ANATOMY AND BIOMECHANICS

The shoulder girdle includes three bones (the scapula, clavicle, and humerus) and three joints (the glenohumeral, acromioclavicular [AC], and sternoclavicular [SC] joints). The scapulothoracic articulation is also considered part of the shoulder girdle. For every 2° of glenohumeral motion, approximately 1° of scapulothoracic motion occurs. The AC and SC joints also participate in this scapulo-humeral rhythm. As a result of this coordinated movement, the shoulder has a greater range of motion than any other joint in the body.

The scapula is a triangular, flat bone that is surrounded by muscle (Figures 14-1 and 14-2). Its curved coracoid process projects anteriorly from the superior border and is the site of origin for the coracobrachialis and the short head of the biceps muscle. The other notable scapular prominence is the acromion, a spinelike process on the posterior aspect. The coracoacromial ligament stabilizes the humeral head in the superior direction. The two coracoclavicular ligaments prevent the clavicle from riding superiorly.

The clavicle is an S-shaped tubular bone that articulates with the acromion laterally and the manubrium medially.

The proximal end of the humerus includes the humeral head, the greater and lesser tuberosities, and the humeral neck. The head of the humerus is retroverted, or posteriorly angled, approximately 30° to match the anterior position of the scapula as it rests on the thoracic cavity. The pear-shaped glenoid fossa articulates with the humerus in a neutral or slightly retroverted position. The glenoid labrum is a rim of fibrocartilaginous tissue that increases the surface area of the glenoid fossa and the stability of the shoulder (Figure 14-3).

The deltoid is a large, powerful muscle whose primary function is shoulder abduction. The anterior half of the deltoid elevates (flexes) the shoulder, and the posterior half provides extension. Underneath the deltoid are the four rotator cuff muscles: the subscapularis, located anteriorly; the supraspinatus, located superiorly; and the infraspinatus and teres minor muscles, located posteriorly. The deltoid provides most of the power in shoulder motion, whereas the rotator cuff muscles act as a force couple to fine-tune and enhance the efficiency and stability of shoulder motion by compressing, depressing, and thus maintaining the humeral head in the glenoid fossa. Other important shoulder muscles include the trapezius, the latissimus dorsi, the serratus anterior, and the pectoralis major.

The subclavian artery passes under the clavicle and continues as the axillary artery as it traverses the anterior aspect of the shoulder joint. Anastomoses of branches of the axillary artery provide important collateral circulation to the upper extremity (Figure 14-4). The main blood supply to the humeral head is the anterior humeral circumflex artery. The nerves about the shoulder include the brachial plexus and its terminal branches, the sympathetic nerves, the supraclavicular nerves, and cranial nerve XI.

Important posterior landmarks include the quadrangular space and the triangular interval (Figure 14-5). The quadrangular space is bordered by the long head of the triceps, the surgical neck of the humerus, the inferior border of the scapula, and the teres major. The axillary nerve and the posterior humeral circumflex artery fill this space. The triangular interval houses the radial nerve and the deep brachial artery. Its borders are the teres major superiorly, the long head of the triceps medially, and the lateral head of the triceps laterally.
Figure 14-1: Anterior View Scapula and Proximal Humerus

- Acromion
- Coracoid process
- Clavicle (cut)
- Superior angle
- Superior border
- Supraspinatus tendon (cut)
- Coracoacromial ligament
- Greater tubercle and
  Lesser tubercle
- Intertubercular sulcus
- Crest of greater tubercle
- Crest of lesser tubercle
- Glenoid
- Head of humerus
- Humerus
- Deltoid tuberosity
- Scapula
- Inferior angle
- Trapezius muscle
- Pectoralis minor muscle
- Omohyoid muscle
- Biceps brachii muscle (long head)
- Supraspinatus muscle
- Subscapularis muscle
- Coracobrachialis muscle
- Biceps brachii muscle (short head)
- Pectoralis major muscle
- Latissimus dorsi muscle
- Teres major muscle
- Deltoid muscle
- Coracobrachialis muscle
- Brachialis muscle

Muscle attachments:
- Origins
- Insertions

Shoulder joint, anterior view

- Acromioclavicular joint capsule
  (incorporating acromioclavicular ligament)
- Acromion
- Coracoacromial ligament
- Supraspinatus tendon (cut)
- Coracohumeral ligament
- Greater tubercle and
  Lesser tubercle of humerus
- Transverse humeral ligament
- Intertubercular tendon sheath
  (communicates with synovial cavity)
- Subscapularis tendon (cut)
- Biceps brachii tendon (long head)
- Capsular ligaments

- Clavicle
- Trapezioid ligament
- Conoid ligament
- Superior transverse scapular ligament and
  suprascapular notch
- Coracoid process
- Communications of subtendinous
  bursa of subscapularis
- Broken line indicates position of subtendinous
  bursa of subscapularis
Chapter 14

PHYSICAL EXAMINATION

Begin the physical examination with an inspection of the patient’s overall posture and alignment of the shoulder. Look for swelling and ecchymosis, which may indicate recent trauma. Note areas of muscle atrophy suggestive of nerve dysfunction. Injury to cranial nerve XI results in atrophy of the trapezius muscle, which is seen superiorly as a reduced neck-to-shoulder contour. Supraspinatus nerve dysfunction causes loss of the normal posterior shoulder contour and prominence of the scapular spine and acromion.

