Conventional Radiography of the Shoulder

Timothy G. Sanders, Col, USAF, MC,* and Sean L. Jersey, Lt, USAF, MSC†

The shoulder girdle is a complex anatomic structure designed to maximize three-dimensional motion of the hand and opposing thumb, and although the shoulder is often thought of as synonymous with the glenohumeral joint, it is actually composed of four separate joints (glenohumeral, acromioclavicular, sternoclavicular, and scapulothoracic), as well as numerous muscles and ligaments that act synergistically to optimize motion of the upper extremity. Advances in cross-sectional imaging over the past decade have revolutionized imaging of the shoulder girdle, especially with regard to the soft-tissue structures. As a result, conventional radiography is often overlooked and underutilized as a diagnostic tool. This article will focus on conventional radiography of the glenohumeral joint and the acromioclavicular joint. It will begin with a review of the basic radiographic techniques and anatomy followed by a discussion of conventional radiographic findings that can be seen in common disorders including trauma, impingement syndrome, and arthritis.

Radiographic Technique and Anatomy

Radiographs are often the first imaging examination performed on an individual with a suspected shoulder abnormality, and the complex anatomy of the shoulder has lead to the development of numerous radiographic views and techniques, each designed to optimize the evaluation of specific parts of the shoulder girdle. Knowledge of the standard views that are available as well as the advantages and disadvantages of each projection will aid in optimizing the radiographic evaluation based on the clinical presentation and suspected abnormality. Below is a description of the most common

views of the shoulder, although numerous variations exist for several of the views.[1]

Anteroposterior (AP) Shoulder View

The AP projection[1] is usually obtained with the patient in the upright or supine position and with the coronal plane of the body parallel to the cassette (Fig. 1A). The beam is directed in a true AP direction relative to the body. This results in slight overlap of the glenoid rim and the humeral head as the glenohumeral joint is tilted anteriorly approximately 40°. Additionally, the lateral border of the scapula and the medial cortex of the proximal humerus form a gentle, smooth convex arch, known as scapulohumeral or Moloney's arch. The standard AP view of the shoulder can be performed with the arm in neutral position, internal rotation, or external rotation. On internal rotation, the humeral head has the appearance of an ice-cream cone. On external rotation, the humeral head has the appearance of an Indian axe. When compared with other views of the shoulder, this position allows for relatively uniform distribution of soft-tissue density across the anatomy, thus providing excellent osseous detail of the entire shoulder girdle. As a result, one or more of the AP projections are almost always included in the standard radiographic examination of the shoulder. These views allow for excellent visualization of the glenohumeral joint, acromioclavicular (AC) joint, and the adjacent osseous structures including the distal clavicle and scapula and thus are very helpful in the setting of acute trauma to evaluate for fracture or dislocation and can also demonstrate abnormalities in the setting of chronic shoulder pain, including calcific tendonitis or bursitis, and AC joint arthritis.
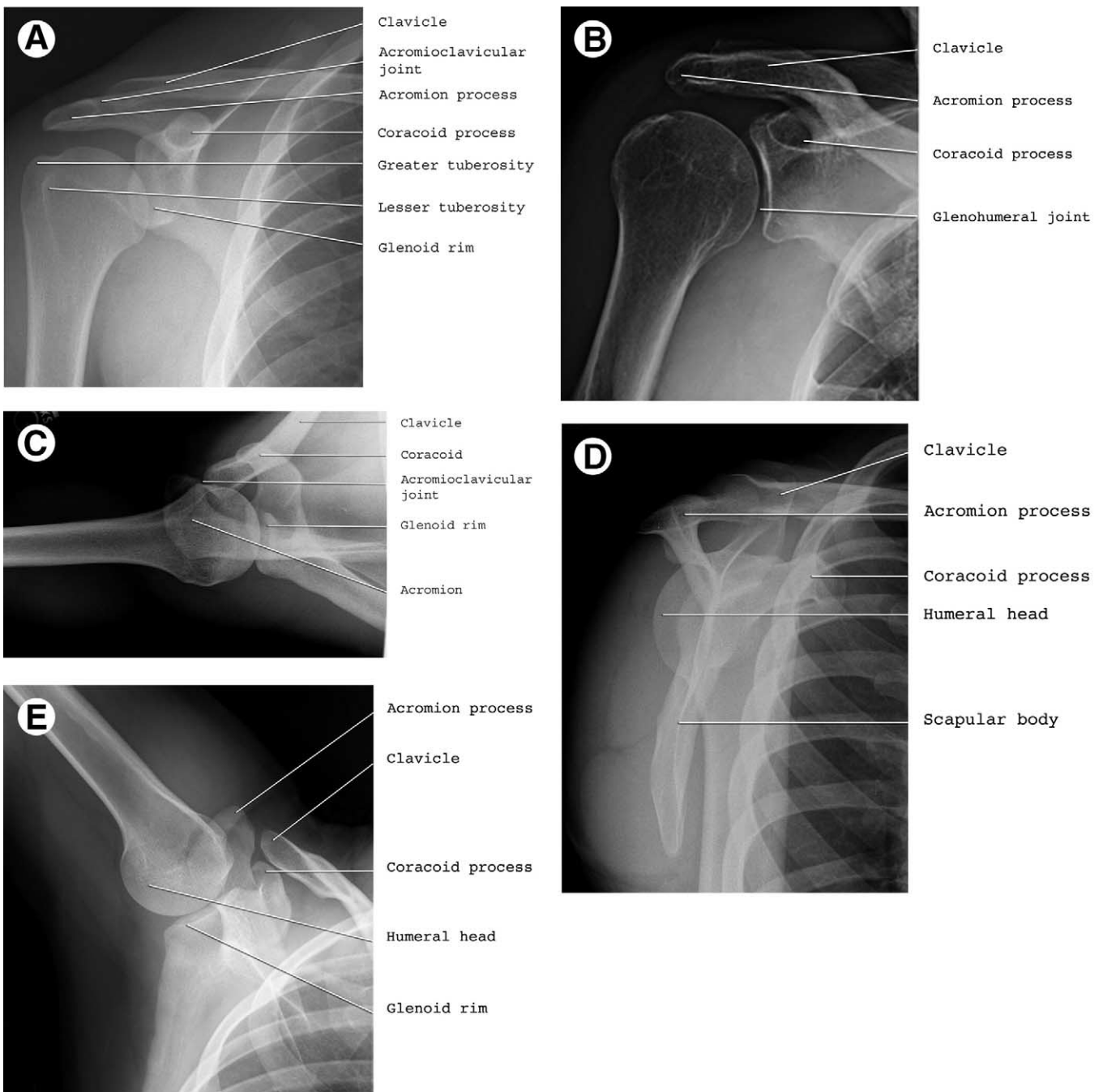
Glenohumeral "True" AP (Grashey) View

The "true" or Grashey AP view differs from the standard AP view in that the patient is rotated posteriorly approximately 35° to 45° so that the plane of the scapula rather than the body parallels the cassette (Fig. 1B). The beam is still directed perpendicular to the cassette and this eliminates the overlap of the glenoid rim and the humeral head, providing a tangential view of the glenohumeral joint.[1] The advantage of this projection is that it allows for evaluation of the glenohumeral joint space, demonstrates subtle superior or inferior migration of the humeral head often seen with instability, and detects joint space narrowing seen in arthritis. However, the

*Department of Radiology, Uniform Services University of the Health Sciences, Bethesda, MD.

†Uniform Services University of the Health Sciences, Bethesda, MD.

Figure 1 (A) AP view of shoulder in external rotation. (B) AP view of glenohumeral joint (Grashey view). (C) Axillary view of shoulder. (D) Scapular "Y" view of shoulder. (E) Stryker notch view of shoulder.

obliquity results in a rapid change of overlying soft-tissue density, which decreases the quality and visualization of the osseous detail. The acromion, AC joint, and distal clavicle are more difficult to evaluate than on the standard AP view.

Axillary Lateral View

The axillary view[2] is typically obtained with the patient supine and the arm abducted 90°, although several variations[3-8] of this view have been developed that require less than 90° of abduction (Fig. 1C). The beam is centered over the mid-glenohumeral joint and is directed in a distal-to-proximal

direction while tilted approximately 15° to 30° toward the spine. This results in a tangential view of the glenohumeral joint from below and is an excellent method for evaluating for anterior or posterior glenohumeral subluxation or dislocation and may also be helpful in the detection of an osseous Bankart fracture involving the anterior glenoid rim. The radiographic quality is often very limited because of the rapid change of overlying soft-tissue density. The osseous detail is often quite poor, but the main value of the projection is in the evaluation of glenohumeral subluxation or dislocation. In the setting of acute trauma, it may be very difficult to obtain this

projection, as the patient may be unable to adequately abduct the arm. Numerous variations of the standard axillary view have been developed, some to minimize required abduction of the arm in the setting of acute trauma, others to emphasize certain anatomic features. The *West Point View* is one example of a variation of the lateral axillary view that was developed to improve detection of a Bankart fracture of the anterior glenoid rim.[9] It is obtained by placing the patient in the prone position with the arm abducted 90° from the long axis of the body with the elbow and forearm hanging off the side of the table. The beam is directed 15° to 25° in an inferior-to-superior direction and tilted 25° toward the spine. Although this projection improves detection of an osseous Bankart lesion, it can be difficult if not impossible to obtain in the setting of acute trauma.

