



Imaging of traumatic shoulder injuries – Understanding the surgeon's perspective[☆]

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ABSTRACT

Imaging plays a key role in the assessment and management of traumatic shoulder injuries, and it is important to understand how the imaging details help guide orthopedic surgeons in determining the role for surgical treatment. Imaging is also crucial in preoperative planning, the longitudinal assessment after surgery and the identification of complications after treatment. This review discusses the mechanisms of injury, key imaging findings, therapeutic options and associated complications for the most common shoulder injuries, tailored to the orthopedic surgeon's perspective.

1. Introduction

Acute traumatic injuries to the shoulder are common and depend on the age of the patient and the mechanism of trauma. Understanding which patients require surgical treatment and which can be treated conservatively is highly dependent on accurate imaging; therefore, it is crucial for radiologists to understand the key imaging considerations for each injury to help the surgeon manage patients effectively. In this review, we will discuss the mechanisms of injury, key imaging findings, therapeutic options and associated complications for the most common traumatic shoulder injuries: proximal humerus fracture, glenohumeral dislocation, traumatic rotator cuff tear, acromioclavicular (AC) joint separation, clavicular fracture, and scapular fracture; focusing on the orthopedic surgeon's perspective.

2. Proximal humerus fracture

2.1. Anatomy and main considerations

Proximal humeral fractures are commonly seen in elderly women after a low energy fall onto an outstretched hand [1–3]. In young

patients, proximal humerus fractures are seen with high-energy trauma, such as motor vehicle accidents. However, younger patients with shoulder trauma are more likely to sustain a dislocation of the glenohumeral and AC joints, rather than a proximal humerus fracture due to the strength of the bones relative to the surrounding soft tissues.

Many classification systems exist for proximal humeral fractures, with the Neer classification being the most widely used in clinical practice [4]. This classification method divides the proximal humerus into four parts: greater tuberosity, lesser tuberosity, humeral head, and humeral shaft; and categorizes fractures according to the number of displaced and/or angulated fragments with a maximum of four (Fig. 1). If any of the four parts is displaced by more than 1 cm or angulated > 45 degrees from an adjacent part, then it constitutes a distinct “part”. It is important to understand that the total number of fracture fragments are not necessarily the same as actual number of fracture parts [5,6]. The majority, 80%, of proximal humerus fractures are 1-part fractures, occur at the surgical neck and are treated conservatively [7]. The Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification of proximal humeral fractures may also be used, which divides fractures into 3 groups (A, B, and C) with emphasis on the blood supply to the articular surface and likelihood of post-traumatic osteonecrosis [8].

Abbreviations: ABER, abducted and external rotated; AC, acromioclavicular; AHI, acromiohumeral interval; ALPSA, anterior labral periosteal sleeve avulsion; AO, Arbeitsgemeinschaft für Osteosynthesefragen; AP, anteroposterior; CT, computed tomography scan; GLAD, glenolabral articular disruption; MR, magnetic resonance; MRI, magnetic resonance imaging; ORIF, open reduction and internal fixation; RCT, rotator cuff tear; US, ultrasound scan.

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2.2. Imaging

On conventional radiographs, combined anteroposterior (AP) and trans-scapular Y views best evaluate the fracture in the Neer classification [9]. Although the Neer classification system is the commonly used, its utility has been questioned due to fair-to-moderate inter and intra-rater variability [6,10,11]. CT can be helpful when radiographs are inconclusive (Fig. 2) or in the assessment of complex fracture patterns. However, even with 3D reformats, CT has not been shown to significantly improve reliability when using the Neer classification [12]. Hence, it is more important to describe the extent of bony involvement, any displacement and/or angulation, and the relationship of the articular surface to the glenoid in the radiologic report.

The modified Neer classification, updated in 2002, includes a new category for valgus-impacted four-part fractures to address valgus rotation of the humeral head within the splayed tuberosities [13]. In these cases, the glenohumeral articular surface is preserved rather than dislocated, as seen with the classic four-part proximal humerus fracture. An intact medial calcar carries a lower risk of post-traumatic avascular necrosis and may be treated without surgery [14,15]. Therefore, this potentially management-altering distinction should be noted by the radiologist.