Next, palpate subcutaneous landmarks to detect deformity or tenderness. For example, with an AC separation, the distal end of the clavicle is prominent. Start at the sternoclavicular joint, and proceed laterally along the clavicle to the acromioclavicular joint. Proceed to the lateral edge of the acromion and the greater tuberosity of the proximal humerus. Also, palpate the long head of the biceps in the bicipital groove of the proximal humerus to detect subluxation or tenderness.

Shoulder range of motion is assessed in four planes (Figure 14-6). The zero starting
Figure 14-3: Shoulder Joint Opened (lateral view)

- Acromion
- Coracoacromial ligament
- Coracoid process
- Coracohumeral ligament
- Biceps brachii tendon (long head)
- Superior glenohumeral ligament
- Subscapularis tendon (fused to capsule)
- Middle glenohumeral ligament
- Inferior glenohumeral ligament
- Insertion of synovium (enlarged for depiction)
- Glenoid cavity (cartilage)
- Subdeltoid bursa
- Supraspinatus tendon (fused to capsule)
- Glenohumeral ligament
- Teres minor tendon (fused to capsule)
- Brachial artery
- Axillary artery
- Clavicular branch
- Pectoral branch
- Superior thoracic artery
- Thoracoacromial artery
- Lateral thoracic artery
- Subscapular artery
- Circumflex scapular artery
- Thoracodorsal artery
- Acromial branch
- Deltoid branch
- Anterior circumflex humeral artery
- Posterior circumflex humeral artery
- Brachial artery
- Deep artery of arm
- Radial collateral artery
- Middle collateral artery
- Level of lower margin of teres major muscle is landmark for name change from axillary to brachial artery
Figure 14-5: Posterior View of Shoulder and Arm

Superficial layer

- Acromion
- Supraspinatus muscle
- Greater tubercle of humerus
- Infraspinatus muscle
- Teres minor muscle
- Axillary nerve and posterior circumflex humeral artery
- Deltoid muscle (cut and reflected)
- Superior lateral cutaneous nerve of arm (from axillary nerve)
- Teres major muscle
- Long head
- Lateral head
- Triceps brachii muscle
- Tendon
- Brachioradialis muscle
- Medial intermuscular septum
- Ulnar nerve
- Medial epicondyle of humerus
- Olecranon of ulna
- Flexor carpi ulnaris muscle
- Anconeus muscle
- Extensor carpi radialis longus muscle
- Extensor carpi radialis brevis muscle
- Extensor digitorum muscle
- Posterior cutaneous nerve of forearm (from radial nerve)

Deep layer

- Capsule of shoulder joint
- Supraspinatus tendon
- Infraspinatus and teres minor tendons (cut)
- Axillary nerve
- Posterior circumflex humeral artery
- Superior lateral cutaneous nerve of arm
- Deep artery of arm
- Radial nerve
- Middle collateral artery
- Radial collateral artery
- Inferior lateral cutaneous nerve of arm
- Lateral intermuscular septum
- Nerve to anconeus and lateral head of triceps brachii muscle
- Posterior cutaneous nerve of forearm
- Lateral epicondyle of humerus
- Long head of triceps brachii muscle
- Lateral head of triceps brachii muscle (cut)
- Medial head of triceps brachii muscle
- Medial epicondyle of humerus
- Ulnar nerve
- Olecranon of ulna
- Anconeus muscle
Figure 14-6: Shoulder Range of Motion

<table>
<thead>
<tr>
<th>Flexion and extension</th>
<th>180°–160°</th>
<th>Slight external rotation and abduction required to reach maximal elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extension</td>
<td>90°</td>
<td></td>
</tr>
<tr>
<td>Flexion (elevation)</td>
<td>180°</td>
<td></td>
</tr>
<tr>
<td>Abduction</td>
<td>0°</td>
<td></td>
</tr>
</tbody>
</table>

Flexion: 90°
Abduction: 0°
Extension: 0°–180°
Slight external rotation and abduction required to reach maximal elevation

May be tested with arm held at side or abducted to 90°

Arm held at side
External rotation

Maximal internal rotation is highest midline spinous process reached by extended thumb (T7 in young adults)

Arm abducted 90° from side

C7
T7
S1
position is with the arm at the side of the body. Flexion, better described as total elevation, is maximum upward movement. Slight external rotation and abduction are required to reach maximum elevation. Abduction is maximum movement in the coronal plane. Normal flexion and abduction occur at 160° to 180°. External rotation may be measured with the arm at the side or abducted to 90°. The degree of internal rotation is the highest midline posterior spinous process reached by the extended thumb. In young adults, internal rotation typically goes beyond the inferior tip of the scapula (approximately the T7 spinous process). Any differences in active versus passive motion, as well as in the quality of movement, should be noted. For example, patients with instability or rotator cuff inflammation may have a dysrhythmic motion. Patients with a rotator cuff tear commonly have a shoulder shrug during abduction. In patients with adhesive capsulitis or arthritis, internal rotation may be limited to the sacrum or the lumbar region.