Scapular "Y" View

The scapular Y view[10] is obtained with the patient upright or prone with the anterior aspect of the affected side rotated 30° to 45° toward the cassette (Fig. 1D). The scapular body is seen in tangent and the glenoid fossa is seen en face as a "Y"-shaped intersection of the scapular body, acromion process, and coracoid process. The humeral head should be centered over the glenoid fossa. This view can be very helpful in the setting of acute trauma to evaluate for anterior or posterior dislocation as the patient can be imaged with little or no movement of the arm and the projection obtains a lateral projection of the glenohumeral joint. This view is also useful for delineating fractures of the coracoid process, scapula, acromion process, and proximal humeral shaft. The scapular Y view is also used to evaluate the contour of the undersurface of the acromion process when "typing" the acromion.

Stryker Notch View

The Stryker notch view[11] can be obtained with the patient in the supine or upright position. The arm is extended vertically overhead; elbow is flexed, and the hand is supported on the back of the head (Fig. 1E). The beam is directed toward the mid axilla and is tilted 10° cephalic. This view nicely demonstrates the posterolateral aspect of the humeral head and is excellent for depicting a Hill–Sachs deformity or flattening of the posterolateral humeral head. Evaluation of glenoid rim fractures or subtle glenohumeral subluxation is limited on this view.

Acromioclavicular Articulations AP and PA Projections

The AC joints are best evaluated in the erect position (either sitting or standing) with the back of the patient flat against the cassette.[1] The arms should hang freely at the sides and the patient may hold sandbags of equal weight in each hand. The addition of weights will accentuate AC joint separation by demonstrating elevation of the distal clavicle on the injured side. The beam is directed toward the midline of the body at the level of the AC joints. This projection can be used to demonstrate AC joint pathology including fracture, separation, and arthritis. Comparison of the contralateral side can

Table 1 Checklist in the Radiographic Evaluation of the Shoulder

Check lung for nodule, Pancoast tumor, pneumothorax and adenopathy
Check acromioclavicular joint for separation or osteolysis
Check glenohumeral joint for
Normal half-moon overlap between the glenoid and humeral head
Normal scapulohumeral or Moloney's arch
Check glenoid for Bankart lesion or rim fracture
Check humeral head for
Hill–Sachs lesion or trough line "reverse Hill–Sachs lesion"
Centering over glenoid fossa on scapular Y-view
Check greater tuberosity for occult fracture

often aid in the detection of subtle abnormalities involving the AC joint.

Table 1 is a checklist of the important landmarks in the radiographic evaluation of the shoulder.

Trauma

Trauma is a common indication for obtaining radiographs of the shoulder and indeed radiography is often the first imaging study to be performed in the setting of shoulder pain following trauma. The specific injury is usually dependent on both the age of the patient as well as the mechanism of injury, and the most common injuries include AC joint separation, fracture of the clavicle, scapula, or proximal humerus, and glenohumeral dislocation. Selection of the proper radiographic views as well as a working knowledge of the normal radiographic anatomy and an understanding of the common radiographic signs of injury will ensure the most accurate assessment with conventional radiographs.

AC Joint Trauma

AC joint injuries are common and typically result from a direct blow to the shoulder or as the result of a fall with the patient landing directly on the distal tip of the clavicle. The proper radiographic technique for evaluation of the AC joint has been described above and comparison with the contralateral AC joint is often helpful. A three-point grading system is used to classify AC joint injuries.[12-14] A mild (Grade I) injury leads to stretching of the AC ligaments without disruption of the joint capsule and presents with point tenderness to palpation but normal radiographs (Fig. 2A). A moderate (Grade II) injury results in disruption of the AC ligaments and widening of the AC joint. The coracoclavicular ligament may be stretched but remains intact. Radiographically, the distal tip of the clavicle is slightly elevated relative to the acromion, but there is still some contact between the distal clavicle and acromion (Fig. 2B). A severe (Grade III) injury results in complete disruption of both the AC ligaments and the coracoclavicular ligament and presents radiographically as elevation of the distal tip of the clavicle. There is usually no contact
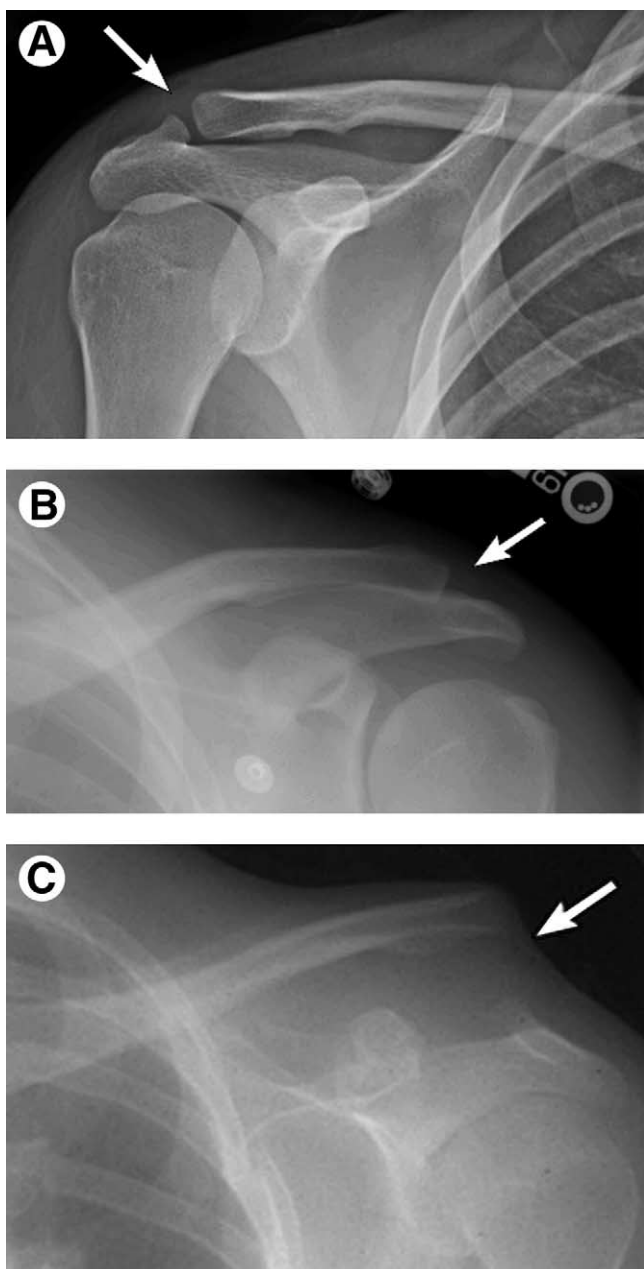
Figure 2 (A) Grade I sprain of AC joint. AP view of shoulder in patient with pain and point tenderness of AC joint after fall onto shoulder demonstrates normal appearing AC joint (arrow) with no separation or fracture. (B) Grade II sprain of AC joint. AP view of shoulder demonstrates slight elevation of distal tip of clavicle. This is consistent with disruption of AC joint capsule; however, coracoclavicular ligament remains intact preventing distal clavicle from completely separating from adjacent acromion. (C) Grade III sprain of AC joint. AP view of shoulder demonstrates complete separation of AC joint (arrow) and disruption of coracoclavicular ligament allowing marked elevation of distal tip of clavicle.

between the distal clavicle and the acromion and widening of the coracoclavicular distance may also occur (Fig. 2C).