2.3. Surgeon's perspective

There is institutional variability in the management of proximal humerus fractures [14,16–18]. In general, a greater degree of comminution and displacement increases the need for surgery due to the risk of

avascular necrosis and non-union [18]. One-part fractures are typically managed conservatively. Treatment of two- and three-part fractures can vary depending on the fracture complexity and patient comorbidities. Patients with four-part fractures often have surgery to minimize the risk of avascular necrosis, chronic pain, and disability [2,15,18]. Surgical options for proximal humeral fractures include plate and screw fixation, intramedullary nailing, or tension band constructs. Hemiarthroplasty and reverse total shoulder arthroplasty are options for elderly patients [19].

Vascular integrity to the proximal humerus is of utmost concern to the orthopedic surgeon. The anterior circumflex humeral artery wraps around the surgical neck of the humerus inserting approximately 8 mm inferior to the articular margin on the medial humerus [16,18]. Disruption of the medial aspect of the proximal humeral metaphysis can compromise arterial supply to the humeral head and should be noted in the report. There is also risk of humeral head avascular necrosis if the surgical neck fracture exits more proximally above the articular margin or if the humeral metaphysis is disrupted from the articular segment. Urgent surgical intervention may be warranted if the humeral head segment is significantly displaced, particularly in younger patients, to address vascular compromise and humeral head osteonecrosis.

It is important to note fractures involving the greater or lesser tuberosity in the imaging report, as avulsion injuries adversely affect rotator cuff function [18,20]. Fractures of the greater tuberosity occur rarely in isolation and should undergo open reduction and internal fixation (ORIF) if the greater tuberosity fragment is displaced > 5 mm to avoid loss of shoulder function [21]. Fractures with varus angulation (Fig. 3) are at higher risk for developing a progressive deformity due to