Assess deltoid muscle strength with the shoulder in 90° abduction. To isolate the anterior deltoid, move the arm forward. Do the reverse to assess the posterior deltoid. The supraspinatus muscle is tested with the shoulder in 90° of flexion and the arm internally rotated and slightly abducted in the plane of the scapula. The external rotation strength of the infraspinatus and the teres minor is tested with the patient’s arms at the sides and externally rotated approximately 30°. To test subscapularis strength, internally rotate the arm behind the back to the lumbosacral level, and ask the patient to lift the arm off and away from the back against resistance.

Examination maneuvers that may elicit pain are performed last. Subacromial impingement signs often are present with rotator cuff disease. Keeping the scapula stabilized (depressed) while elevating the arm with the shoulder internally rotated causes the supraspinatus tendon to impinge on the anterior inferior acromion. Another technique is demonstration of pain with the shoulder flexed to 90°, the elbow flexed to 90°, and then moving the shoulder into internal rotation. Arthritis in the AC joint is suggested when cross-body adduction (ie, flexing the shoulder to 90°, then adducting the arm) elicits pain. Patients with anterior instability may have a positive apprehension test, that is, they express apprehension and a sense of instability when the shoulder is placed in 90° abduction and then maximum external rotation.

Finally, a screening examination of the cervical spine should be performed because some shoulder symptoms may represent cervical spine disease.

DEGENERATIVE DISEASES AND DISORDERS

Rotator Cuff Syndrome

Disorders of the rotator cuff commonly affect patients older than 40 years of age. It represents a spectrum of disorders ranging from subacromial bursitis to rotator cuff tendinopathy to a partial- or full-thickness tear of the rotator cuff. Causes include intrinsic and extrinsic factors. The intrinsic factor is early degenerative changes that are typically observed in the “watershed” region of the supraspinatus tendon (area with diminished blood supply). Extrinsic factors include a thickened coracoacromial ligament, an inflamed subacromial bursa, and a hook-shaped acromion. As the arm is ab ducted, a degenerative supraspinatus tendon moving under the acromion may be further irritated by these extrinsic factors (Figure 14-7). Rotator cuff disease also may be caused by calcium deposited in the tendon as part of the healing response. This calcific tendinopathy may be asymptomatic, or it may aggravate the syndrome and occasionally may cause an acute inflammatory process and severe pain that may be dissipated by spontaneous rupture or needle aspiration.

The typical symptom of rotator cuff disease is dull, aching pain on the lateral side of the shoulder that is worsened by overhead activities and when the patient lies on the affected side. Examination often demonstrates tenderness along the lateral acromion or the lateral aspect of the proximal humerus. Abduction in
The Shoulder and Arm

The 70° to 120° arc increases pain, which can be decreased by moving the arm into internal rotation. Dysrhythmia of shoulder motion is noted with high-grade tendinopathy. Associated contracture of the posterior gleno-humeral capsule results in decreased internal rotation. Weakness of the supraspinatus and external rotators is common and may be caused by pain, a tendon tear, or both. Subacromial impingement signs are often positive.

Most patients with rotator cuff disease can be treated nonoperatively. Activity modifications, ice, and nonsteroidal anti-inflammatory drugs (NSAIDs) are front-line modalities. The focus of physical therapy involves strengthening exercises for the adjacent rotator cuff and parascapular muscles and stretching of the contracted posterior capsule. If the symptoms are severe, a corticosteroid injection into the subacromial bursa may reduce inflammation and pain. With the addition of a local anesthetic, the injection can confirm a diagnosis of rotator cuff disease if pain is relieved on repeat testing of the impingement signs.

If the patient continues to have pain and dysfunction, decompression of the subacromial arch is indicated. This procedure includes a partial acromionectomy that primarily removes the undersurface of the acromion, as well as resection of the inflamed subacromial bursa and coracoacromial ligament (Figure 14-8). Rotator cuff tears are also repaired if found at the time of operation. Surgery for rotator cuff disease can be performed as an open or arthroscopic procedure.

Glenohumeral Arthritis

Primary osteoarthritis is the most common type of glenohumeral arthritis. Osteonecrosis and severe rotator cuff tears are the most common causes of secondary osteoarthritis. In addition to pain with activity and pain at the extremes of motion, patients with glenohumeral arthritis complain of inability to comb their hair, touch their contralateral shoulder, or reach behind their back.

Examination reveals reduced motion, particularly in the arc of internal rotation and abduction. On occasion, muscle atrophy...
results from limited use, a large, longstanding tear in the rotator cuff, or both. Radiographs demonstrate decreased joint space, osteophyte formation at the inferior pole of the humeral head, and sclerosis or bony erosion of the glenoid fossa (Figure 14-9).

Treatment goals include pain relief and improved function. Nonoperative modalities include activity modification, exercise to improve motion and strengthen muscles in a nonforceful manner, and the judicious use of NSAIDs and intra-articular steroid injections. Surgical alternatives include arthroscopic débridement, arthrodesis, and joint replacement. If arthropathy affects both the humeral head and the glenoid, total shoulder replacement with an unconstrained prosthesis that is combined with soft tissue balancing provides the most predictable outcome (Figure 14-10). Possible complications after surgery

Figure 14-9: Osteoarthritis of the Shoulder

AP radiograph of shoulder demonstrates typical changes of osteoarthritis of the shoulder with narrowing of the joint and prominent osteophyte formation at the inferior aspect of the humeral head.