Posttraumatic osteolysis of the distal clavicle can occur as a result of chronic repetitive microtrauma to the AC joint as seen in weightlifters or can occur following a one-time mild-

Figure 3 Posttraumatic osteolysis of distal clavicle. This patient experienced prior Grade II sprain of AC joint and now demonstrates slight elevation of distal tip of the clavicle. There is also loss of normal cortical white line (arrow) of distal tip of clavicle with minimal lucency involving distal clavicle.

to-moderate sprain of the AC joint (Fig. 3). It results in pain that is typically self-limiting with resolution of symptoms over several months. In the early stages, radiographically there is loss of the normal cortical white line of the distal clavicle and findings may progress to include resorption of the distal 1 to 2 cm of the clavicle; however, the acromion remains normal in appearance. During the healing phase, a portion of the distal clavicle may reconstitute; however, the distal cortex usually remains indistinct with occasional subchondral sclerosis or cyst formation.[15-17] Differential diagnosis includes rheumatoid arthritis, hyperparathyroidism, and infection (Table 2).
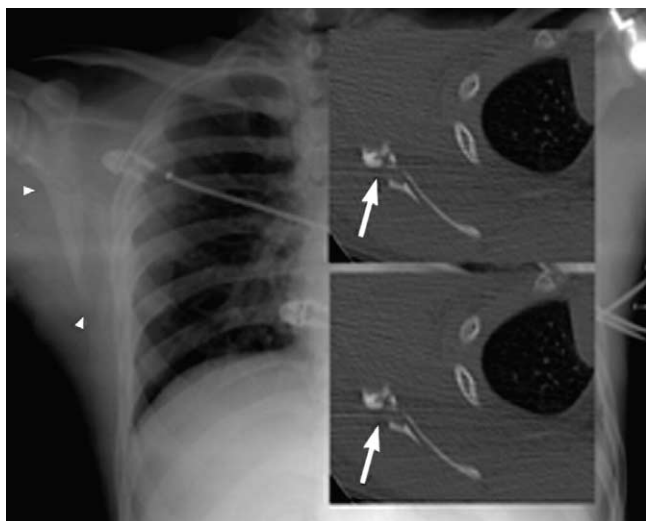
Scapular Fractures

Scapular fractures are uncommon, but when they do occur they usually result from significant direct trauma. The scapula is covered and protected by extensive musculature including the rotator cuff muscles, which usually function to hold the fragments in near anatomic position following fracture, thus minimizing the clinical significance of these fractures. The most common mechanism of injury is direct trauma during a motor vehicle accident, and although most scapular fractures are visible on conventional radiographs of

Table 2 Potential Causes of Resorption of Distal Clavicle, "SHARP"

| |
|---|
| **S**eptic arthritis |
| **H**yperparathyroidism |
| **A**nkylosing spondylitis, **A**myloid arthropathy |
| **R**heumatoid arthritis |
| **P**osttraumatic osteolysis |

Figure 4 Scapular fracture. Chest radiograph in this patient following motor vehicle accident demonstrates mildly displaced fracture (arrowheads) of body of scapula. An inlay of CT scan clearly delineates extent of fracture (arrows).
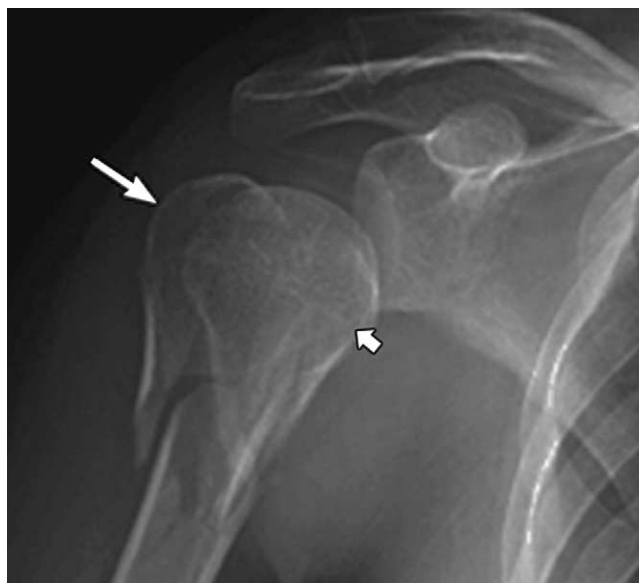
Figure 6 Two-part Neer fracture. AP view of shoulder demonstrates two-part Neer fracture. Greater tuberosity (long arrow) is displaced greater than 1 cm from humeral head fragment (short arrow), which remains in near anatomic position.
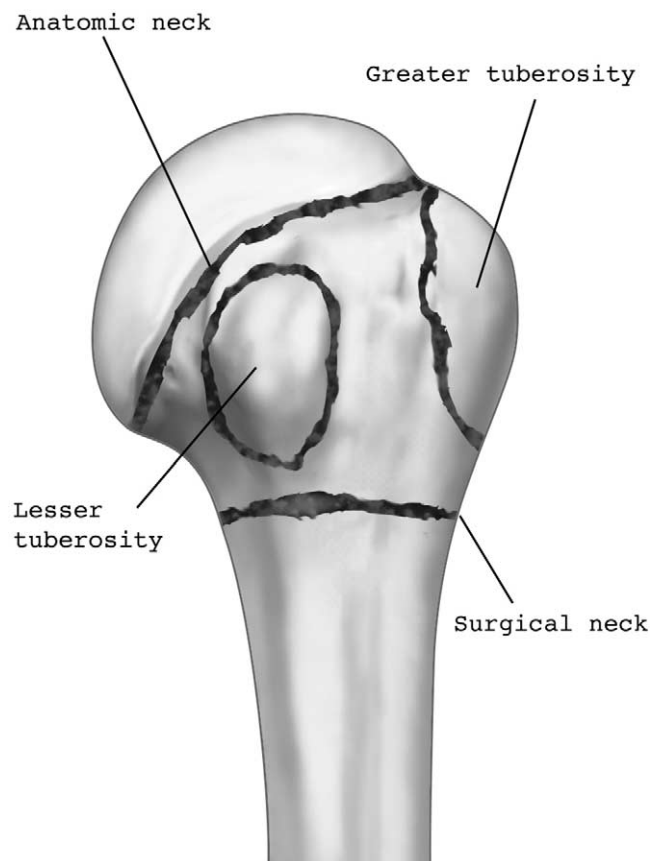

Figure 5 Neer classification scheme of proximal humeral fractures. Artwork demonstrates four components used in Neer classification scheme.

the chest, they are frequently overlooked because attention is diverted to other more serious injuries of the head, abdomen, or thorax.[18] Fractures of the glenoid, coracoid, and acromion can be associated with dislocation or direct trauma.[19] Ossification centers of the coracoid, scapular body, and acromion have a typical radiographic appearance and should not be misinterpreted as a fracture. Although scapular fractures are usually visible on conventional radiographs, the extent and complexity of fracture are best delineated with CT imaging (Fig. 4).

Proximal Humerus Fractures

Fractures of the proximal humerus occur in all age groups but are most common in patients over 50 years of age, and typically result from a fall on an outstretched arm or secondary to direct trauma. Neer developed a four-part classification scheme as a means of describing proximal humeral fractures and predicting clinical outcomes.[20] The system uses the four components of the humeral head, which include the anatomic neck, surgical neck, greater tuberosity, and lesser tuberosity (Fig. 5). To be considered significantly displaced, a fracture fragment must be angulated more than 45° or must be displaced greater than 1 cm from its original position. A one-part fracture is one in which no fragment is significantly displaced or angulated, while significant displacement or angulation of a single fragment is referred to as a two-part fracture, and significant displacement of two fragments is referred to as a three-part fracture (Fig. 6). A four-part fracture refers to a severely comminuted fracture with significant displacement or angulation of its fragments. One-part fractures occur most commonly and are usually treated with closed reduction with most patients experiencing good functional recovery. Prognosis for full functional recovery de-
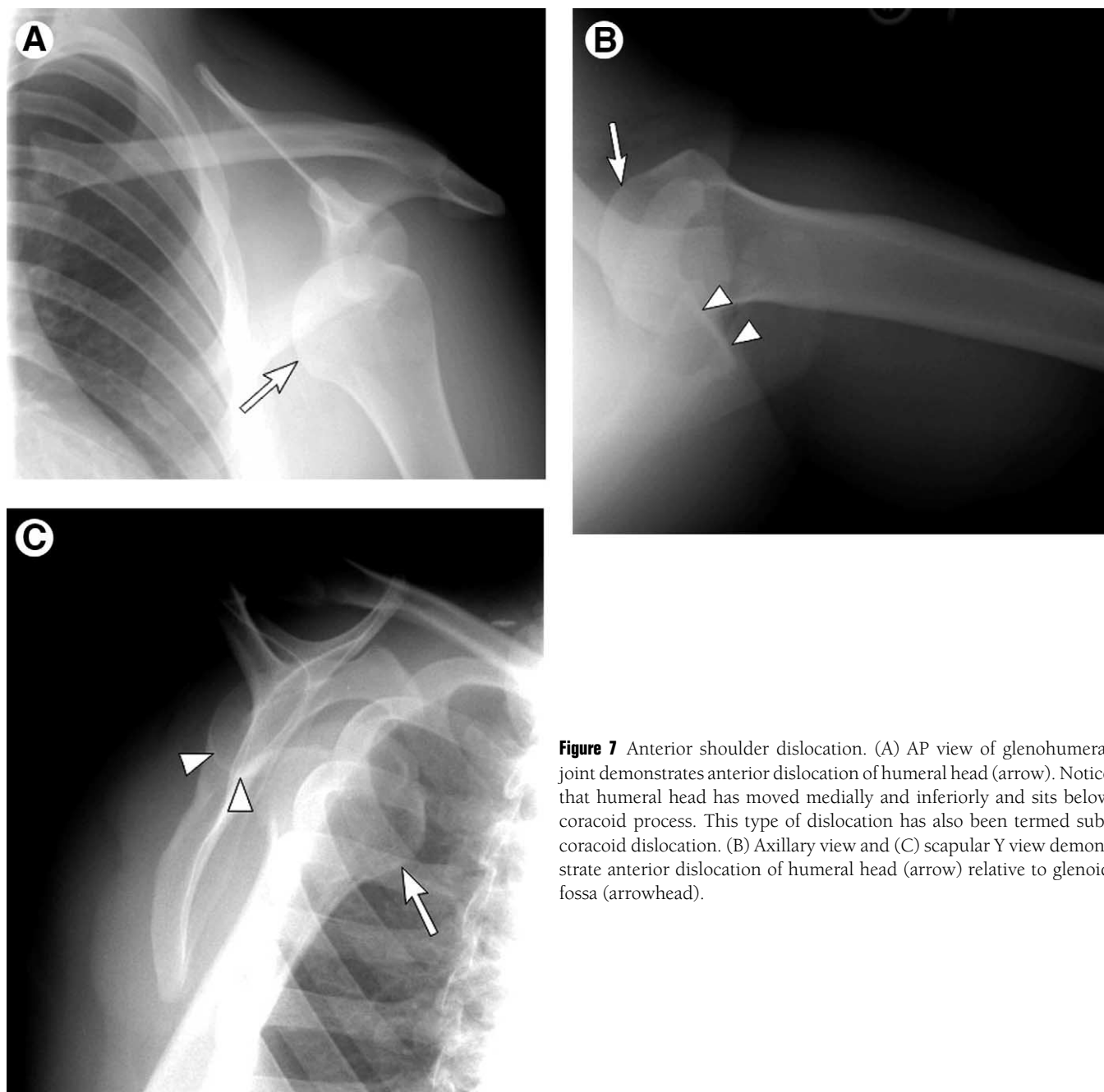
Figure 7 Anterior shoulder dislocation. (A) AP view of glenohumeral joint demonstrates anterior dislocation of humeral head (arrow). Notice that humeral head has moved medially and inferiorly and sits below coracoid process. This type of dislocation has also been termed subcoracoid dislocation. (B) Axillary view and (C) scapular Y view demonstrate anterior dislocation of humeral head (arrow) relative to glenoid fossa (arrowhead).