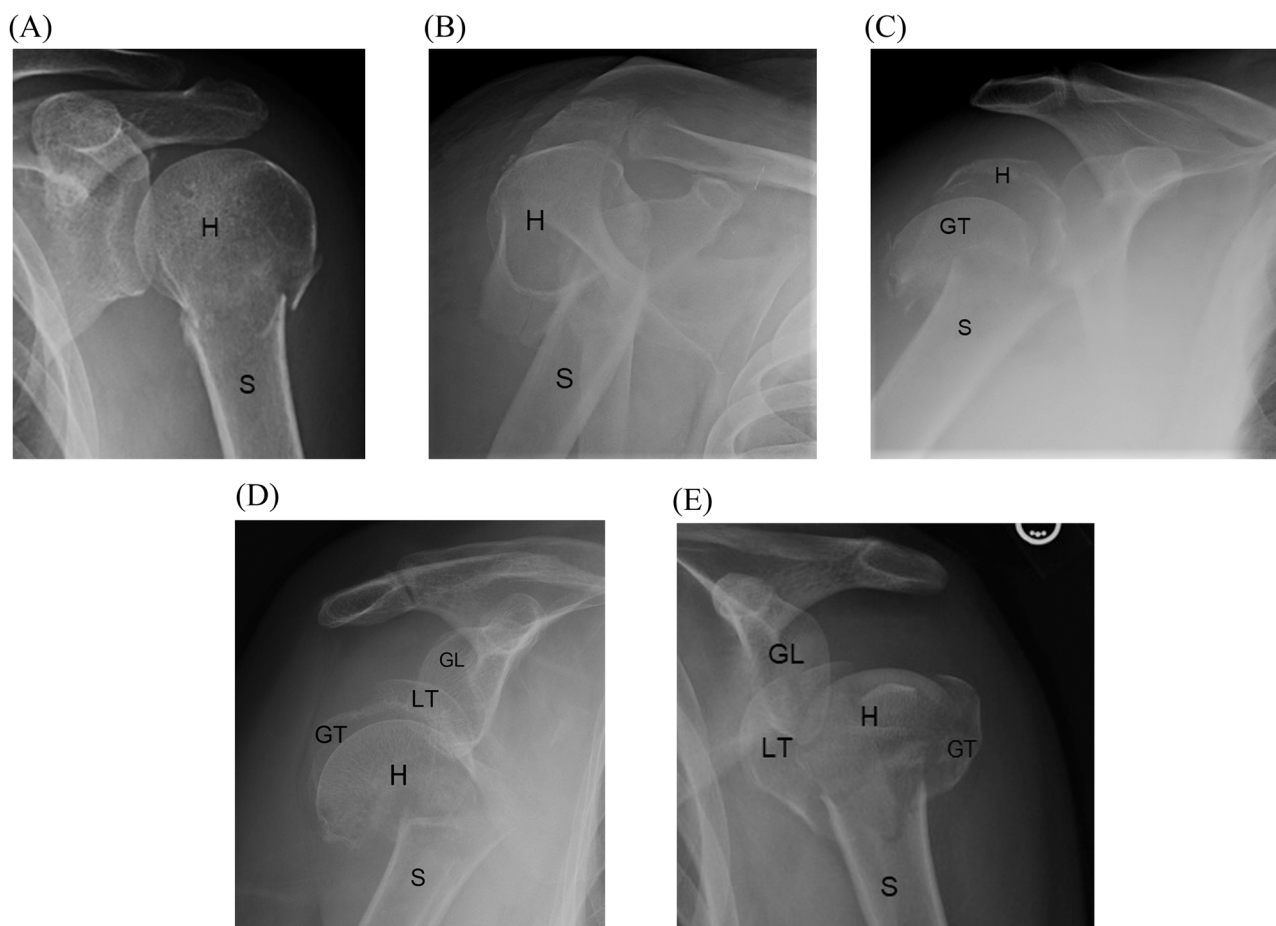


Fig. 1. Neer classification of proximal humerus fracture with (A) one-, (B) two-, (C) three-, (D) classic four-, and (E) valgus-impacted four-part fractures. In the classic four-part fracture, the humeral head articular surface no longer articulates with the glenoid, whereas the articulation is maintained in a valgus-impacted four-part fracture. GT, greater tuberosity; LT, lesser tuberosity; H, humeral head; S, humeral shaft; GL, glenoid.

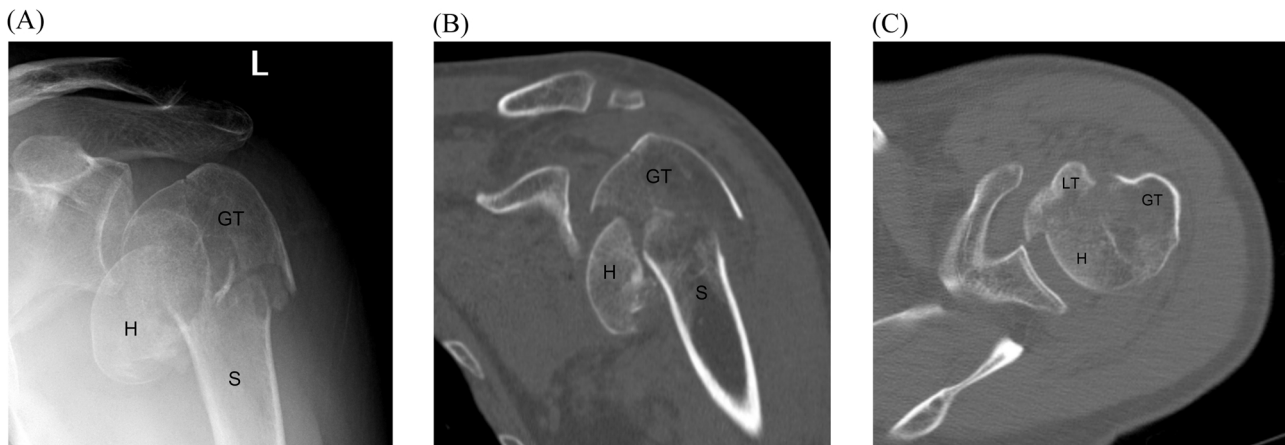


Fig. 2. A 65-year-old woman with proximal humerus fracture. (A) Frontal shoulder radiograph shows a complex fracture through the surgical neck with displaced humeral head and greater tuberosity. (B and C) Nonenhanced coronal and axial CT images better characterize the injury as a four-part fracture, with the greater tuberosity (GT), lesser tuberosity (LT), humeral head (H), and humeral shaft (S) all displaced by ≥ 1 cm or angulated $\geq 45^\circ$.



Fig. 3. A 47-year-old male with proximal humerus fracture through the surgical neck in varus alignment. Varus alignment carries a worse prognosis compared to normal or valgus alignment.

muscular forces acting on the fragments, necessitating frequent follow-up to monitor the fracture's alignment and potential need for surgical correction [22]. In contrast, valgus fractures are generally more stable and can be treated conservatively. Proximal humerus fractures often develop an apex anterior deformity due to the pull of the pectoralis major tendon on the anterior humeral shaft. Therefore, it is important to note any angulation on the trans-scapular Y view. The resulting deformity can be an indication for surgery to prevent loss of forward abduction.