Figure 14-10: Prosthetic Replacement of Shoulder Joint

Complete shoulder prosthetic replacement of the humeral head and glenoid can provide good pain relief for patients with degenerative osteoarthritis of the glenohumeral joint.
include fracture of the humeral shaft, injury of the axillary or musculocutaneous nerve, infection, glenohumeral instability, and loosening of prosthesis components.

**Acromioclavicular Joint Arthritis**

Arthropathy of the acromioclavicular joint may be traumatic in origin or may be associated with rotator cuff disease. Typical symptoms include pain at the superior aspect of the shoulder with overhead cross-arm activities and pain exacerbated by bench press and push-up exercises.

Examination demonstrates tenderness at the AC joint and pain with adduction cross-body maneuvers. Associated signs of rotator cuff disease are often present. Radiographs typically reveal osteophyte formation on the undersurface of the distal clavicle. On occasion, periarticular inflammation may cause osteolysis and resorption of the distal clavicle.

Nonoperative treatment includes activity modification, rotator cuff strengthening, and the judicious use of NSAIDs and AC joint corticosteroid injections. The preferred treatment with persistent and disabling symptoms is distal clavicle resection, performed either as an open or arthroscopic procedure.

**Adhesive Capsulitis**

Adhesive capsulitis, also known as frozen shoulder, is a painful disorder characterized by progressive loss of both active and passive motion (Figure 14-11). The disorder is more common in the 5th to 7th decades, in females, in the nondominant shoulder, and in patients with diabetes mellitus or hypothyroidism. The loss of motion particularly affects overhead activities such as lifting objects off a shelf and activities requiring internal rotation such as fastening a bra.

Adhesive capsulitis is associated with intrinsic shoulder conditions, such as trauma or postsurgical stiffness, and extrinsic disorders that secondarily limit shoulder motion, such as cervical spine disease, acute cardiopulmonary disorders, and breast surgery. The histopathology is characterized by an inflamed synovium with perivascular lymphocytic infiltration. Over time, the capsule becomes thickened and fibrotic, adhesions develop between the capsule and the cartilage, and the axillary pouch is obliterated.

Examination demonstrates pain at extremes of motion and loss of both active and passive motion. Placing the patient in a supine position and comparing external and internal rotation with the arm at 45° and 90° of abduction to the opposite side is a sensitive test in the early phase of the disease. Radiographs are typically normal. Misdiagnosis of rotator cuff disease may result in improper treatment.

Treatment begins with patient education, pain management, and gentle active and passive range-of-motion exercises. Corticosteroid injections into the glenohumeral joint can help with early pain management and produce a more rapid restoration of motion. Most patients demonstrate gradual recovery of full motion over a few months, but some experience recalcitrant symptoms for years before symptoms abate. In this situation, manipulation of the shoulder under anesthesia should be considered, provided the patient understands that continued physical therapy most likely will be needed. Arthroscopic lysis of adhesions achieved by cutting the thickened capsule near its insertion at the glenoid labrum, then performing a manipulation, can promote rehabilitation. Manipulation must be gentle because forced manipulation may cause intraoperative fracture or tendon tears.

**Shoulder Pain in the Overhead Athlete**

Glennohumeral joint mobility enhances the performance of the athlete or laborer involved in overhead activities, but repetitive stress also makes the shoulder vulnerable to injury. Most shoulder injuries in overhead athletes are due to poor mechanics and subsequent muscle fatigue. The mechanism of injury is best exemplified in baseball pitchers. The phases of a baseball pitch are (1) windup, (2) early cocking, (3) late cocking, (4) acceleration, (5) deceleration, and (6) follow-through. Phases 3 to 5 put the shoulder at
Markedly limited active and passive motion, right shoulder. Abduction movement is mostly from scapulothoracic motion. All planes of shoulder motion restricted and painful at extremes.

Posterior view reveals atrophy of scapular and deltoid muscles. Broken lines, indicating position of spine of scapula and axis of humerus on each side, show little or no motion in right shoulder.

Figure 14-11: Adhesive Capsulitis

The Shoulder and Arm

greater risk for injury. During late cocking, the humerus is moving toward maximum external rotation, a position that places the infraspinatus and teres minor tendons in a more posterior position. In this position, these tendons may impinge on the posterosuperior labrum, a disorder called internal impingement. This position also places the humeral head at risk for anterior instability. During the acceleration phase, the humerus internally rotates very rapidly. If the scapular stabilizing muscles have inadequate strength, attrition can develop in the anterior rotator cuff muscles. During the deceleration phase, rapid external rotational forces on the posterior rotator cuff can cause posterior shoulder pain.

Shoulder pain in throwing athletes is typically described as anterior pain that increases as pitching velocity is increased. These patients typically note that they cannot achieve maximum pitching speed. Less common is posterior shoulder pain. In younger patients, such as the high school or collegiate athlete, shoulder pain most often results from glenohumeral instability. The use of improper mechanics during the windup and cocking phases shifts forces typically generated by lower limb and trunk muscles toward greater dependence on shoulder muscles. As rotator cuff muscles fatigue, the humeral head develops abnormal translation at extreme positions of the shoulder. The result is occult instability and secondary impingement. Therefore, treatment is directed toward proper throwing mechanics, stretching of contractures, and strengthening of the rotator cuff and scapular stabilizing muscles.