clines and the risk for complications such as avascular necrosis of the humeral head worsens with increasing numbers of fracture parts.[21]

Glenohumeral Dislocation

The anatomic configuration of the glenohumeral joint provides for tremendous range of motion but at the price of instability as the humeral head is dislocated more than any other single joint in the body. Approximately 95% of all dislocations are anterior in direction, but the humeral head may also dislocate posteriorly, inferiorly (luxatio erecta), or in a superior direction.[22,23]

Anterior glenohumeral dislocations typically result from a fall on an outstretched arm with the arm in slight abduction at the time of impact. During anterior dislocation, the humeral head moves anteriorly, inferiorly, and medially, typically coming to rest beneath the coracoid process, thus making anterior dislocation easy to detect on conventional radiographs (Fig. 7A-C).[24] First-time dislocation in a young person (under 35 years of age) usually results in a tear or avulsion of the anterior labroligamentous complex from the inferior glenoid, referred to as a Bankart lesion.[25] A Bankart fracture refers to an injury that includes not only an anterior labral injury but also a fracture of the anteroinferior glenoid (Fig. 8A and B). Impaction of the posterosuperior humeral head against the inferior glenoid rim can result in an impaction fracture of the humeral head referred to as a Hill–Sachs defect (Fig. 9). Less commonly, the inferior glenohumeral
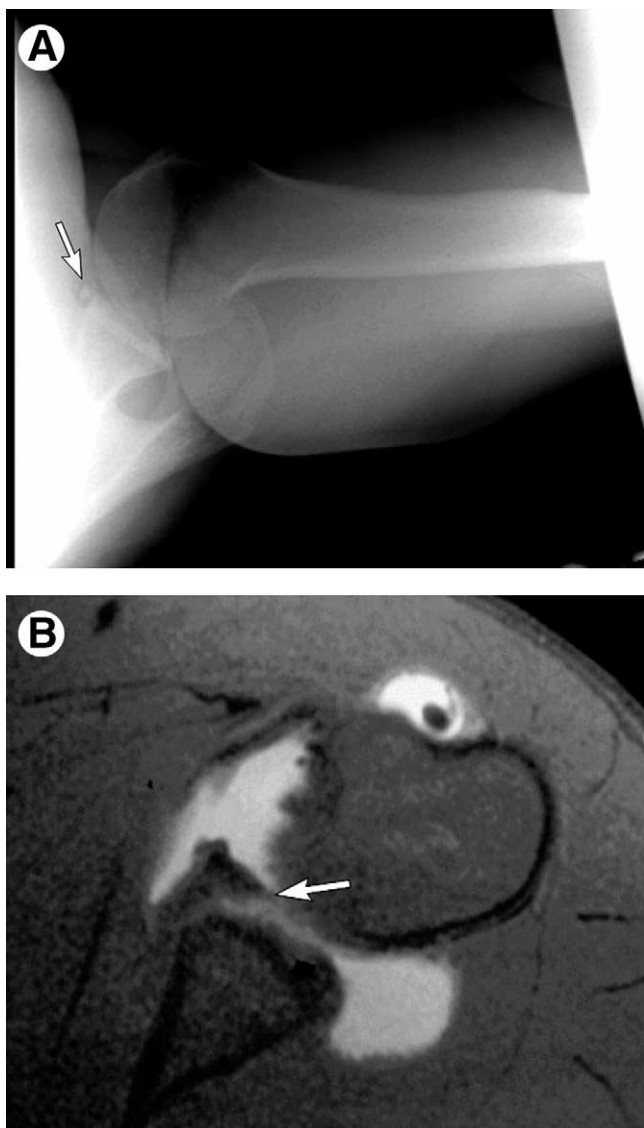
Figure 8 Bankart fracture. (A) Axillary view of glenohumeral joint demonstrates small fracture fragment (arrow) adjacent to anterior glenoid. This fracture results from impaction injury of humeral head against anteroinferior glenoid rim and can lead to recurrent instability of glenohumeral joint. (B) Axial T1-weighted MR image with intraarticular gadolinium demonstrates minimally displaced Bankart fracture (arrow).

ligament is avulsed from its humeral attachment, which may be detected radiographically if there is an associated bony avulsion, known as bony humeral avulsion of the glenohumeral ligament (BHAGL). First-time dislocators over the age of 35 are less likely to develop a Bankart lesion of the anteroinferior labrum. Instead, this group of individuals usually experiences either disruption of the rotator cuff, avulsion of the greater tuberosity (Fig. 10A and B), or avulsion of the subscapularis muscle and anterior capsule from the lesser tuberosity.[26] Although radiographs can demonstrate the osseous injuries that result from anterior dislocation, soft-tissue injuries of the capsule and labrum are best evaluated with magnetic resonance (MR) imaging with or without the addition of intraarticular contrast.[27,28]

The Hill–Sachs defect is usually best depicted on the AP radiograph of the shoulder with the arm in internal rotation and appears as an area of flattening or concavity of the posterolateral aspect of the humeral head (Fig. 9). The Stryker Notch view is also very useful in depicting a Hill–Sachs defect, whereas the defect may be completely obscured on the axillary view or AP radiograph with external rotation. Osseous Bankart lesions involving the inferior glenoid rim are often subtle lesions that are best depicted on either the AP or the axillary view of the shoulder. The West Point axillary view as described above is a special adaptation of the axillary view that was developed to accentuate detection of a Bankart lesion.[9]

Table 3 summarizes the radiographic findings of anterior glenohumeral dislocation.

Posterior glenohumeral dislocation differs from anterior dislocation in that the mechanism of injury is a fall on an outstretched arm with the arm in *adduction* rather than *abduction*. Violent muscle contractions associated with seizure or electrocution is the classic mechanism leading to posterior glenohumeral dislocation; however, this type of dislocation may also result from a fall on an outstretched flexed and adducted arm. This has been reported most commonly in bicyclists and skiers, but can also occur in other athletic sports. Unlike anterior dislocation, the radiographic findings of acute posterior dislocation are subtle and often difficult to detect, often resulting in a delay of the proper diagnosis.

Patients typically present clinically with a painful shoulder that is adducted and locked in internal rotation.[29] The humeral head is fixed to the posterior glenoid, thus preventing external rotation or abduction of the arm without extreme pain, and this constellation of findings can be misdiagnosed as a frozen shoulder.[30] Visual inspection demonstrates loss of the characteristic rounded appearance of the shoulder and may reveal a prominence posteriorly, coupled with flattening of the anterior shoulder and a prominent coracoid process.

