholaminergic function, altered limb representation in the somatosensory cortex, genetic factors, and psychophysiologic interactions may all play a role. Cases of CRPS-1 have been reported after fractures and as iatrogenic complications of surgery or after minor procedures, including subcutaneous excision and intravenous injection. Forceful manipulations and tight casts also are alleged to have produced the syndrome. In 10 to 26% of patients, no inciting event is identified.

Although malingering and secondary gain are suspected in some patients, they are not the causes in most patients, as evidenced by pathologic tissue changes in patients who actually have CRPS-1. CRPS-1 occurs in children and adolescents. Girls are affected three times as often as boys, and the median age is 12 years. The lower limb is affected twice as often as the upper, and history of inciting trauma can be identified in only half the children with the disorder.

Diagnosis. No correlation exists between the severity of the original trauma and the incidence, severity, and cause of the symptoms, making early diagnosis a challenge, especially after trivial injury. Early diagnosis is crucial because the earlier treatment is initiated, the better the response. Although consensus-based diagnostic criteria were proposed by the IASP in 1994, because of their low specificity, there is no agreement on the best method for diagnosis of CRPS, and several sets of diagnostic criteria exist. Bruehl’s and Veldman’s criteria sought to improve the IASP criteria, but there is no reason to recommend one set of criteria over another (Table 49-6). Treatment. Treatment of CRPS is controversial. Debate arises because published randomized controlled trials provide limited evidence to formulate treatment recommendations; individual response to treatment varies; and experts disagree regarding the pathogenesis of the disease. A multidisciplinary approach, including physical therapy and psychological counseling, is often necessary for treatment of CRPS. For some patients, definitive
treatment involves sympathetic blockade, usually with regional anesthesia and occasionally by surgical sympathectomy. Oral medications, including bisphosphonates, calcitonin, indomethacin, corticosteroids, tricyclic antidepressants, gabapentin, acupuncture, spinal cord stimulation, regional nerve blocks, and other medications and methods, have been used to treat RSD with variable success. In one study, vitamin C was shown to reduce the incidence of RSD after wrist fracture.

**Fat Embolism Syndrome**

*Fat embolism* refers to the presence of fat globules in the lung parenchyma and peripheral circulation after a long bone fracture or major trauma. The phenomenon of fat embolization is probably common as a subclinical event after long bone fracture. Intravascular fat droplets appear in nearly one of five patients admitted with major trauma, although not all patients are symptomatic or require treatment.

Fat embolism syndrome is a serious manifestation of fat embolism, occurring most commonly after long bone fractures (usually tibia and fibula) in young adults and after hip fractures in elderly patients. Symptoms usually appear 1 to 2 days after an acute injury or after intramedullary nailing. Respiratory distress and hypoxemia are the earliest, most common manifestations. Acute respiratory distress syndrome (ARDS) may occur and is the usual cause of death. Neurologic involvement, manifesting as restlessness, confusion, or deteriorating mental status, also is an early sign, as are thrombocytopenia and a petechial rash. Fever, tachycardia, jaundice, retinal changes, and renal involvement may occur. Fat is seen in the urine in 50% of patients within 3 days of the injury. The incidence of full-blown fat embolism syndrome varies from 0.5 to 2% in patients with isolated long bone fractures to 5 to 10% in patients with multiple fractures. Management of fat embolism syndrome is primarily supportive, usually in an intensive care unit. The mortality rate is 20%, but most patients recover without severe sequelae. No specific therapy has shown benefit.

**Fracture Blisters**

Fracture blisters are tense blisters or bullae that accompany high-energy injuries in areas of relatively little skin coverage over a fracture site. The ankle, elbow, foot, and knee (in that order) are the most common sites; all of these contain fewer hair follicles and sweat glands to anchor together the epidermal-dermal junction than do other limb locations. Fracture blisters are believed, in many cases, to occur in the setting of increased underlying tissue pressure and may be a harbinger of compartment syndrome.

Early surgical intervention reduces the incidence of fracture blister formation. In addition, the presence of a fracture blister requires an alteration of the surgical approach or a delay in surgery. Most experts discourage incisions through a fracture blister because such incisions seem to increase infection and skin breakdown. Measures to perform early surgery after high-energy

---

### Table 49-6 Diagnostic Criteria for Complex Regional Pain Syndrome (CRPS) Type 1*

<table>
<thead>
<tr>
<th>NAME</th>
<th>CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>IASP 1994 consensus criteria</td>
<td>Criteria 2, 3 and 4 are necessary for a diagnosis of CRPS type 1. 1. Type 1 is a syndrome that develops after an initiating noxious event. 2. Spontaneous occurrence of pain in the absence of an external stimulus, allodynia (pain caused by a mechanical or thermal stimulus that normally does not provoke pain), or hyperalgesia (exaggerated response to a stimulus that is normally painful) that is not limited to the territory of a single peripheral nerve and is disproportionate to the inciting event. 3. There is or has been evidence of edema, skin blood flow abnormality, or abnormal sudomotor activity (sweating) in the region of the pain since the inciting event. 4. This diagnosis is excluded by the existence of conditions that would otherwise account for the degree of pain and dysfunction.</td>
</tr>
<tr>
<td>Bruehl's criteria: IASP-family</td>
<td>1. Continuing pain disproportionate to any inciting event. 2. Patient must report at least one symptom in each of the following categories: a. Sensory: reports of hyperesthesia b. Vasomotor: reports of temperature asymmetry or skin color changes or skin color asymmetry c. Sudomotor or edema: reports of edema or sweating changes or sweating asymmetry d. Motor or trophic: reports of decreased range of motion or motor dysfunction (weakness, tremor, dystonia) or trophic changes (hair, nail, skin) 3. Must display at least one sign in two or more of the following categories: a. Sensory: evidence of hyperalgesia (to pinprick) or allodynia (to light touch) b. Vasomotor: evidence of temperature asymmetry or skin color changes or asymmetry c. Sudomotor or edema: evidence of edema or sweating changes or sweating asymmetry d. Motor or trophic: evidence of decreased range of motion or motor dysfunction (weakness, tremor, dystonia) or trophic changes (hair, nail, skin)</td>
</tr>
<tr>
<td>Veldman's criteria</td>
<td>1. Presence of four out of five symptoms: a. Diffuse pain during exercise b. Temperature difference between affected and unaffected extremity c. Color differences between affected and unaffected extremity d. Volume differences between affected and unaffected extremity e. Limitations in active range of movement of the affected extremity 2. Occurrence or increase of symptoms during or after use. 3. Symptoms in an area larger than the area of the primary injury.</td>
</tr>
</tbody>
</table>