A tear in the superior quadrant of the glenoid labrum is another injury observed in athletes. These SLAP (superior labrum anteroposterior) lesions may extend anteriorly or posteriorly and also may violate the attachment of the biceps tendon. A type I SLAP lesion involves degeneration or fraying of the superior labrum but does not affect the attachment of the biceps. Type II tears involve the biceps anchor and are detached from the glenoid fossa. Type III tears are bucket handle–type tears that spare the biceps attachment. Type IV tears are similar to type III tears but involve the biceps anchor. Patients have superior shoulder pain that develops with overhead lifting or throwing activities. If rehabilitation fails, arthroscopic débridement, repair, or both may be helpful.

Nerve Entrapment Syndromes and Injuries

Brachial plexus injuries range from momentary paresthesia to permanent paralysis. The upper plexus (C5, C6, and C7 trunks) is typically stretched and injured when the shoulder is depressed and adducted by a direct blow while the neck is pushed in the opposite direction (Figure 14-12). The lower trunks (C8 and T1) are stretched and injured when the arm is forcefully abducted. The entire brachial plexus may be paralyzed by major trauma, causing extreme traction.

Stingers, which are transient stretch injuries to the upper trunk of the brachial plexus, most commonly occur in football players injured by a direct blow to the head, neck, or shoulder. The patient notes sharp shoulder pain that radiates down the arm, is associated with weakness, and lasts a few seconds or minutes. At the other end of the spectrum is high-energy falls or motor vehicle accidents that cause avulsion of the plexus and associated multiple injuries. High-energy falls or motor vehicle accidents are likely to result in axonal disruption and permanent injury.

A detailed neurologic examination is required for determining the extent and location of injury. Preganglionic injuries are more likely with lower plexus injuries. The presence of Horner syndrome, with ipsilateral ptosis, miosis, anhidrosis, and enophthalmos, confirms a preganglionic location and suggests a poor prognosis. With an upper plexus injury, intact function of the serratus anterior and rhomboids (innervated by long thoracic and dorsal scapular nerves) indicates a postganglionic injury and a better prognosis.

The suprascapular nerve travels through the superior notch of the scapula and the spinoglenoid notch to supply the supraspinatus and infraspinatus muscles (see Figure 14-
In these tight confines, the nerve can become entrapped. Nerve compression at the level of the superior scapular notch affects both supraspinatus and infraspinatus muscles. Compression at the spinoglenoid notch, which commonly is caused by a ganglion cyst originating from the glenoid labrum, affects only the infraspinatus. Symptoms include a dull ache posterior to the shoulder along the lateral scapula. Examination shows muscle atrophy and weakness.

The musculocutaneous nerve may become compressed within the coracobrachialis muscle. Symptoms include weakness of the elbow flexors and hypesthesia of the lateral forearm.

Winging of the scapula can be caused by injury to either of two nerves: the long thoracic nerve or cranial nerve XI. Neuropathy of the long thoracic nerve causes paralysis of the serratus anterior muscle. Patients report the indolent onset of fatigue and aching pain with overhead activities. The strength of the serratus anterior is assessed by asking the patient to keep the arm elevated while applying resistance. Winging and prominence of the vertebral border of the scapula occur with weakness of the serratus anterior, which
is an important retractor of the scapula. This neuropathy frequently resolves spontaneously. Injury to cranial nerve XI may result in paralysis of the trapezius muscle and scapular winging. This nerve may be injured during surgery performed in the posterior cervical triangle.

Thoracic outlet syndrome involves entrapment of the brachial plexus, vessels to the upper limb, or both, as they pass through the interval between the scalene muscles and the first rib, then into the axilla. This disorder is described in Chapter 6.

**TRAUMA**

**Fractures in Adults**

**Fracture of the Proximal Humerus**

Fractures of the proximal humerus result from a fall on an outstretched hand or a direct impact. These fractures are particularly common in elderly individuals with osteoporosis. Most of these injuries are minimally displaced fractures through the surgical neck and can be treated by sling immobilization and a progressive rehabilitation program. Displaced fractures may have two, three, or four major fragments consisting of (1) the articular segment, (2) the greater tuberosity with the attached supraspinatus muscle, (3) the lesser tuberosity with the attached subscapularis muscle, and (4) the humeral shaft (Figure 14-13). Fractures are considered displaced if the distance between the fragments is greater than 1 cm or if angulation of the fragments is greater than 45°. The risk of posttraumatic arthritis and osteonecrosis increases with the number of major fragments, the degree of displacement, and associated glenohumeral dislocation.

Treatment options depend on the age of the patient, the activity demands of the patient, the fracture personality, and the quality of the bone stock. Two-part displaced fractures generally require reduction maneuvers with or without internal fixation. Three- and four-part fractures, fortunately, are uncommon and typically require internal fixation or hemiarthroplasty if the blood supply to the humeral head has been disrupted.

**Fracture of the Clavicle**

The clavicle is the bone that is most frequently fractured. Most clavicle fractures are the result of an indirect force, such as falling on the lateral point of the shoulder or falling on an outstretched hand. The middle third of the clavicle is the most common site of injury; approximately 80% of clavicle fractures occur in this location; 15%, in the lateral third; and 5%, in the medial third (Figure 14-14).