Figure 9 Hill–Sachs defect. True AP radiograph of glenohumeral joint demonstrates flattening (arrow) of posterosuperior aspect of humeral head consistent with Hill–Sachs defect. This flattening results from impaction of humeral head against anteroinferior glenoid rim at time of anterior dislocation.
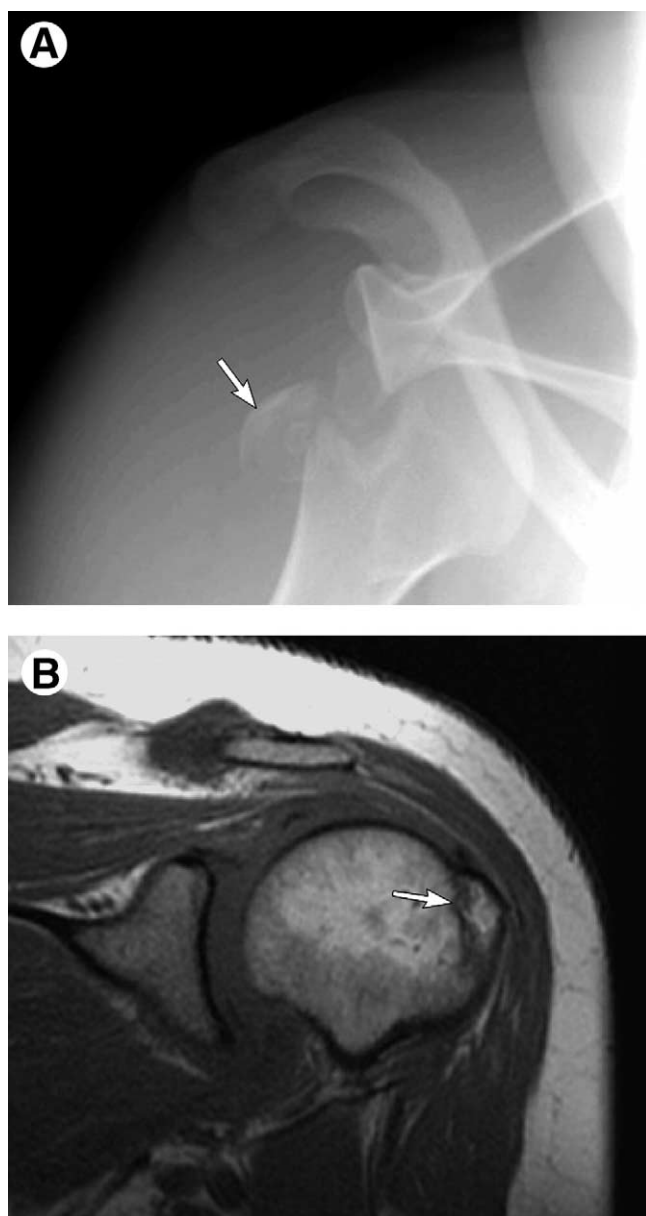
Figure 10 Greater tuberosity avulsion fracture. (A) AP radiograph of shoulder demonstrates displaced avulsion fracture of greater tuberosity (arrow) resulting from an anterior dislocation. This injury is more likely to occur in patients over 35 years of age and occasionally these fractures are non-displaced and radiographically occult. (B) T1-weighted coronal MR image of shoulder demonstrates non-displaced avulsion fracture (arrow) of greater tuberosity in middle-aged man status post anterior shoulder dislocation. This fracture was occult radiographically.

These physical findings are often subtle and, depending on the mechanism of injury, associated fractures of the scapula, coracoid, or humerus may further complicate recognition of posterior dislocation. For these reasons, proper radiographic evaluation with a high index of suspicion is critical to establish an early diagnosis.

During posterior dislocation, the humeral head is displaced directly posterior, which can make diagnosis on an AP radiograph of the shoulder rather difficult. There are several subtle radiographic signs that when present on an AP radiograph should raise the suspicion for posterior dislocation. The first clue is that on an AP radiograph the humeral head is fixed in internal rotation. The humeral head will appear to be in the same position on internal and external rotation AP views, as the patient is unable to externally rotate the humeral head. Often, the posteriorly dislocated humeral head will be slightly laterally displaced, which will result in a gap on the AP radiograph referred to as the "rim" or "empty notch" sign. Alternatively, on the AP radiograph the humeral head may be superimposed on the glenoid fossa so that the articulating surface of the humeral head appears to lie slightly medial to the glenoid fossa (Fig. 11A). Finally, when the humeral head impacts against the posterior glenoid, it can result in an impaction fracture of the anterior aspect of the humeral head superomedially. This is analogous to the Hill–Sachs defect that occurs with anterior dislocation and has been referred to as the "reverse" Hill–Sachs defect (Fig. 11B). On the AP radiograph this is referred to as the "trough" sign and appears as a linear density that parallels the articular surface of the humeral head in the normally featureless superomedial aspect of the humeral head (Fig. 11C).[31] Fracture of the posterior glenoid is referred to as a reverse Bankart lesion. All of these signs on the AP radiograph are subtle and unreliable; therefore, it is crucial to obtain a lateral view of the shoulder in cases of suspected posterior dislocation. Options include one of the variations of the axillary view or the scapular "Y" view. The scapular "Y" view is preferable in the setting of acute trauma because it can be obtained with little or no manipulation of the arm. Posterior dislocation is obvious on either view as the humeral head sits posterior to the glenoid[10] (Fig. 11B).

Table 4 summarizes the radiographic findings of posterior glenohumeral dislocation.

A small percentage of dislocations are either inferior (luxatio erecta) with the humeral head displaced inferiorly and the arm fixed in a fully abducted position in the erect position, or superior with the humeral head located superior to the glenoid and inferior to the acromion, usually resulting in disruption of the superior joint capsule and rotator cuff[22] (Fig. 12).

Impingement

Painful impingement of the shoulder is a clinical entity that results from compression of the rotator cuff and subacromial-subdeltoid bursa between the greater tuberosity of the humeral head and the protective overriding osseous outlet and acromion. The diagnosis of impingement is a clinical diagno-

Table 3 Radiographic Findings of Anterior Shoulder Dislocation

Hill–Sachs defect

Bankart fracture

Loss of normal half-moon overlap between the glenoid and humeral head

Disruption of scapulohumeral or Moloney's arch

sis and cannot be established on the basis of imaging findings alone.[32,33] It is typically established on the basis of pain produced by abduction and elevation of the arm. Clinical impingement includes subacromial-subdeltoid bursitis and ten-
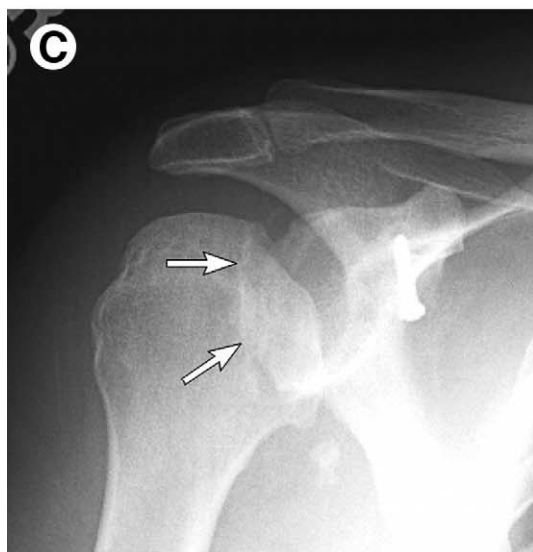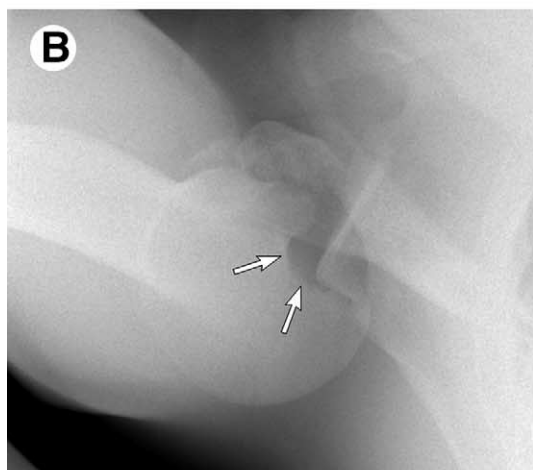
Table 4 Radiographic Findings of Posterior Shoulder Dislocation

Trough line or reverse Hill–Sachs defect
Reverse Bankart fracture
Fracture of lesser tuberosity
Positive rim sign (widening of glenohumeral joint >6 mm)
Loss of normal half-moon overlap between the glenoid and humeral head
Humeral head appears in same position on internal and external rotation AP views
Disruption of scapulohumeral or Moloney's arch

dinopathy resulting from the compressive forces of the adjacent osseous structures. Over time, impingement can lead to a partial or full-thickness tear of the rotator cuff. Certain anatomic configurations or abnormalities of the osseous outlet and acromion can place individuals at increased risk for the clinical syndrome of impingement. Numerous radiographic findings have been described that are associated with the clinical syndrome of impingement and include the following.

The morphology of the undersurface of the acromion has been correlated with the clinical syndrome of impingement (Fig. 13). Four types of morphology have been described and are best evaluated radiographically on the scapular "Y" view. These include a flat undersurface (Type I), a gentle undersurface curvature (Type II), an anterior hook (Type III), and convexity of the undersurface of the acromion near its distal end (Type IV).[34-36] Types II and III are associated with an increased incidence of the clinical syndrome of impingement (Fig. 14A and B). Other findings that can be seen with the clinical syndrome of impingement include an inferiorly directed spur extending off of the undersurface of the acromion (Fig. 15A), anterior or lateral down sloping of the acromion[37] (Fig. 15B), and thickening of the coracoacromial ligament, which is occasionally visible on radiographs as calcification within the ligament.[38] Finally, an unfused os acromiale can act as an unstable fulcrum with deltoid muscle contraction and lead to the clinical syndrome of impingement[39] (Fig. 15C and D).