IASP, International Association for the Study of Pain.

*IASP definition of CRPS–1: A variety of painful conditions following injury that appear regionally, having a distal predominance of abnormal findings, exceeding in both magnitude and duration the expected clinical course of the inciting event and often resulting in significant impairment of motor function, and showing variable progression over time. (All three criteria sets use this definition).
injuries and to minimize increases in tissue pressures might reduce the incidence of this complication. Intact blisters should be covered with povidone-iodine solution and a sterile dressing. Unroofing the blister and applying coverage with silver sulfadiazine paste has been reported to decrease the incidence of complications.64

Complications of Immobilization

Fractures frequently result in long periods of immobilization. Immobility may lead to multiple medical problems, especially in elderly patients, including pneumonia, deep venous thromboembolitis, pulmonary embolism, urinary tract infection, wound infection, decubitus ulcers, muscle atrophy, stress ulcers, gastrointestinal hemorrhage, and psychiatric disorders (Box 49-5). Early ambulation is a major goal of optimal orthopedic care.

Damage Control Orthopedic Surgery

Over the past few decades, the management of the multiply injured trauma patient has changed considerably. Historically, patients with multiple injuries were treated nonoperatively as it was believed they were too ill to tolerate surgery. In the 1970s, literature began to appear suggesting adverse outcomes as a result of prolonged recumbency. In addition, operative fracture fixation techniques were evolving, and this lead to the advent of early fracture stabilization and the notion of early total care of the polytrauma patient.65 During the 1990s, the concept of damage control surgery came to the forefront of trauma surgical care. In a landmark paper, Rotondo and colleagues reported on the successful use of an abbreviated operation in patients with penetrating abdominal trauma to avoid the lethal triad of hypothermia, acidosis, and coagulopathy, and coined the phrase “damage control.”66 Similar principles were found to be applicable to the management of pelvic and long bone fractures in the polytrauma patient. Early total care with immediate definitive fixation of all major fractures saw a gradual move toward early temporary fracture stabilization, resuscitation of the patient to a stable physiologic state, then definitive fixation at a later time once the patient’s physiology had been stabilized.65 Temporary fracture stabilization is usually accomplished by application of external fixation devices to aid in hemorrhage control and tissue oxygenation, but the timing and optimal type of fracture surgery in the multiply injured trauma patient are still subjects of research.67

Box 49-5 Complications of Fractures and Immobility

Fractures
- Hemorrhage
- Vascular injuries
- Nerve injuries
- Compartment syndrome
- Volkmann’s ischemic contracture
- Avascular necrosis
- Reflex dystrophy
- Fat embolism syndrome

Immobility
- Pneumonia
- Deep venous thrombosis
- Pulmonary embolism
- Urinary tract infection
- Wound infection
- Decubitus ulcers
- Muscle atrophy
- Stress ulcers

SUBLUXATION AND DISLOCATIONS

Nomenclature

Abnormal forces applied to joints may result in the loss of continuity between two articulating surfaces. Partial loss of continuity is termed subluxation, and complete loss is termed dislocation. In general, dislocations are named for the major joint involved, as in a dislocated shoulder or hip. In three-bone joints, the injury is named for the joint involved if the disturbance involves the two major bones, or, if the lesser bone is involved, the disturbance is named for that bone. Separation of the femur from the tibia is termed dislocation of the knee, whereas displacement of the patella from its normal articulation is termed dislocation of the patella (Fig. 49-10). At the elbow, separation of the olecranon from the humerus is a dislocation of the elbow, whereas separation of the radius from the humerus is termed radial head dislocation.

Dislocations and subluxations should be described according to the direction of the distal segment relative to the proximal segment or of the displaced bone relative to the normal structures. The injury shown in Figure 49-11 is termed dorsal dislocation of the interphalangeal joint of the thumb. Disruption of articulation also may occur in combination with a fracture. The term fracture-dislocation is used to describe this combination. If the overlying skin is broken in any way, dislocations, subluxations, or fracture-dislocations are described as open and constitute the same emergency as does an open fracture alone.

Figure 49-10. Dislocation of the patella.

Figure 49-11. Dorsal dislocation of the distal phalanx of the thumb.
Assessment

In most cases of dislocation, severe to excruciating pain is present because the joint capsule is stretched or torn. Movement of the joint exacerbates the pain. This useful sign is lost in an obtunded, intoxicated, or unconscious patient and may result in a missed diagnosis if a careful survey is not performed. Some dislocations, such as anterior shoulder dislocation, cause an obvious deformity, whereas others, such as posterior shoulder dislocation, may be subtle. Swelling of soft tissues also may obscure the diagnosis, such as in the tarsal-metatarsal region. Gentle passive testing of range of motion should be performed but never forced. Assessment for neurovascular function is similar to that for fracture. Certain dislocations (e.g., knee) are so commonly associated with vascular injuries that a careful assessment of blood flow is important in evaluating these injuries.