2.4. Complications

One of the most common complications of a displaced proximal humeral fracture is nerve injury, sometimes leading to permanent motor dysfunction. The axillary nerve is most frequently involved, accounting for up to 58% of cases as detected on electromyogram, and the suprascapular nerve can be injured in up to 48% of cases [23]. Vascular injuries are more common in elderly patients and can be associated with brachial plexus injuries. Diagnosis of vascular compromise can be made clinically or with angiographic imaging, if necessary (Fig. 4). Adhesive capsulitis is also common following fractures of the proximal humerus,

with loss of range of motion occurring with both closed and open management. The overall rate of osteonecrosis after proximal humeral fracture is approximately 33% [24]. Early surgical intervention decreases the risk of avascular necrosis; however, the risk remains high in three and four-part fractures [25]. After surgery, the most common postsurgical complications include screw penetration ("cut-out") through the humeral head for ORIF (3–16%) (Fig. 5), humeral head avascular necrosis (9%) (Fig. 6), chronic instability after arthroplasty (5%), and loss of range of motion (15–26%) [26,27].

Report checklist

1. How many distinct fracture parts are present (4 maximum)?
2. Is there an avulsion fracture of the greater or lesser tuberosities?
3. Does the fracture involve the medial humeral metaphysis (potential injury of circumflex artery)?
4. Does the surgical neck fracture extend into the articular surface of humeral head (higher risk of AVN)?
5. Is there varus (less common and worse prognosis) alignment of the fracture?
6. Is there an apex anterior deformity at the surgical neck?
7. Is there a valgus-impacted four-part fracture (may not require surgery)?
8. Is there a vascular injury or a high-risk of avascular necrosis suspected?

3. Glenohumeral dislocation

3.1. Anatomy and main considerations

The glenoid covers only one third of the humeral head articular surface and the joint capsule is relatively lax. This makes the joint highly susceptible to instability and prone to dislocation [28]. Glenohumeral dislocation account for 50% of all dislocations and are most common in young men [3]. The shallow glenoid anatomy is also a predisposing factor to repeated dislocations [3]. Glenohumeral dislocations are categorized by the location of the humeral head in relation to the glenoid: anterior (90–95%), posterior (2–4%), and superior and inferior (luxatio erecta humeri) subtypes (Fig. 7) [7].

With anterior dislocation, The impact of the relatively soft humeral head striking against the more rigid anterior glenoid rim leads to a Hill-Sachs fracture at the posterolateral humeral head [29]. Greater degrees of abduction and external rotation of the humerus during trauma lead to a more superiorly and posteriorly located Hill-Sachs defect, respectively [29]. Large Hill-Sachs deformities, involving 20–40% of the articular surface, should be noted, as they can be associated with recurrent shoulder instability and increase the likelihood for surgical treatment [29–31]. A Bankart injury at the antero-inferior glenoid occurs in 40% of anterior shoulder dislocations and are the counterpart to the Hill-Sachs fracture (Fig. 8) [3,29,32]. Bankart injuries can have variable