Several radiographic findings have been associated with chronic massive tears of the rotator cuff and, although these generally lack sensitivity, when seen in combination, they are specific for rotator cuff tear. These include narrowing of the normal distance between the undersurface of the acromion

Figure 11 Posterior dislocation of humeral head. (A) AP radiograph of shoulder demonstrates medial cortex of humeral head (arrow) to overlie glenoid fossa (arrowheads) and indicates posterior dislocation of humeral head. (B) Axillary view of shoulder demonstrates posterior dislocation of humeral head with impaction fracture (arrows) of anterior aspect of humeral head ("reverse" Hill–Sachs defect). (C) AP radiograph of shoulder demonstrates a vertical line (arrows) running parallel to the medial cortex of humeral head. This is referred to as the "trough line" sign and represents reverse Hill–Sachs defect as seen on AP radiograph.

Figure 12 Luxatio erecta. AP radiograph of shoulder demonstrates humeral head (arrow) to be displaced directly inferiorly relative to glenoid fossa and arm is fixed in fully abducted position.

and the superior margin of the humeral head[40] (less than 6 to 7 mm is generally considered abnormal), reversal of the normal convexity of the undersurface of the acromion, formation of subcortical cysts on the undersurface of the acromion, and finally, cystic change in the region of the greater tuberosity of the humeral head. Radiographic findings of superior migration of the humeral head combined with subcortical cystic change of the greater tuberosity allows for the diagnosis of chronic massive rotator cuff tear with the greatest degree of specificity (Fig. 16).[41,42]

Table 5 summarizes the radiographic findings of chronic rotator cuff tear.

Arthritis

Arthritis is a common clinical entity that often involves either the glenohumeral joint or the AC joint. Conventional radiog-
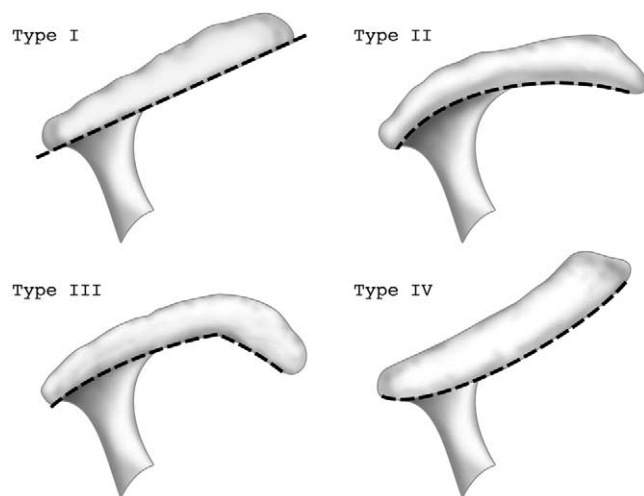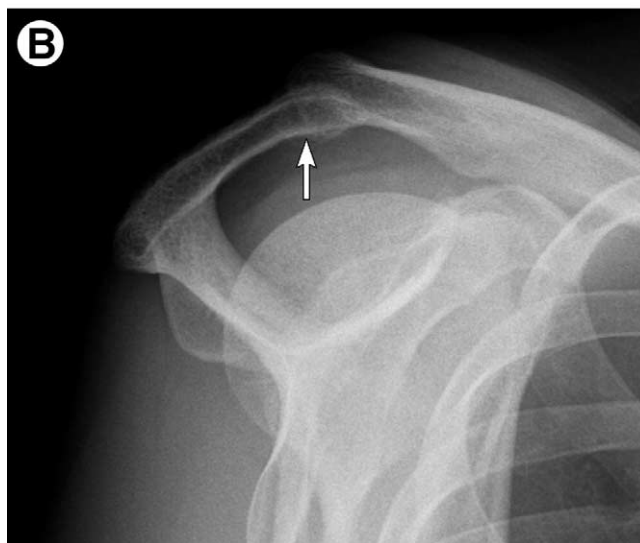

Figure 13 Acromial morphology.

raphy is an excellent means of evaluating the shoulder for the presence of arthritis and is often the preferred imaging modality to establish a specific diagnosis, as well as to determine the extent of disease and to follow response to therapy.

Rheumatoid Arthritis

Shoulder involvement is characterized by bilateral symmetric involvement of the GH and AC joints. Symmetric loss of the GH joint space is typical and marginal erosions most often involve the superomedial aspect of the humeral head. Generalized osteoporosis is common and bone production including osteophyte, although absent in most joints, can be a prominent radiographic finding of rheumatoid arthritis in the glenohumeral joint.[43] The AC joint demonstrates erosion

Figure 14 Acromial morphology. Scapular Y views demonstrate flat undersurface of acromion (arrows) in (A) consistent with Type I acromion. In (B) there is gentle undersurface curvature (arrow) consistent with Type II acromion. Type II acromion is associated with higher incidence of clinical syndrome of impingement.
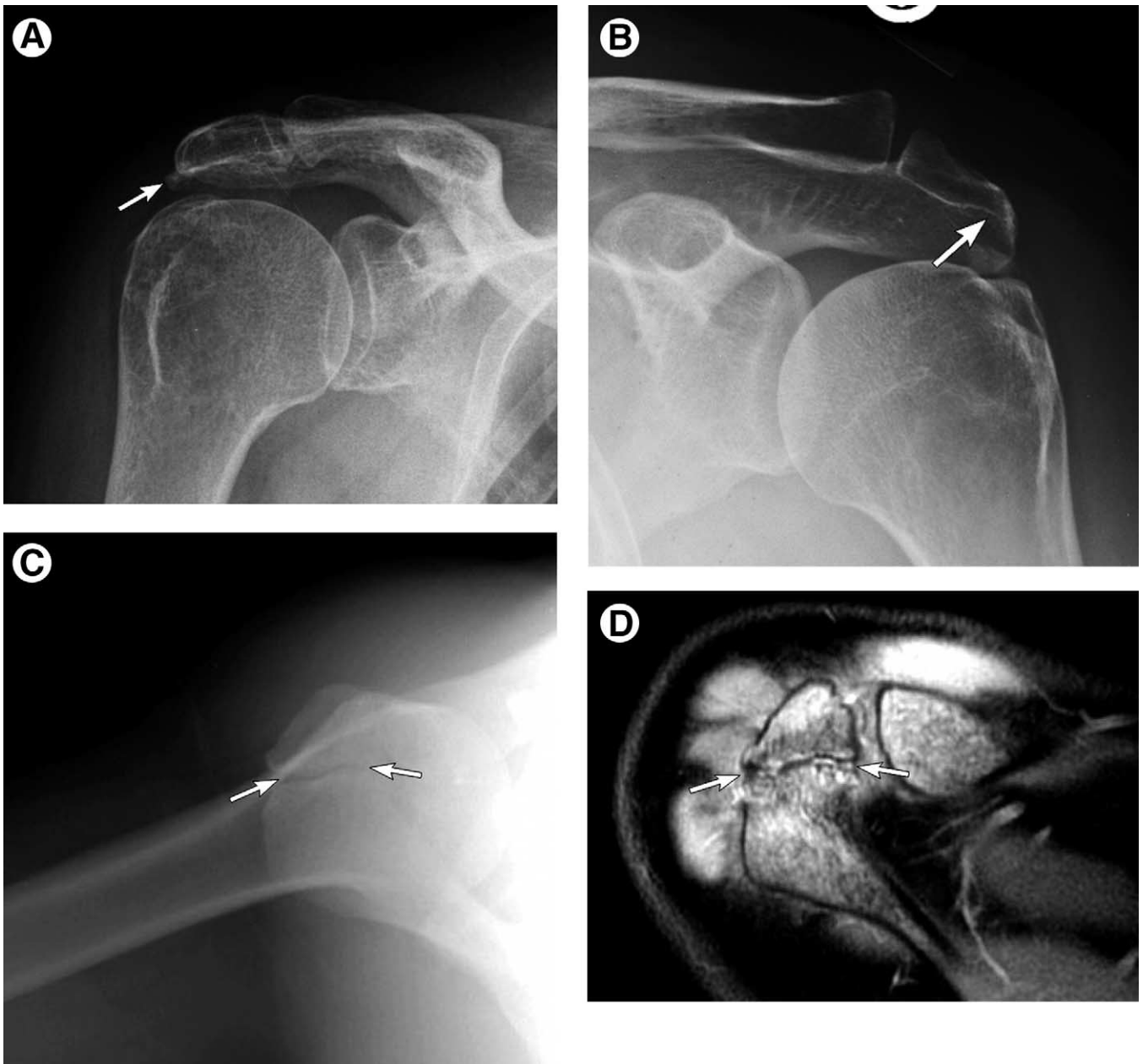
Figure 15 Osseous outlet configurations associated with clinical syndrome of impingement. (A) AP radiograph of shoulder demonstrates small osteophyte (arrow) extending off lateral aspect of acromion. (B) AP radiograph of shoulder demonstrates lateral down sloping (arrow) of acromion. (C) Axillary view of shoulder and (D) axial T2-weighted MR image demonstrate unfused (arrows) os acromiale. Unstable os acromiale can act as fulcrum and result in clinical syndrome of impingement during contraction of deltoid muscle.

and tapering of the distal clavicle with involvement of the acromial side of the joint as well (Fig. 17).