Plain radiographic studies detect most dislocations, provided that the correct views are ordered. Radiographs should be performed before and after attempts at reduction of first-time or complicated dislocations, unless there is neurovascular compromise. This confirms the diagnosis and ensures that associated fractures are documented before treatment is undertaken.

Treatment

Methods of relocating specific joints are reviewed in subsequent chapters, but a few principles apply. In general, the sooner a joint is relocated, the better. Later, swelling and muscle spasm make reduction more difficult. Also, pain is not adequately relieved until the extremity and the forces applied to it at that moment. A history is often desirable, particularly in lateral ankle injuries because this helps prevent interposition of soft tissues in the joint that can preclude reduction. As this maneuver is accomplished, the disarticulated surface is manipulated back or may snap back spontaneously toward its normal anatomic position. If the reduction is difficult, it should not be forced. A single good attempt is better than repeated attempts in an inadequately relaxed patient. Some joints cannot be reduced in the ED because (1) the opposing muscles are contracting too forcefully and general anesthesia is necessary to overcome these forces or (2) mechanical obstruction by a bony fragment or a torn piece of cartilage, tendon, joint capsule, or skin requires surgical removal for reduction to occur.♥

SOFT TISSUE INJURIES

Sprains

Nomenclature

Ligamentous injuries resulting from an abnormal motion of a joint are termed sprains. A sprain is injury to the fibers of a supporting ligament of a joint. Sprains may be graded according to the severity of pathologic findings; clinically, however, the grades are often indistinct. First-degree sprains are characterized by minor tearing of ligamentous fibers with resultant mild hemorrhage and swelling. Minimal point tenderness can be elicited. Stressing the ligament produces some pain, but there is no opening or abnormal joint motion.

A second-degree sprain is a partial tear of a ligament, meaning more fibers are torn than in the first-degree injury. Clinical findings include moderate hemorrhage and swelling, tenderness, painful motion, abnormal motion, and loss of function. There may be a tendency toward persistent instability and recurrence, and prevention of these complications is a major goal of treatment.

A third-degree sprain describes the complete tearing of a ligament. Signs include a further exaggeration of the signs mentioned for second-degree sprain. In addition, stressing the joint reveals grossly abnormal joint motion, provided that this is not limited by pain or swelling. Analgesia and the evacuation of a hemarthrosis may be used to allow a more complete diagnosis of these injuries. Chronic joint instability is the rule if severe ligamentous injuries do not heal properly.

Assessment

The clinical presentation of a sprain of the extremity may be indistinguishable from that of a fracture. The injury frequently occurs during vigorous athletic activity when forces applied in opposite directions result in a joint being stressed in an abnormal or exaggerated direction. The patient may complain of hearing a “snap” or a “pop” at the moment of injury and conclude that a fracture is present. Other patients report “seeing stars” or “almost passing out” at the moment the injury occurred and may still be in extreme pain, appearing pale and diaphoretic if seen shortly after the injury. Analgesia should be provided to these patients. Evaluation should include a careful history of the exact sequence of events at the time of the injury and ascertaining the position of the extremity and the forces applied to it at that moment. A history of any sounds that accompanied the injury should be elicited. Examination of the joint should include stressing it to show abnormal motion. If radiographs are planned to rule out a fracture anyway or if exquisite pain is produced by mild attempts to apply stress, it is probably better to delay stressing until films have verified the absence of a significant fracture. Plain radiography is indicated in some, but not all, cases to rule out a fracture. It has been well demonstrated that clinical decision rules can reduce the number of radiographic studies without missing significant fractures.♥

Avulsion fractures may occur concomitantly with sprains. In children, epiphyseal fractures occur more commonly than ligamentous disruption because of the relative ligamentous strength compared with the ease of disrupting the epiphyses. Arthroscopy or MRI is indicated in the follow-up evaluation of some of these injuries (e.g., for suspected cruciate ligament tears) when significant pain or disability is present.♥

Treatment and Disposition

Specific management of sprains varies depending on the location and severity of the injury. In general, initial measures should include the traditional recommendations of ice, elevation, and analgesia. Nonsteroidal anti-inflammatory drugs (NSAIDs) are effective analgesics in many patients. Several studies have found a more rapid decrease in swelling, increased exercise endurance, and earlier return to work with use of NSAIDs.♥

Immobilization through use of one of the following methods provides protection and comfort in the initial management of most injuries. Because the severity of injury is sometimes difficult to establish at the first visit, it is reasonable to immobilize the affected joint for the first 48 to 72 hours, after which the extent of injury can be better determined. At that time, early mobilization is often desirable, particularly in lateral ankle injuries because this leads to earlier return to work and athletic activities and better preservation of proprioceptive neuromuscular function.♥ Use of an inflatable “air cast” alone or in conjunction with an elastic ankle wrap has been shown to be effective in decreasing the symptomatic period.♥ For lower extremity injuries, protected weightbearing with crutches provides patients with comfort and avoids
motion of the impaired part. In elderly patients, safe ambulation sometimes cannot be accomplished, and a short hospitalization or admission to a skilled nursing facility may be necessary.

For complete or nearly complete ligamentous disruption, urgent orthopedic consultation is usually mandatory. Less severe injuries can be followed up 3 to 7 days postinjury when acute swelling has subsided. Copies of plain films ordered in the ED should be sent with the patient if possible. Physical therapy and rehabilitative exercises sometimes are begun at these visits and carried on for several weeks. Because ligaments are relatively avascular, healing is slow, and patients with significant sprains should be informed of this. Sprains should be diagnosed as precisely as possible and should not be trivialized. Too often after radiographs have ruled out fracture of an affected extremity, the term sprain is applied indiscriminately or the patient is told that the injury is only a sprain, a misleading expression that should be avoided. Aside from creating false expectations regarding recovery, thoughtless mislabeling of injuries not in evidence may lead to missed occult fractures in adults or epiphyseal injuries in children.