**Figure 14-13: Fracture of Proximal Humerus**

Neer four-part classification of fractures of proximal humerus.
1. Articular fragment (humeral head).
2. Lesser tuberosity.
3. Greater tuberosity.
4. Shaft.
If no fragments displaced, fracture considered stable (most common) and treated with minimal external immobilization and early range-of-motion exercise. Displacement of 1 cm or angulation of 45° of one or more fragments necessitates open reduction and internal fixation or prosthetic replacement.
Examination reveals localized tenderness and swelling. An AP radiograph of the clavicle demonstrates most injuries. Most clavicle fractures can be treated nonoperatively with either a sling or a figure-of-eight harness. Injuries with marked displacement in the lateral or middle third of the clavicle have a greater risk of malunion or nonunion and should be evaluated for internal fixation.

**Fracture of the Scapula**

Most fractures of the scapula result from a high-energy, direct impact to the back. Therefore, concomitant injury to the ribs, lung, thoracic spine, or brachial plexus is common. Examination shows localized tenderness, swelling, and pain on attempted motion of the arm. Radiographs should include a PA view of the chest, an AP view of the shoulder that includes the scapula, and if possible, an axillary and transscapular view.

Fractures may involve the body of the scapula, the glenoid, the acromion, the coracoid process, or a combination. Because of the surrounding musculature, fractures of the body of the scapula have a good prognosis. They are generally treated nonoperatively with a sling then early range-of-motion exercises as the pain subsides. Displaced intra-articular glenoid fractures (>2 mm), fractures of the neck of the scapula with severe angulation, and displaced fractures of the acromion and coracoid may require internal fixation. A floating shoulder is a concomitant fracture of the scapula and ipsilateral clavicle. Whether this injury requires internal fixation of one or both fractures is controversial.

**Fracture of the Humeral Shaft**

Fractures of the humeral shaft generally are caused by direct trauma. An associated stretch injury of the radial nerve with resultant paralysis of the wrist and finger extensors is relatively common. The nerve injury should be documented and observed, because most resolve in 4 to 6 months.

Nonoperative treatment of humeral shaft fractures is preferred, because the union rate is high, and shoulder and elbow function are excellent even with moderate angulation. The fracture is initially treated with a coaptation splint, followed by prefabricated functional braces that permit shoulder and elbow motion (Figure 14-15).

Indications for operative intervention include the following: (1) a segmental fracture that cannot be aligned properly, (2) associated ipsilateral elbow or forearm fractures (floating elbow), (3) open fractures, (4) polytrauma with injuries requiring prolonged bed rest or significant closed head injuries, (5) pathologic fractures, (6) fractures associated with vascular injury, and (7) radial nerve palsy that develops during a closed reduction maneuver (the radial nerve may become entrapped and compressed at the fracture site).

**Fractures in Children**

The clavicle is the site of most pediatric shoulder injuries and, as in adults, more than 80% involve the middle third. Virtually all do well with nonoperative treatment. The clavicle is the most common site of fracture during delivery with an incidence of approximately
This injury may cause pseudoparalysis and initial concern of brachial plexus injury.

Fracture of the distal lateral aspect of the clavicle in children occurs by the same mechanism of injury that causes an acromioclavicular separation in adults. These injuries remodel quite well and can be managed with a sling. Fracture of the medial clavicle is the least common site of injury. Medial clavicle fractures in children are commonly physeal injuries, which because the epiphysis of the medial clavicle is the last secondary center to ossify (begins around 18 years of age) may not be apparent on initial radiographs.

Fracture of the proximal humerus in children most commonly is a type II physeal injury (see Figure 10-3). Due to large growth potential of the physis of the proximal humerus (provides 80% growth of humerus) and the flexibility of the shoulder joint, these fractures do well with closed management. Moderate angulation of approximately 40° to 50° can be accepted except in the older adolescent (Figure 14-16).
Figure 14-17: Anterior Dislocation, Glenohumeral Joint

Subcoracoid dislocation (most common)

Clinical appearance

Anterior dislocation. Anterior rim of glenoid indents posterolateral part of humeral head

After reduction. Defect persists, causing instability and predisposing to recurrent dislocation

Stimson maneuver
Patient prone on table with affected limb hanging freely over edge; 10- to 15-lb weight suspended from wrist. Gradual traction overcomes muscle spasm and in most cases achieves reduction in 20 to 25 minutes
Dislocations

Dislocation/Instability of the Glenohumeral Joint

Dislocation of the shoulder was described in the Edwin Smith Papyrus (3000 to 2500 BC). Later, Hippocrates described a reduction technique for treatment of acute dislocation and a surgical procedure for treating recurrent instability.

Dislocation of the glenohumeral joint may be anterior, posterior, or multidirectional. Anterior is most common, accounting for approximately 98% of the dislocations. Anterior dislocations may occur at any age but are more common after athletic injuries in adolescents and young adults. The anterior capsule and associated ligaments are stretched or torn with subsequent anterior dislocation of the humeral head when the arm is positioned in abduction, extension, and external rotation. The humeral head usually rests in a subcoracoid position, but it may be positioned inferior to the glenoid or subclavicular.

These patients experience the sudden onset of pain and an inability to use the arm after a fall or forceful throwing movement. Inspection typically shows the patient supporting the arm with the other hand. Examination reveals flattening of the deltoid prominence, prominence of the acromion, fullness of the subcoracoid region, and downward displacement of the axillary fold (Figure 14-17). Any attempt at motion elicits pain.