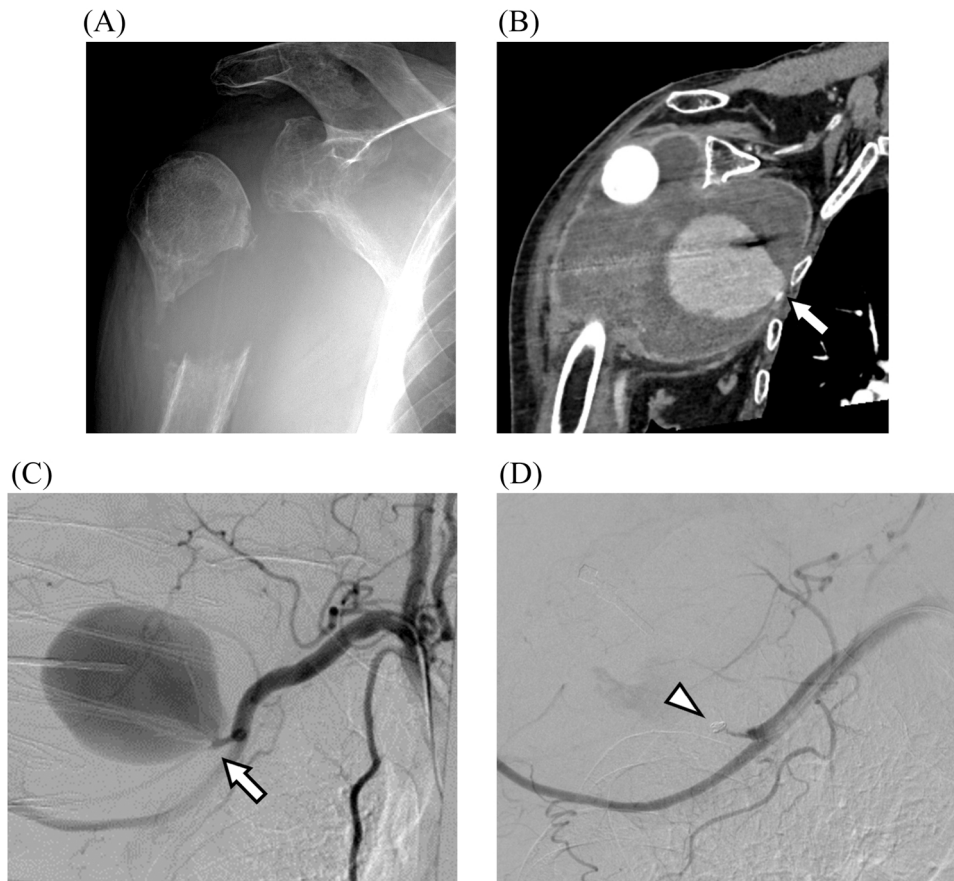


Fig. 4. A 61-year-old man with proximal humerus fracture resulting in a large pseudoaneurysm. (A) Trans-scapular Y-view shows a displaced fracture through the surgical neck. Coronal CT angiography (B) and conventional angiography (C) reveals a pseudoaneurysm originating from anterior humeral circumflex artery origin (arrows) with surrounding hematoma. (D) Successful coil embolization of the pseudoaneurysm (arrowhead) is seen on angiography.

appearances and be categorized by involvement of the labrum, articular cartilage, bony periosteum, and/or bone [33].

Posterior shoulder dislocations occur when the humeral head is forced posteriorly, often seen with direct anterior trauma or seizures [7, 15]. The posteroinferior glenoid head may be involved, resulting in a reverse bony Bankart lesion, and the impression at the anteromedial aspect of the humeral head, a reverse Hill-Sachs lesion (Fig. 9). Glenoid fractures after any shoulder dislocation are an important imaging finding, as loss of glenohumeral contact area will affect joint stability and the ability to achieve stable reduction.

Anterior shoulder dislocations are typically managed with a closed reduction followed by physical therapy to strengthen the rotator cuff and periscapular musculature. Prolonged post-reduction immobilization in young adult first-time dislocators is controversial and does not decrease recurrence rates [34,35]. Bony Bankart lesions can be repaired either arthroscopically or with an open approach, both restoring shoulder function, but arthroscopy is associated with a higher rate of recurrent instability and need for repeat surgery (Fig. 10) [36]. Stiffness with external rotation is a common postsurgical complication.

3.2. Imaging

Shoulder dislocations can be assessed with well-positioned radiographs, including axillary and/or trans-scapular Y-views; however, in difficult cases, CT should be used (Fig. 11). A key diagnostic point is to identify the coracoid process on each view. The coracoid process will indicate the anterior aspect of the glenohumeral joint and assessing the humeral head in relation to the coracoid will indicate the direction of the dislocation. For anterior dislocations, the humeral head is held in

external rotation and will be positioned anteromedially to its normal anatomic position, towards the coracoid process. Posterior shoulder dislocations can be difficult to diagnose on an AP view alone and can be missed in up to 50% of initial shoulder radiographs [3,32,37]. Therefore, axillary and/or trans-scapular Y-views must be included in the evaluation of suspected shoulder dislocation whenever possible. In the absence of other views, there are several clues on the frontal view that raise suspicion for a posterior glenohumeral dislocation. The humeral head is typically held in internal rotation. Additionally, an external rotation view may not be obtainable or cause the patient severe pain. There can be widening (>6 mm) of the glenohumeral joint space on the frontal view, called the “positive rim sign”; and a “trough sign” can be present which is a sclerotic line that forms at the site of the depressed anterior humeral head fracture, best seen on the axillary view [3].