Strains

Nomenclature

A strain is an injury to a musculotendinous unit resulting from violent contraction or excessive forcible stretch. The term pulled muscle sometimes is used interchangeably with muscle strain. These injuries are graded in a manner similar to sprains.

A first-degree (mild) strain is a minor tearing of the musculotendinous unit, characterized by minor swelling, local tenderness, and minimal restriction of movement. Findings increase along a continuum such that in a second-degree (moderate) strain, more fibers are torn, but without complete disruption; swelling, ecchymosis, and loss of strength are more marked. In a third-degree (severe) strain, the muscle or tendon is completely disrupted, with resultant separation of muscle from muscle, muscle from tendon, or tendon from bone. An accompanying avulsion fracture may be present on radiographs in either second- or third-degree injuries.

Assessment

Signs and symptoms include pain, ecchymosis, swelling, and loss of function. A force applied to the muscle, either passive stress or active contraction, produces sharp pain at the site of injury even as the injured muscle may be relatively comfortable at rest. A palpable defect sometimes is present at the site of a complete rupture, which usually involves the region of the muscle-tendon junction, or a bunching up of the muscle may be appreciated. Ultrasound is increasing being used to diagnose an assortment of soft tissue injuries, including rotator cuff tears, tendon ruptures, and muscle tears. Among nonathletes, strains commonly are seen in patients who have either overstressed a muscle group or tried to generate excessive force in an unconditioned muscle. Examples are the weekend gardener or mover who experiences lower back strain on Monday morning, the aerobics student who strains the rectus muscles, and the weightlifter with chest wall pain resulting from pectoralis major strain. These are usually first-degree injuries, and the onset is slow. Rapid acceleration (e.g., in a tennis player) may result in a third-degree gastrocnemius or plantaris tear, whereas pushing off to jump is a common cause of ruptures of the Achilles tendon in a basketball player. A sudden violent attempt at lifting in an older individual can result in a complete biceps brachii disruption. Sudden generation of forces of which the thighs are capable results in second-degree strain of the hamstrings, quadriceps, or thigh abductor muscles.

In athletes, generation of tremendous contraction forces coupled with excessive forcible stretching (while the body may be either accelerating or “planting”) results in severe strains. Involvement of almost any muscle group is possible, and the onset of such injuries is usually acute. Immediate removal from activity, application of ice, and rest of the affected limb for 48 to 72 hours usually are advised for prevention of further injury. A competitive athlete usually is unable to continue anyway because of the accompanying loss of function. After a brief rest period, however, early mobilization and rehabilitation should be encouraged.

Treatment and Disposition

Treatment depends on the degree of disruption, location, and functional loss. Most first-degree injuries respond in a few days to rest, application of ice, and, for some patients, analgesics. NSAIDs commonly are recommended and prescribed, although their efficacy for other than analgesic purposes is unproven. Second-degree strains are treated similarly, with protection against aggravating activity required for longer periods. Third-degree strains receive similar initial treatment in the ED plus early orthopedic consultation. Some of these injuries are amenable to surgical repair, whereas others may be treated with immobilization. The muscle affected and the age, occupation, and activity level of the patient all are factors in deciding whether surgical intervention is appropriate. Early mobilization is an important tenet in the treatment of muscle strains; its timing may be based on the ability to stretch the injured muscle as much as the uninjured contralateral muscle, and the use of the injured muscle without pain during basic movements. Many athletes and their trainers believe, and it is universally espoused, that many strains can be prevented by proper preseason conditioning, warm-up, stretching exercises, and avoidance of overexertion, although limited scientific data exist to support these recommendations.

Tendinitis and Tendinosis

Tendinitis is classically described as an inflammatory condition characterized by pain at tendinous insertions into bone, occurring in the setting of overuse. It is now believed that the pathophysiology of this condition is more complex than mere overuse, with the roles of load and use affecting cell-matrix interaction. Causative factors are believed to include aging, with decreased blood supply and decreased tensile strength; muscle weakness and imbalance; insufficient flexibility; male gender; obesity (in weight-bearing joints); smoking; malalignments; training errors; and improper equipment. In addition, certain systemic diseases, including diabetes mellitus, chronic renal failure, rheumatoid arthritis, and systemic lupus erythematosus; steroid use; and occasionally fluoroquinolone use are associated with the development of tendinopathy.

The histopathology of tendinitis is characterized by degeneration and disorganization of collagen fibers; infiltration by macrophages, plasma cells, and lymphocytes rather than leukocytes; and increased vascularity. Inflammatory changes are not a principal finding in tendinitis. This evolving understanding of tendinitis in the future should allow for more logical treatment of these injuries aimed at the underlying pathophysiology. It also has led some authors to propose that chronic painful conditions of the tendon should be referred to as tendinosis rather than tendinitis or other terms previously used to describe this condition, including tendinitis, degenerative changes, chronic tendinopathy, or partial rupture. In this chapter, tendinitis and tendinosis are used interchangeably.

Common sites for tendinitis are the rotator cuff of the shoulder, the Achilles tendon, the radial aspect of the wrist (de Quervain’s tenosynovitis), and the insertion of the hand extensors on the
lateral humeral epicondyle (tennis elbow). Also commonly involved in athletes are the patellar tendon, particularly in athletes engaged in jumping sports; the biceps femoris, semitendinosus, and semimembranosus (hamstring syndrome); the posterior tibial tendon (shin splint syndrome); the iliobial band; and the common wrist flexors (medial epicondylitis) (involvement is seen in little league pitchers and golfers). In some locations, most commonly the shoulder, calcium deposition occurs along the course of the tendon, resulting in a painful condition termed calcific tendinitis. This condition also may occur in the wrist, hand, neck, hip, knee, ankle, or foot.