Osteoarthritis

Osteoarthritis appears to be more common as a patient ages and the presence of GH osteoarthritis has been shown to correspond to the presence of rotator cuff pathology.[44] One hypothesis is that rotator cuff pathology results in leakage of joint fluid and loss of intraarticular pressure leading to microinstability of the GH joint and progressive superior migra-

tion of the humeral head. This in turn leads to excessive wear and tear on the GH joint articular cartilage resulting in the development of osteoarthritis. The term cuff-tear arthropathy has been coined to refer to this entity.[45] The common findings are described above under the section on massive rotator cuff tear and include superior migration of the humeral head, osteophyte formation, subchondral bone formation, and cystic formation involving the under surface of the acromion and the greater tuberosity of the humeral head (Fig. 16). Narrowing of the GH joint with subchondral sclerosis and osteo-

Figure 16 Massive tear of rotator cuff with resultant cuff-tear ar-thropathy. AP radiograph demonstrates high-riding humeral head with humeral head articulating with undersurface of the acromion (arrow). Acromion demonstrates concavity of undersurface and subcortical sclerosis. In addition, there is osteophyte formation (ar-rowhead) extending off inferomedial aspect of humeral head.

phyte formation is also common.[46] These changes also com-monly involve the AC joint following trauma and typically involve both sides of the joint.

Calcium Pyrophosphate Crystal Deposition Disease

This crystalline deposition disease can involve either the AC joint or the GH joint and is one of the predisposing factors that can lead to the development of osteoarthritis of the shoulder.[47,48] Early in the disease the presence of chondro-calcinosis can be observed in either the fibrocartilage or the hyaline cartilage of the joint (Fig. 18). Late in the disease the GH joint will demonstrate the typical appearance of osteoar-thritis, including joint space narrowing, subchondral sclero-sis, and osteophyte formation, and the crystalline deposition may not be obvious radiographically.[49]

**Table 5** Radiographic Findings of Chronic Rotator Cuff Tear

High riding humeral head

Narrowing of the acromiohumeral distance (<6–7 mm)

Remodeling of the inferior surface of the acromion

Reversal of the normal convexity of the undersurface of the acromion

Cystic changes in the greater tuberosity of the humeral head

Disruption of scapulohumeral or Moloney's arch
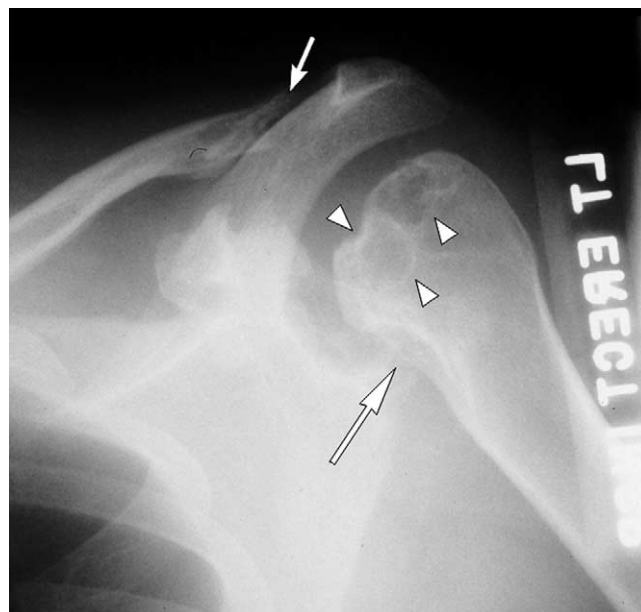
Figure 17 Rheumatoid arthritis. AP radiograph of shoulder demon-strates numerous marginal erosions of proximal humerus, involving medial aspect of humeral head (arrowheads) and medial aspect of proximal humeral shaft (long arrow). In addition, there are erosions and tapering of distal clavicle (short arrow). (Images contributed by Donald J. Flemming, Bethesda, Maryland.)

Hydroxyapatite Crystal Deposition Disease

Also known as calcific tendonitis, bursitis involves the shoul-der more often than any other joint.[50] It typically results in pain, localized swelling, erythema, and decreased range of
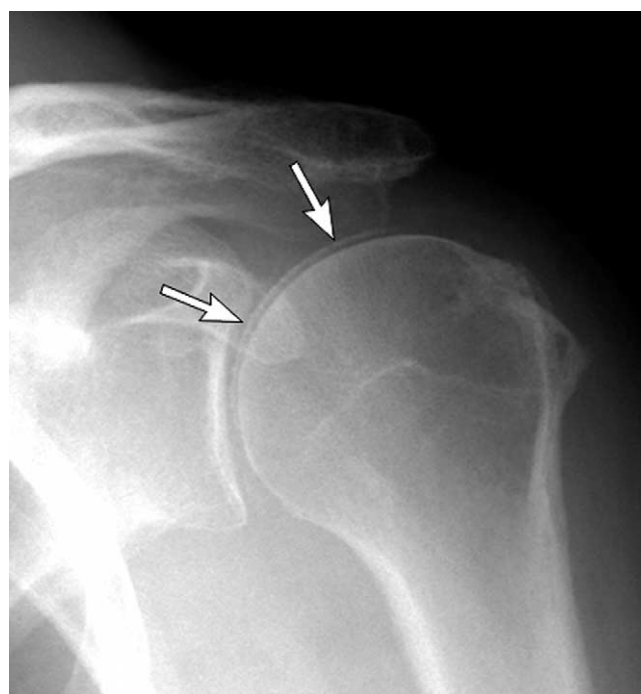
Figure 18 Calcium pyrophosphate deposition disease. AP radio-graph of left shoulder shows linear collection of chondrocalcinosis (arrows) within hyaline articular cartilage of humeral head.
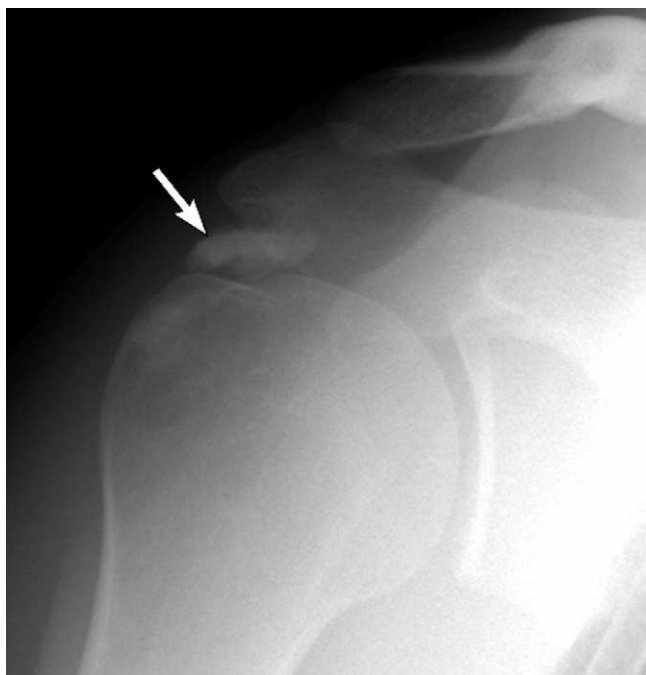
Figure 19 Hydroxyapatite deposition disease. AP radiograph of shoulder reveals well-defined oval collection of calcification (arrow) within supraspinatus tendon.