If a complex injury pattern is suspected, such as fracture/dislocation, CT can be helpful to determine the mechanism of injury (Fig. 12), intra-articular bodies preventing reduction (Fig. 13), and any associated pathology. CT imaging can also be used to quantify the degree of glenoid bone loss using the “best-fit circle” technique on the sagittal plane (Fig. 14) [33]. Recurrent glenohumeral joint instability is likely if the glenoid bone loss is > 7 mm in width or > 20–30% of the total glenoid surface area [15,29].

Soft tissue Bankart lesions and subtypes result from the avulsion of the anterior inferior (3–6 o’clock position) glenolabral ligament complex. These injuries are best assessed on MRI and can involve the scapular periosteum and hyaline cartilage (Fig. 15). The normal anterior inferior labrum is triangular with a sharp free margin on axial MRI images. Following an injury, the labrum loses its triangular shape and can appear amorphous or abnormally small. It is often displaced

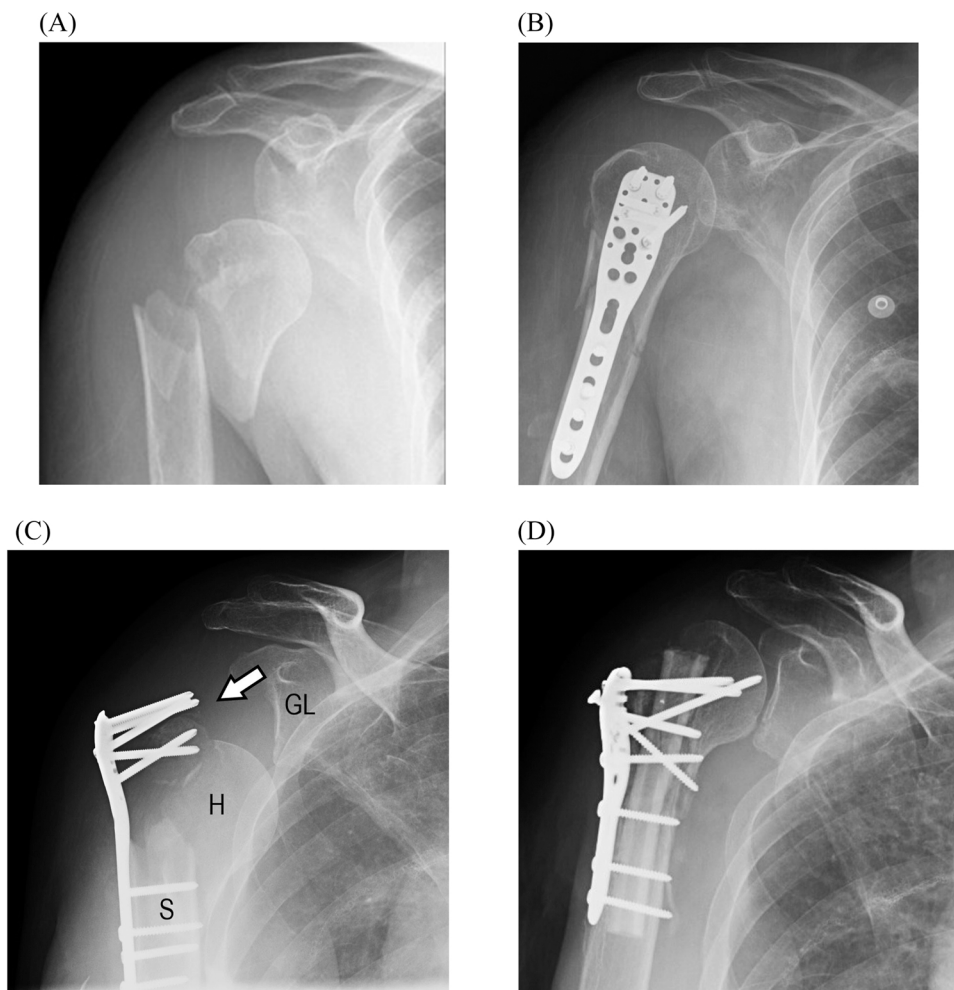


Fig. 5. A 51-year-old female with proximal humerus fracture complicated by hardware backout. (A) Right proximal humeral fracture with inferior dislocation of the humeral head in relation to the glenoid fossa is treated by surgical fixation (B). (C) One month postoperative radiograph shows complete separation of the humeral head from the superior fracture plate and screws (arrow) with recurrent humeral head subluxation, which required placement of a strut graft (D). H, humeral head; S, humeral shaft; GL, glenoid.