Physical examination reveals pain with motion and limitation of function and may include point tenderness and palpable crepitation over the involved tendon with motion. In general, a clinical test can be performed by forcible flexion of the involved muscle while keeping the point of insertion fixed or by operating the involved muscle against resistance. Either test should intensify the discomfort. Radiographs are usually negative. A small fleck of bone may suggest an avulsion, or the surface of the bone at the attachment may be roughened, indicating periostitis. As mentioned, there also may be calcium deposits along the course of the tendon, which should not be confused with an avulsion fracture. Ultrasound is sometimes useful in confirming the diagnosis of tendinitis. Although a normal tendon is characterized by a relatively homogeneous pattern, tendinitis is characterized by one or more of the following features: loss of the fibrillar echotexture, focal tendon thickening, diffuse thickening, focal hypoechoic area, irregular or ill-defined borders, or microruptures.

There is little evidence to support any specific treatment for tendinosis. The classic approach consists of rest, ice, and NSAIDs initially, followed by rehabilitation and training and control of force loads to prevent recurrences. Although NSAIDs may be useful for a brief period at the onset of symptoms for their analgesic effects, no evidence exists that they significantly alter the pathophysiology of this condition, and no rationale exists for ordering them in patients at any risk for complications from this class of drugs. Peritendinous local infiltrations of anesthetics and corticosteroids may be useful but should not be repeated too often because tendon rupture may occur. Injection therapy is especially useful in calcific tendinitis around the shoulder. Injection of steroids directly into the Achilles tendon should be avoided because of reports of partial or complete rupture after even a single injection. Some cases of calcific tendinitis that do not respond to conservative therapy may require either arthroscopic or open surgery.

**Bursitis**

Bursitis is a painful inflammation of the bursa that may be traumatic, infectious, or related to systemic illness. Commonly involved sites include the olecranon, the greater trochanter of the femur, and the prepatellar and anserine bursae around the knee. Physical findings are tenderness and swelling over the involved bursa, whereas warmth and overlying erythema may signal infection. If infection is suggested, aspiration of the bursal fluid and Gram’s staining and culture are recommended. Otherwise, treatment may be conservative and is similar to treatment for tendinitis, with ice, NSAIDs, or steroid injections. Most patients can be treated as outpatients.

**TREATMENT MODALITIES**

**Splinting and Bandaging**

Suggested or confirmed fractures or dislocations should be splinted to avoid damage to muscles, nerves, vessels, and the skin. Splinting also may restore blood flow to ischemic tissue by removing pressure caused by a bone fragment resting against a blood vessel. In addition, splinting may relieve the pain associated with movement of fracture fragments.

**Field Care**

Splinting should begin in the field because it reduces the risk of further neurovascular compromise, prevents a closed injury from potentially being converted to an open one during transport, reduces the patient’s pain, and facilitates subsequent ED assessment and imaging. Numerous commercial devices are available, and most ambulances carry an assortment of immobilization devices (Fig. 49-12). Minimal equipment includes long and short backboards, cervical collars, sandbags, and extremity splints. A half-ring traction splint also is essential. Inflatable splints are favored by some authors because they are convenient, easy to apply, transparent, and radiolucent and because they tamponade low-pressure bleeding. Other authors prefer to avoid these devices because theoretically they could contribute to the development of a compartment syndrome. If used, inflatable splints should be inflated only by mouth and to the point that still permits indentation by gentle finger pressure.

Field personnel should splint possible fractures before the patient is moved. Severely angulated long bone fractures should be straightened in the field before they are splinted. Splints should

---

**Figure 49-12. Commercial splints.**
be applied in such a way as to immobilize the joints above and below the fracture site to avoid motion of the involved bone. The skin should be padded to avoid local necrosis, and the splint should be secured by use of a circumferential wrapping material. This material should allow for some expansion and should not be applied in a constricting manner.

Emergency Department Care

In the ED, the indications for splinting are the same as in the field. All splints should be checked and if properly applied need not be changed. Hare traction should be removed in the ED because it may angulate femur fractures. Splinting or other immobilization is also used after diagnosis and treatment of injuries. In some cases a splint is all that is needed for definitive treatment. Injuries other than sprains and fractures (e.g., inflammatory and infectious processes, bites, burns, and repaired injuries of muscle bellies or tendons) also benefit from immobilization. Splints also can be used to improve function, such as with wristdrop that accompanies radial nerve palsy. When the injury is immobilized, it is important to stress elevation of the affected part to avoid edema formation. Many different devices and materials are available. Some devices that are commonly used are described next.

Upper Extremity

Sling-and-Swathe and Velpeau Bandages. Sling-and-swathe and Velpeau bandages are useful in immobilizing the shoulder, humerus, and elbow. They are commonly used after reduction of dislocated shoulders and to treat impacted fractures of the humeral neck. The axillae should be padded and powdered to avoid skin maceration. A commercial shoulder immobilizer also is available and is useful after reduction of a shoulder dislocation. Its advantages are ease of application and ease of removal and reapplication by the patient for bathing.

Clavicle Splint. Historically, middle third fractures of the clavicle routinely were initially treated with a figure-of-eight clavicle strap with or without the addition of a sling. This device is commercially available or can be fashioned from tubular stockinette. If used, a clavicle splint should be applied snugly enough to keep the shoulders back in the “at-attention” position, but not so tight as to compress the axillary artery or brachial plexus. Chafing of the skin can be avoided by padding and powdering the axillae. Superiority of the figure-of-eight clavicle strap over a simple sling has not been shown.