Nerve injury may occur and most commonly affects the axillary or musculocutaneous nerve; however, the median, ulnar, and radial nerves also may be injured and should be examined. Axillary, AP, and scapular Y radiographs should be obtained before reduction so that the type of dislocation and any associated fractures may be documented. Radiographs may show a defect in the posterolateral humeral head, called a Hill-Sachs lesion, resulting from impaction of the humeral head on the anterior rim of the glenoid fossa. Avulsion of the anteroinferior glenoid labrum, called a Bankart lesion, also may occur. Hill-Sachs and Bankart lesions are predisposing factors for recurrent instability.

Several methods have been described to reduce an anterior shoulder dislocation. As with any dislocation, the joint should be reduced as soon as possible, and the reduction should not be performed forcefully. Intra-articular injection of local anesthetics and intravenous analgesics and muscle relaxants can significantly reduce the associated muscle spasm. In the traction-countertraction method, a sheet is placed in the axilla and diagonally across the chest. An assistant provides countertraction while the physician applies distal traction to the arm with the biceps relaxed (elbow flexed). Gentle internal rotation may be added. In the Stimson maneuver, the patient is prone, with the arm hanging off the edge of the table. A 10- to 15-lb weight is tied to the wrist for longitudinal traction.

After reduction, AP and axillary radiographs should be obtained to confirm concentric reduction. Hill-Sachs and bony Bankart lesions also may be identified on postreduction radiographs. The arm is immobilized in a sling, and the patient begins circumduction exercises at 1 week and range-of-motion exercises at 3 weeks. The abduction–external rotation position is avoided for 6 weeks. Strengthening exercises are initiated after the patient has regained full range of motion without apprehension.

Surgical intervention rarely is needed for acute glenohumeral joint dislocation but usually is required for a fracture-dislocation and when the glenohumeral joint remains unreduced. Early surgical repair of a Bankart lesion may be indicated for patients with significant predisposing factors to recurrent dislocation. The presence of chronic instability with recurrent dislocation is more likely in females, younger patients, and patients with a Bankart or Hill-Sachs lesion. Surgical reconstruction in cases of chronic instability includes repair of an avulsed glenoid labrum and further tightening of the anterior capsule as needed.
Posterior glenohumeral dislocations are uncommon, and the diagnosis may be missed, particularly if only an AP radiograph is obtained (Figure 14-18). Posterior dislocations occur with an internal rotation–adduction force and are more common in patients who have a seizure disorder or who have experienced an electric shock injury. Examination reveals decreased fullness of the deltoid, posterior prominence of the humeral head, and marked restriction of abduction and external rotation. Appropriate radiographs are the same as for an anterior dislocation. Reduction is accomplished by distal traction and the application of manual pressure to the humeral head in an anterior direction.

Patients with chronic anterior shoulder instability may provide a history of recurrent dislocation and/or a history that the shoulder slips or feels unstable when the arm is in a position of abduction and external rotation. The apprehension sign is typically present. Patients whose shoulder instability has a traumatic cause usually have a unidirectional instability and a Bankart lesion, and they often require surgery—thus, the acronym TUBS. The atraumatic type of shoulder instability is usually multidirectional, bilateral, and more likely to respond to a rehabilitation program. However, if surgery is required, an inferior shift of the capsule with closure of the rotator interval is the preferred technique—thus, the acronym AMBRI.

It should be emphasized that treatment for glenohumeral instability should start with muscle-strengthening exercises. Neuromuscular coordination exercises designed to develop proper mechanics are also part of the rehabilitation program. Taping or bracing during athletic activity may minimize recurrence.

**Acromioclavicular Joint Dislocation**

Acromioclavicular joint dislocation, or shoulder separation, is most commonly caused by a fall on the lateral point of the shoulder. Examination reveals localized tenderness and prominence of the displaced distal clavicle. The severity of the separation is based on the amount of injury to the acromioclavicular (AC) and coracoclavicular (CC) ligaments (Figure 14-19). Grade I and II injuries are treated nonoperatively. Most grade III AC joint dislocations may be treated by range-of-motion and strengthening exercises after the

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**Figure 14-18: Posterior Dislocation, Glenohumeral Joint**

Anteroposterior radiograph. Difficult to determine if humeral head within, anterior to, or posterior to glenoid cavity

Lateral radiograph (parallel to plane of body of scapula). Humeral head clearly seen to be posterior to glenoid cavity
Injury to acromioclavicular joint. Usually caused by fall on tip of shoulder, depressing acromion (shoulder separation).

Figure 14-19: Acromioclavicular Dislocation

Grade I

Grade II

Grade III

Grade IV

Pain subsides. For some athletes in contact sports and workers in jobs that require heavy labor, however, surgical intervention may yield more predictable results. Grade IV and grade V and VI AC separations (not shown) are uncommon (<1%) and, because of their severity, typically require open repair.

Sternoclavicular Joint Dislocation

Dislocations of the SC joint are uncommon. Anterior dislocation with the clavicle displaced anterior to the sternum is the most common type. The typical mechanism of injury is an indirect force on the lateral aspect of the shoulder, resulting in anterior transla-
tion of the medial clavicle. Examination reveals a prominent bump and tenderness over the SC joint. Reduction can be performed with lateral traction and pressure over the medial clavicle. Redislocation is common, but further treatment is not necessary because most chronic anterior SC dislocations become asymptomatic.