anteromedially in relation to the glenoid. It is important to comment on the location of the labrum, its size, and whether there is injury of the anterior scapular periosteum and/or adjacent cartilage. The classic soft tissue Bankart lesion has complete tearing of the medial scapular periosteum and detachment of the labrum anteriorly from the glenoid. A Perthes lesion is similar to the classic Bankart except that the scapular periosteum is stripped away from the bone, but it is still attached. An Anterior Labral Periosteal Sleeve Avulsion (ALPSA) injury has medial displacement of the labroligamentous complex with absence of the labrum on the glenoid rim. Lastly, a GlenoLabral Articular Disruption (GLAD) lesion is a partial tear of anterior inferior labrum with a defect in the adjacent cartilage. Although the majority of large labral tears can be seen on conventional MRI; MR arthrography offers better sensitivity and specificity in detecting subtle labral tears and is the modality of choice [38,39]. An ABER MRI sequence (Fig. 16) that places the arm in an ABducted and External Rotated position can help identify these labral injuries as the position creates tension on the anterior inferior labroligamentous structures [40]. This sequence requires repositioning of the patient which can prolong imaging scan time and cause patient discomfort.

3.3. Surgeon's perspective

Shoulder instability can present with nonspecific clinical findings; hence imaging can be extremely helpful in identifying an instability event. Hill-Sachs and bony Bankart fractures are diagnostic of prior shoulder dislocation and the severity of injury, hence are important for the radiologist to describe [29,30]. While conventional radiographs are

highly sensitive for the detection of anterior shoulder dislocations, traumatic shoulder dislocations are invariably associated with soft tissue injuries whose prognostic implications are best assessed with MRI [41].

Bony Bankart injuries can typically be treated conservatively. However, there are factors precluding a proper joint reduction. Fracture fragments displaced into the glenohumeral joint can prevent reduction and require CT for anatomic assessment before intraoperative removal. Displaced Bankart lesions present a technical challenge for orthopedic surgeons because reduction and fixation are difficult both arthroscopically and with an open approach. It is important for the radiologist to note intra-articular osseous fragments and the degree of glenoid surface involvement and glenoid fracture displacement, which affects the surgical plan [29,30].

3.4. Complications

The primary complication for patients after an anterior shoulder dislocation is recurrent instability. The incidence ranges from 14% to 100%, with a much greater risk for recurrent dislocation in young first-time dislocators [42]. Damage to the inferior glenohumeral ligaments, the key shoulder stabilizers, can predispose a patient to recurrent dislocations. Anterior shoulder dislocations are associated with injuries to the axillary artery (13–42% of patients) and brachial plexus, which can be evaluated by angiographic studies and MRI, respectively [43,44]. With posterior shoulder dislocation, neurovascular compromise is uncommon; however, glenolabral and capsular injuries can lead to chronic posterior instability [45]. Although shoulder instability is more common in young adults, with a male predominance, older patients are more