Plaster and Fiberglass Splints. Well-fitting, customized plaster splints can be fashioned easily to immobilize the elbow, forearm, wrist, and hand. The advantage of these splints is the ability to mold them to an exact size and shape (e.g., along the ulnar side of the forearm and hand to immobilize a midshaft fourth or fifth metacarpal fracture, the so-called “gutter splint”). Several commercially available products consist of multiple layers of plaster or fiberglass strips, inside a covering of foam and flannel, on a continuous roll that can be applied to any length. While the splint is still wet, a bandage is wrapped over it, and the splint is molded and held in the desired position as the plaster or fiberglass resin hardens.

Forearm and Wrist Splints. Numerous preformed splints are available for splinting fractures of the distal forearm and wrist. They are lightweight, neat, and easy to apply and are easily removed and replaced by the patient (Fig. 49-13).

Lower Extremity

Femur and Hip. Fractures of the femoral shaft can be immobilized with a traction device, such as the Hare traction splint or a similar appliance (Fig. 49-14). These devices should be applied in the field if possible; most ambulances carry them. The principle is that a proximal ring engages the ischial tuberosity for countertraction while the longitudinal traction is applied through the ankle by means of an ankle hitch. A commercial ankle hitch is recommended, but if one is not available, an improvised hitch can be fashioned with a triangular bandage or a wide piece of cloth tied in a Collins hitch. The patient’s ankle bones, Achilles tendon, and arch of the foot should be padded, and the circulation should be checked to ensure it is intact. A properly applied splinting device relieves pain from a fracture rather than exacerbating it.

The Sager splint might offer advantages over other appliances in that it is applied to the medial and lateral aspect of the thigh rather than having a half-ring posteriorly (Fig. 49-15). The Sager splint is more acceptable for use in the presence of pelvic fractures and avoids compression of the sciatic nerve. Because the half-ring devices may produce angulation at the fracture site, the Sager device is purported to result in better alignment, although this has never been measured. The Sager splint is shorter and more compact than the Hare traction splint, rendering it more acceptable for certain transport helicopters and body scanners. Also, the amount of traction is metered at the ankle, and overtraction can be avoided.

Knee. Commercially available knee immobilizers can be used after acute injuries to provide firm but not rigid stabilization of the knee. The device is essentially a foam cylinder with medial and lateral aluminum stays, attached by Velcro straps, and spanning the upper thigh to upper ankle. This device is commonly used after trauma to let the knee “cool off” until a better physical examination or diagnostic study can be performed in a few days.

Another dressing that may be applied at the knee is the Jones “compression” dressing. Some authors believe the word compression should not be used here, to discourage application that is too tight. The Jones dressing is a bulky dressing that is used by some clinicians in situations when swelling is expected, including internal fixation procedures. The ability to flex and extend at the knee is maintained. The dressing consists of a thick layer of
absorbent cotton bandage (Webril) wrapped with an elastic bandage, followed by another layer of cotton bandage, followed by an additional elastic wrap. If more stability is required, slabs of plaster can be placed on the medial and lateral side of the limb, just under the last bandage. Caution is exercised because burns have been reported with this type of dressing when too many layers of plaster are used. A similar type of bulky dressing may be used for some injuries of the ankle and fractures of the calcaneus. In general, commercial knee immobilizers have replaced the Jones dressing in the treatment of acute knee injuries.

Ankle. Immobilization of the ankle can be accomplished by numerous means. Plaster splints can be used temporarily for the treatment of nondisplaced ankle fractures or for the treatment of severe sprains. These can be fashioned in the same manner as described for the upper extremity. An alternative method is to apply a full circular cast, bivalve it on either side, discard the anterior piece, and affix the posterior mold with an elastic bandage or bias-cut stockinette. Most ankle injuries should be splinted with the patient’s ankle in neutral position. Injuries to the Achilles tendon, plantaris muscle, or gastrocnemius muscle initially should be treated with the foot held in slight equinus (plantar flexion) for comfort. The toes should be free to move distal to the metatarsophalangeal joints, and the proximal border should end below the tibial tubercle to avoid pressure on the peroneal nerve.

Adhesive strapping is an alternative method of ankle immobilization that provides good support and limitation of motion. Taping reportedly loses its “protective properties” with cyclic loading and sweating; although this is cited as a disadvantage, it may actually be helpful in encouraging and allowing early mobilization. This method is lightweight and not bulky, and a shoe can be worn over the material. Tape is applied in a noncontinuous manner, which allows for swelling and avoids constriction. First, the hair is shaved. Next, strips of tape are measured and torn off; 1½-inch or 2-inch cloth-backed adhesive tape or Elastoplast is used. Elastoplast is an elastic-backed tape, constructed to stretch only in the longitudinal direction; this serves to spring the foot back automatically to a neutral position if the foot is plantarflexed for any reason. The tape should be applied directly to the skin after a skin adherent, such as tincture of benzoin, is applied. The tape should lie flat because wrinkles may damage the skin (Fig. 49-16). The use of tape is associated with dermatologic complications, including itching or contact dermatitis, owing to adhesion of the tape to the skin.