Posterior SC joint dislocations are rare but more serious because of the potential resultant injury to the great vessels that exit the heart and the vital structures of the neck, especially the trachea. Dyspnea, dysphagia, or signs of venous congestion are indicative of a posterior SC dislocation.

**Tendon Ruptures**

Most tendon ruptures about the shoulder are similar to those in other anatomical areas and are associated with attritional changes, are most common in middle-aged patients, and typically occur at the musculotendinous junction. The most common rupture occurs at the proximal aspect of the long head of the biceps. The rupture may be spontaneous or associated with lifting. A popping sound followed by sharp pain is typical.

Examination shows mild swelling, ecchymosis, and a bulge in the midarm that results from distal retraction of the biceps. The bulge is accentuated when the patient contracts the biceps against resistance with the elbow flexed (Figure 14-20).

**Figure 14-20: Rupture of Long Head Biceps Brachii Muscle**

Rupture of tendon of long head of right biceps brachii muscle indicated by active flexion of elbow

Nonoperative treatment is satisfactory for most patients because motion is regained and loss of strength is minimal and not disabling. Operative repair should be considered in young athletes and heavy laborers.

Rupture of the distal biceps tendon is relatively uncommon, is disabling, and should be repaired.

Other tendon ruptures about the shoulder include the pectoralis major, deltoid, subscapularis, and long head of the triceps. These injuries are uncommon, subsequently are more disabling, and frequently require surgical repair.

**PEDIATRIC DISORDERS**

**Neonatal Brachial Plexus Palsy**

Neonatal brachial plexus palsy is paralysis of upper extremity muscles noted at birth. The incidence is approximately 1 per 2000 births. Because of improved obstetric care, the neurologic injury is less severe than in the past, but the incidence is approximately the same. This condition typically arises from traction injuries that occur during delivery of large neonates (birth weight >4000 g), pelvic dystocia, or both. An upper plexus injury (Erb palsy) is most common and typically occurs during a cephalic delivery when the head has presented but there is difficulty in delivering the shoulder. A lower plexus injury (Klumpke paralysis) is associated with a breech delivery in which the upper limb is forced into full abduction. Pan plexus palsy is a more severe traction injury that involves the entire brachial plexus.

Examination findings vary according to the pattern and severity of nerve injury. Because of weakness of the deltoid, shoulder external rotators, elbow flexors, and wrist extensors, neonates with Erb palsy keep the shoulder adducted and internally rotated, the elbow extended, the forearm pronated, and the wrist flexed (headwaiter position). Klumpke paralysis, in contrast, primarily affects the wrist and hand. Pan plexus palsy causes the upper extremity to be flail. Horner sign may be present in Klumpke or pan plexus palsy.
Initial treatment involves a month of rest in a position that protects the stretched nerves, followed by stretching of contracted muscles while the patient awaits recovery. Most children have significant recovery without surgical treatment. Early plexus surgery should be considered at 4 to 6 months in infants who have not regained palpable elbow flexion or who have pan plexus palsy. Older children (2 to 4 years of age) with significant muscle imbalance can be helped by muscle releases and tendon transfers that improve function and decrease the risk of progressive deformity. Earlier procedures are indicated in children who develop posterior shoulder subluxation or dislocation.

**Congenital Elevation of the Scapula (Sprengel Deformity)**

Sprengel deformity results from failure of scapular descent during in utero development (Figure 14-21). The scapula, in addition to being elevated, is mildly hypoplastic. The affected side of the neck appears fuller and shorter. Patients with Sprengel deformity often have congenital scoliosis, Klippel-Feil syndrome, and renal abnormalities. An omovertebral bone is an osseous or cartilaginous bridge that connects the cervical spine to the superior angle of the scapula and is often associated with Sprengel deformity. This bridge and associated muscle contraction combined with abnormal position of the scapula results in variable loss of shoulder motion.

Surgical intervention is indicated to correct severe deformities. Common surgical techniques include resection of the omovertebral bar and inferior repositioning of the scapula. Clavicular osteotomy may be performed to minimize the risk of brachial plexus injury.

**Cleidocranial Dysostosis**

Cleidocranial dysostosis is an autosomal dominant condition that affects intramembranous bone formation and results in incomplete formation of the clavicles, skull, and pubis. The entire clavicle may be absent, or only a small segment of the middle or distal third may be missing. The defect is bilateral 80% of the time. The child typically has a large head, a small face, a long neck, drooping shoulders, and a narrow chest. Hypermobility of the shoulder girdles is demonstrated by the patient’s inability to position the humeral heads in the anterior midline. Cleidocranial dysostosis usually is not disabling, but parents should make sure
the child with open fontanelles wears protective headgear and receives appropriate treatment for abnormal dentition.

**Congenital Pseudarthrosis of the Clavicle**

Congenital pseudarthrosis of the clavicle is due to pressure from the developing subclavian artery. It usually involves the right side unless *situs inversus* occurs. The affected side has a bony prominence, but functional deficits are mild. For children with pain or cosmetic concerns, internal fixation and bone grafting are usually successful. The appearance of the surgical scar must be considered in the surgical decision.

**ADDITIONAL READINGS**