Figure 20 Amyloid arthropathy. AP radiograph of shoulder in this patient with history of long-term dialysis and shoulder pain shows poorly defined osteolytic lesion involving humeral head (arrow) and loss of normal glenohumeral joint space (arrowheads).

motion usually secondary to pain.[51] The radiographic findings include cloud-like amorphous calcification located within either one of the tendons of the rotator cuff or within the subacromial-subdeltoid (SA) bursa.[52] It has been reported that ill-defined amorphous calcification is more likely to result in symptoms, whereas well-defined or corticated calcification is a more chronic form that is often less symptomatic (Fig. 19). The crystalline deposition can rupture out of the tendon and extend into either the adjacent SA bursa, the bone, or occasionally the joint. On MR imaging, there may be associated bone marrow edema adjacent to the site of calcific tendonitis that may mimic tumor or infection.[53,54] The amorphous-appearing calcification can regress and will occasionally completely disappear.[49,52,55]

Amyloid Arthropathy

The deposition of beta-2-microglobulin is a well-known complication of long-term dialysis and in the shoulder results in asymmetric periarticular soft-tissue masses, subchondral cysts, and erosions of the humeral head and the glenoid, joint effusion, and usually preservation of the joint space.[56,57] Although this arthropathy can mimic other entities radiographically, the history of chronic dialysis is usually sufficient when combined with the imaging findings to make the proper diagnosis (Fig. 20). The differential diagnosis includes pigmented villonodular synovitis, synovial chondromatosis, rheumatoid arthritis, and tuberculous arthritis. MR imaging is a helpful tool for the evaluation of amyloid arthropathy and the deposits may be depicted on MR imaging before visualization on conventional radiographs.[58] The deposits, although variable in signal intensity, usually demon-strate areas of low to intermediate signal on both T1- and T2-weighted images.[59,60]

Neuropathic Arthropathy

Jean Martin Charcot first described the relationship between arthropathy and central nervous system lesions in 1868, and since that time, joints affected by this disorder have been referred to as Charcot joints. Neuropathic arthropathy (Charcot joint) is characterized by striking bone changes that occur secondary to loss of sensation. In the shoulder this disorder is most often caused by syringomyelia; however, other disorders such as chronic alcoholism have also been implicated. The radiographic changes are often rapid in onset and dramatic in appearance and range from hypertrophic to atrophic changes. In most locations throughout the body, neuropathic arthropathy presents radiographically as aggressive-appearing osteoarthritis with extensive bone production, fragmentation, loss of the normal joint space, and subluxation or dislocation (Table 6). However, in the shoulder the most common appearance is that of atrophic changes. At the onset of symptoms radiographs demonstrate a rapid onset of soft-tissue swelling centered around the joint. There is dissolution of the osseous structures typically on both sides of the joint with

Table 6 The D's of Neuropathic Joint

Destruction
Dislocation
Debris
Dissolution
Density (Normal or Increased)
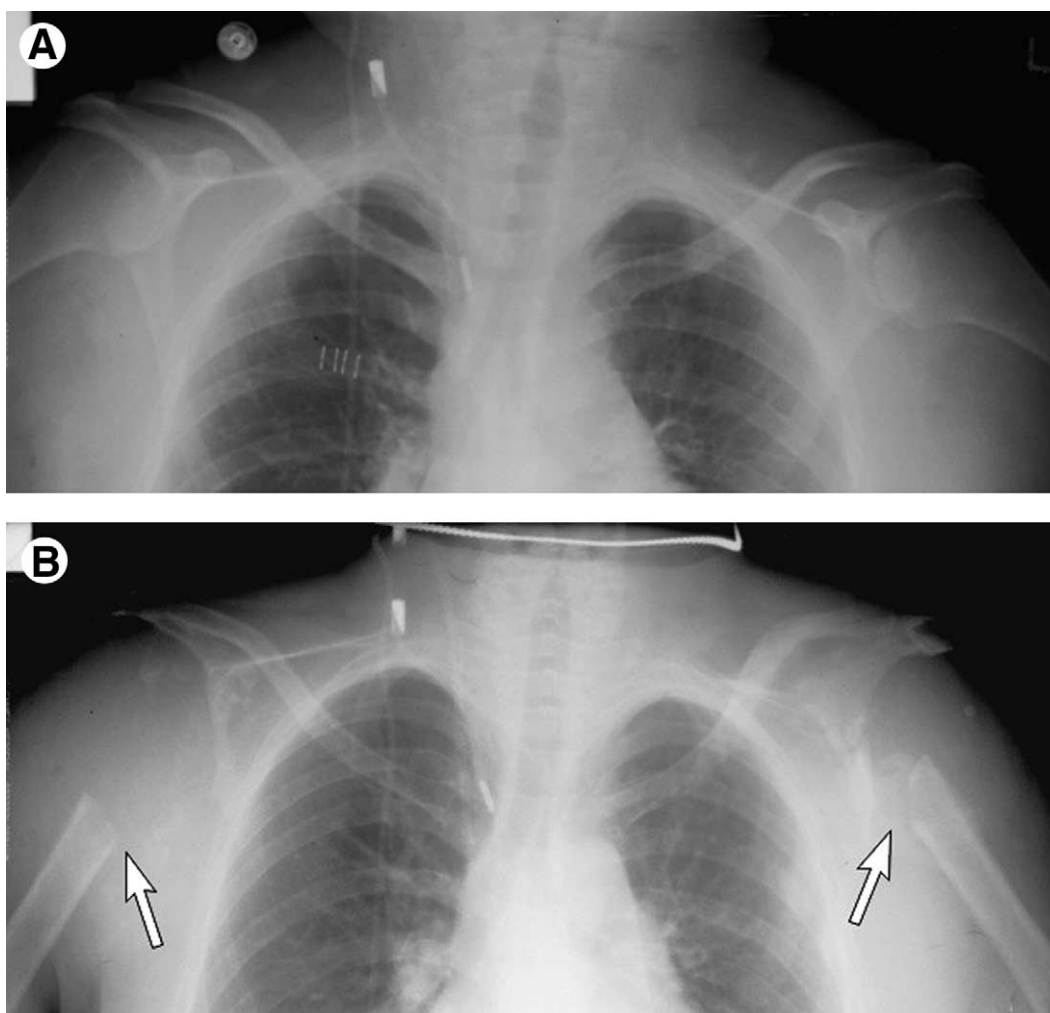
Figure 21 Neuropathic arthropathy. (A) AP chest radiograph demonstrates normal appearing shoulders bilaterally. Note that ventriculoperitoneal shunt is in place in this patient who sustained head and cervical spine injury in prior motor vehicle accident. (B) Follow-up AP radiograph less than 1 month following original film demonstrates complete resorption of humeral heads bilaterally. There is bilateral joint distention, debris, and complete dissolution of humeral heads giving rise to appearance of surgical amputation. This dramatic radiographic change occurred in less than 1 month and is consistent with atrophic form of neuropathic arthropathy.

marked fragmentation, debris, and subluxation or dislocation of the humeral head. The changes can occur very rapidly often over the course of a few weeks and it often leads to the appearance of surgically amputated ends of bones[61] (Fig. 21A and B). The differential diagnosis includes infection and tumor. Tumor, however, does not typically involve both sides of the joint, and the history of syringomyelia combined with the classic radiographic appearance helps to secure an accurate diagnosis.[62] There is currently no treatment to halt or replace bone loss but physical therapy is effective in most cases for maintaining function.
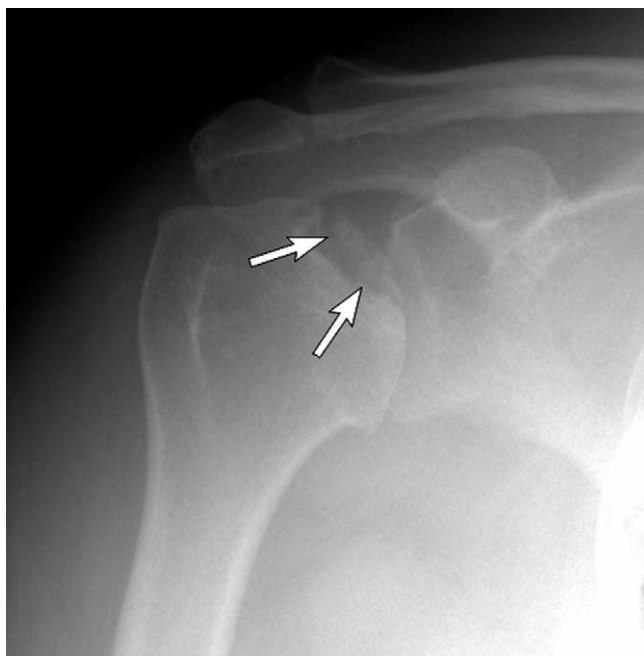
Osteonecrosis

Osteonecrosis of the humeral head can occur as a result of prior fracture or secondary to a long list of systemic abnormalities including steroid use or connective tissue disor-

ders.[20] Radiographically, early osteonecrosis appears as patchy ill-defined subchondral osteoporosis and smudging of the trabecular pattern. As the process advances, a subchondral lucency may occur, followed by cortical collapse and eventual fragmentation of the humeral head (Fig. 22). Typically, only the humeral side of the joint is involved. Conventional radiography lacks sensitivity early in the disease process and imaging to include either nuclear medicine bone scintigraphy or MR imaging is more sensitive in the detection of early disease.

Summary

Conventional radiography is a useful tool in the evaluation of shoulder pain whether in the setting of acute trauma or chronic pain and in most clinical situations should be the first imaging modality performed. Knowledge of the various pro-

Figure 22 Osteonecrosis. AP radiograph of shoulder demonstrates linear subchondral fracture (arrow) involving medial aspect of subchondral bone of humeral head. Appearance and location are classic for advanced osteonecrosis of humeral head.

jections and radiographic findings described above will ensure an optimal evaluation of the shoulder regardless of the suspected etiology of the shoulder pain.

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