For mild-to-moderate sprains, functional treatment options including elastic bandaging, soft cast, taping, or orthoses were found to be statistically better than immobilization for multiple outcome measures. Lace-up supports may be more effective than elastic bandaging and result in less persistent swelling in the short
term as compared with semirigid ankle supports, elastic bandaging, and tape.98

For moderate-to-severe lateral ankle sprains, a commercial mechanical support composed of molded plastic with Velcro straps (e.g., AirCast Air-Stirrup) is more effective than elastic bandaging alone (Fig. 49-17).77,99 This product may be worn in the patient’s shoe and permits early weightbearing and return to activity. It is designed to permit dorsiflexion and plantar flexion but to limit inversion and eversion, a concept referred to as functional bracing. Some authors also find this device useful for athletic activities instead of adhesive taping to prevent recurrences.78,100 Although these orthoses are relatively expensive, the cost might be more than offset by their ease of application, their reusability, and the benefit derived from earlier return to work.

Severe ankle sprains also may benefit from immobilization in a Cam Walker, which is a commercial appliance consisting of a layer of padding extending from the tibial tubercle to the metatarsal heads, supported by metal plates along the length of the lower leg. These plates articulate with a molded hard plastic boot at the ankle. The position of the foot can be adjusted as desired, and when set, the ankle is kept firmly immobile. The rounded undersurface of the boot allows for ambulation without movement of the ankle joint.

Casts

Plaster or synthetic (fiberglass) casts perform a function similar to splints in that they provide stability and pain relief. Casts are not mandatory for all fractures, and in situations in which they are, application is usually not an immediate necessity. Because they are circumferential, casts provide more effective immobilization of a fracture, but they require more skill and time to apply. Swelling and subsequent pressure under the cast are highest during the first 24 hours after injury. Complications of casting include compartment syndrome, thermal injury, pressure sores, bacterial and fungal infections (especially if a wound is present under the casted area), and pruritic dermatitis.101 Plaster is applied as strips or rolls of cloth that are impregnated with a hemihydrate of calcium sulfate. When this cloth is dipped in lukewarm water, a creamy paste is formed that can be molded into a cast. An exothermic reaction takes place that causes the plaster to harden and can burn the skin.102 Factors that have been shown experimentally to increase skin temperatures during plaster application are dip-water temperatures greater than 24° C, cast thickness greater than eight plies, and inadequate ventilation of the newly applied cast.103 Immersing the plaster in water for too short a time or squeezing too much water out also may lead to generation of excess heat. To avoid pressure on the skin and over bony prominences, stockinette and layers of cotton sheet wadding (Webril) are snugly applied first. Padding that migrates under a formed cast can be uncomfortable and result in pressure sores. Padding alone does not prevent burns.

Variations of the basic cast exist. A window may be placed in the cast, and the cutout area may be used for access to skin wounds that require care during immobilization. Walking heels may be worked onto a lower extremity cast and should be placed in the center of the foot. Synthetic casts (fiberglass and other materials) are lightweight, durable, and water-resistant.104 In addition, their setting temperatures are significantly lower, and they are less likely to produce burns. However, they are more expensive and more difficult to apply.

Patients with casts may visit the ED for complaints related to their casts; these usually are pain, local irritation, swelling, or numbness of the distal part. A cast that is too tight results in swelling, pain, coolness, and change in skin color of the distal parts. Pain also may be caused by the initial injury or by local pressure,
or it may be a result of a developing compartment syndrome or wound infection. When a patient complains of pain, it is prudent to bivalve the cast and inspect the extremity. This is done by cutting the plaster and the padding on each side and removing half the cast at a time, with the other half used as a mold to keep the extremity immobile. Afterward, the bivalved cast can be held together with bias-cut stockinette or elastic wrap until a new cast is applied. If relieving external pressure does not alleviate symptoms, the diagnosis of compartment syndrome should be seriously considered. casts may obscure wound infections, sources of sepsis, and even the source of tetanus. The clinician should not hesitate to bivalve the cast and inspect the extremity.

The need for mandatory routine cast checks 1 day after initial application has been questioned. In a retrospective study of 250 patients, none experienced problems from neurovascular compression, although 24% required some alteration of the cast. In the study, it may be simply that the casts were applied incorrectly in the first place. It is probably advisable to continue routine cast checks if casts are applied in the ED.

**Thermal Therapy**

Some confusion exists as to the role of cryotherapy versus heat therapy in the treatment of acute orthopedic injuries. Part of this confusion arises because heat may be more soothing to the patient. Cold causes vasoconstriction, limiting blood flow and hemorrhage into the traumatized area. Metabolic requirements are reduced in cooled tissues, as is histamine, and less capillary breakdown occurs as a result. The sooner postinjury ice therapy is initiated, the more beneficial the reduction in metabolism will be. Reduced blood flow also limits edema formation. Lower extravascular fluid pressure allows for better lymphatic drainage of injured areas. Cryotherapy produces three, and perhaps four, stages of sensation of which the physician and the patient should be aware. In the first stage, a cold sensation is noted for 1 to 3 minutes. The second stage consists of a burning or aching sensation for 2 to 7 minutes after the application of cold. This stage is uncomfortable but needs to be endured if the benefits of the next two stages are to be received. Heat therapy, by contrast, is soothing, and patients are likely to prefer this to the second stage of cryotherapy. The third stage begins 5 to 12 minutes after the application of ice and produces local numbness or anesthesia. The pain-spasm cycle is interrupted. While the patient is under this anesthetic effect, passive exercise may be desirable. This exercise helps to prevent atrophy, mobilize edema, clear injury debris, and reduce adhesions. However, several reviews of cryotherapy for soft tissue injury all reflect the lack of adequate science in establishing recommendations for cryotherapy. Application of ice appears to be effective in reducing pain, but there is no credible evidence that it accelerates healing.

A fourth stage sometimes occurs 12 to 15 minutes after intense cryotherapy is begun, consisting of reflex deep tissue vasodilation without a corresponding increase in metabolism (reminiscent of the situation in rewarming shock). Because of this, a maximum of 10 to 15 minutes of cold application per treatment usually is advised. A systematic review of small, limited-quality studies assessed cryotherapy in the management of soft tissue injuries noted wide variation on the optimal mode, duration, and frequency of ice application. Therefore recommendations for an optimal cryotherapy protocol cannot be made.

Absolute contraindications to cryotherapy include severe cold allergy (with hives and joint pain) and Raynaud’s phenomenon and disease. Relative contraindications include some rheumatoid conditions and paroxysmal cold hemoglobinuria with renal dysfunction and secondary hypertension. Anesthetic skin in a paralyzed or comatose patient is at risk with ice therapy. Complications
of cryotherapy can include skin burns and nerve damage but are rare, especially in the athletic population most at risk for serious injuries. Heat increases blood flow and the inflammatory response and edema. Warm tissues and cells have a higher metabolic rate and increased requirements of nutrients and oxygen. Ice, rather than heat, is the method of choice of most authorities in the acute treatment and rehabilitation of acute orthopedic injuries and should be initiated as soon as possible for maximum benefit.

**Autologous Blood Product and Growth Factors**

In recent years, growth factors have been used for the management of soft tissue injury related to acute trauma and overuse injury. Platelets contain growth factors in their alpha-granules, including insulinlike growth factor-1, basic fibroblast growth factor, platelet-derived growth factor, epidermal growth factor, vascular endothelial growth factor, and transforming growth factor-β1, and these are thought to help the regeneration of tissues that otherwise have low healing potential. Growth factors can be delivered as a preparation of platelet rich plasma (PRP), autologous blood injection, and autologous conditioned serum. PRP injections have been described in patients with patellar and elbow tendinosis, Achilles tendon injury, and acute ligamentous and muscle injuries, and they have also been administered intraoperatively during anterior cruciate ligament reconstruction and rotator cuff repair.

Theoretic advantages to the use of PRP include faster recovery and improved functional outcome, but evidence supporting the use of PRP in different tissues is limited and further studies are required before conclusions are drawn.

**KEY CONCEPTS**

- Consultation with an orthopedist should be sought for the treatment of most long bone fractures, open fractures, injuries with joint violation, and injuries with neurovascular compromise.
- Compartment syndrome is associated most commonly with a closed long bone fracture of the tibia but also is well described in the thigh, forearm, arm, hand, and foot and can occur with soft tissue trauma alone. Elevation of a limb with resultant reduction in the local arteriovenous gradient may be counterproductive and may exacerbate compartment syndrome.
- Because of their blood supply, certain bones may undergo avascular necrosis after fracture, especially if fractures are comminuted and go untreated for any length of time. The femoral head, talus, scaphoid, and capitare are particularly prone to this complication.
- Fat embolism syndrome is a serious manifestation of fat embolism, occurring most commonly after long bone fractures in young adults (usually tibia and fibula) and after hip fractures in elderly patients. ARDS is the earliest, most common, and serious manifestation. Neurologic involvement, manifesting as restlessness, confusion, or deteriorating mental status, is also an early sign, as are thrombocytopenia and a petechial rash.
- In children, epiphyseal fractures occur more commonly than ligamentous disruption because of the relative ligamentous strength compared with the ease of disrupting the epiphyses.

The references for this chapter can be found online by accessing the accompanying Expert Consult website.
References

85. Scott A, Ashe MC: Common tendinopathies in the upper and lower 
86. Alfredson A, Lorentzon R: Chronic Achilles tendinosis:
87. Fenwick SA, Hazleman BL, Graham PR: The vasculature and its role in 
89. Khan KM, Cook JL, Bonar F, Harcourt P, Aström M: Histopathology of 
common tendinopathies. Update and implications for clinical 
90. Maffulli N, Wong J, Almekinders LC: Types and epidemiology of 
91. Harvie P, Pollard TC, Carr AJ: Calcific tendinitis: Natural history and 
16:169.
43:969.
93. Andres BM, Murrell GA: Treatment of tendinopathy: What works, 
what does not and what is on the horizon. Clin Orthop Relat Res 2008; 
466:1359.
94. Feucht CL, Patel D: Analgesics and anti-inflammatory medications in 
6:245–250.
96. Stell I: Management of acute bursitis: Outcome study of a structured 
is best practice? A systematic review of the last 10 years of evidence. 
99. Lamb SE, et al: Mechanical supports for acute, severe ankle sprain: 
a pragmatic, multicentre, randomised controlled trial. Lancet 2009; 
100. Handoll HH, Rowe BH, Quinn KM, de Bie R: Interventions for 
preventing ankle ligament injuries. Cochrane Database Syst Rev 2001; 
3:CD000018.
103. Halanski MA, Halanski AD, Oza A: Thermal injury with contemporary 
case-application techniques and their use in soft tissue injury? 
104. Jones MH, Amendola AS: Acute treatment of inversion ankle sprains: 
2007; 455:169.
105. Boyce SH, Quigley MA, Campbell S: Management of ankle sprains: A 
randomized controlled trial of the treatment of inversion injuries using 
an elastic support bandage or an Aircast ankle brace. Br J Sports Med 
107. Hubbard TJ, Denegar CR: Does cryotherapy improve outcomes with 
108. Collins NC: Is ice right? Does cryotherapy improve outcome for acute 
109. Bleakley C, McDonough S, McAuley D: The use of ice in the 
treatment of acute soft-tissue injury: A systematic review of 
110. Creaney L, Hamilton B: Growth factor delivery methods in the 
111. Taylor DW, Pettera M, Hendry M, Theodoropoulos JS: A systematic 
review of the use of platelet-rich plasma in sports medicine as a new 
112. Mishra A, Pavelko T: Treatment of chronic elbow tendinosis with 