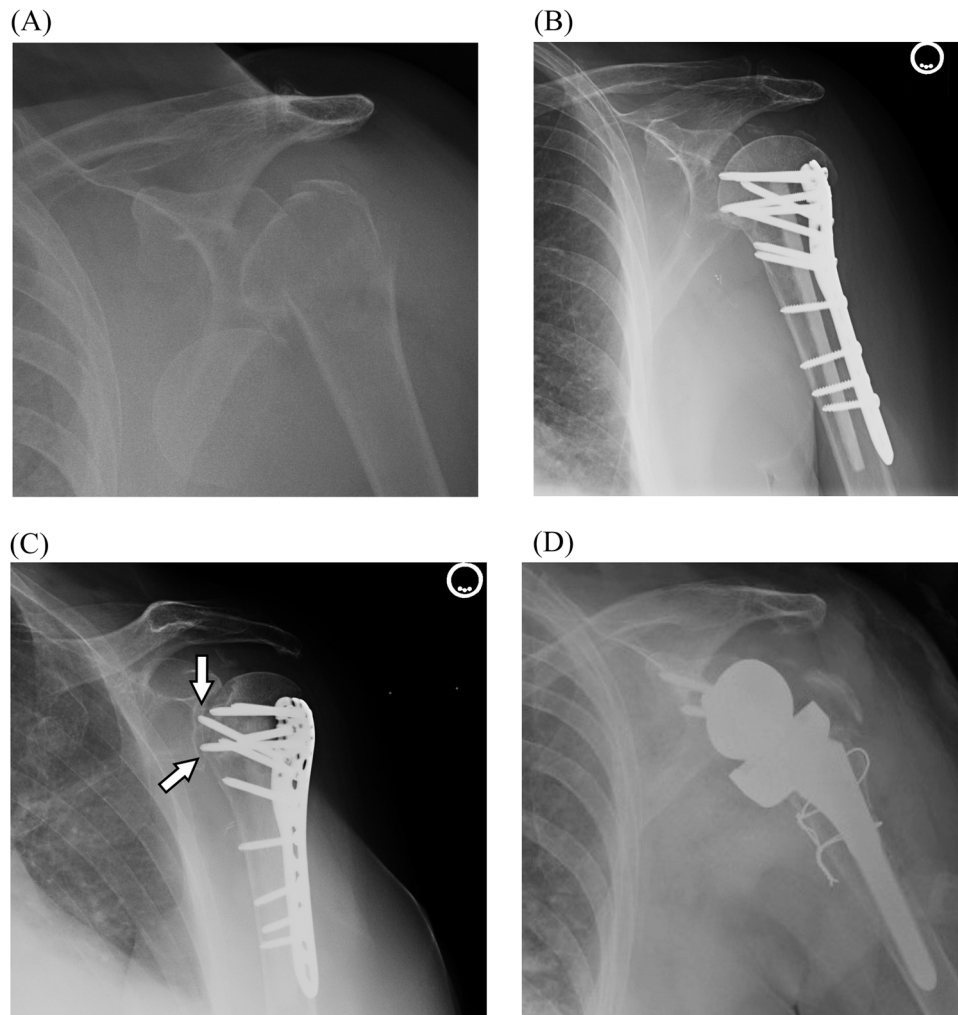


Fig. 6. A 60-year-old female with proximal humerus fracture complicated by avascular necrosis. (A) Left proximal humeral fracture with inferior posterior dislocation of the humeral head is treated by surgical fixation (B). (C) New collapse of the left humeral head with extension of screws beyond the articular surface (arrows) is consistent with avascular necrosis that is treated by reverse total shoulder arthroplasty (D).

likely to sustain a rotator cuff injury [46]. Hence, imaging signs of rotator cuff pathology, such as decreased acromiohumeral interval, should be noted in the report.

Report checklist

1. Is the humeral head in fixed external or internal rotation?
2. Is the humeral head abnormally positioned relative to coracoid process?
3. Is there is a Hill-Sachs fracture? If present, does it involve more than 20% of articular surface?
4. Is there a bony Bankart injury? If present, what is the fragment's width and percentage of the glenoid's articular surface?
5. Are there intra-articular fracture fragments? Do any prevent reduction?
6. Is there a soft tissue labral Bankart injury? Describe involvement of the labrum, articular cartilage, bony periosteum, and/or inferior glenohumeral ligaments.
7. Is there evidence of an associated rotator cuff muscle/tendon injury?

4. Traumatic rotator cuff tears

4.1. Anatomy and main considerations

The rotator cuff muscles provide stability to the humeral head during shoulder movement. However, because the humeral head is so much larger than the glenoid, the rotator cuff works to maintain the center of motion as the arm moves which make the rotator cuff prone to repetitive injury. Rotator cuff tears (RCTs) can be degenerative or traumatic in

etiology. The majority of RCTs are degenerative. Repetitive motion leads to tendinosis, then gradual thinning and eventually tearing, often with impingement as an accelerating risk factor [15]. Traumatic RCTs are less common and occur in young and middle-aged men from sudden acceleration-deceleration and rotational forces applied through the arm to the shoulder, most often related to motor vehicle collision or sports injuries [47]. The average age of patients with a traumatic RCT was 34 years, compared to 54 years for degenerative tears in a large meta-analysis study [47].

The supraspinatus, followed by the infraspinatus, are the mostly commonly injured rotator cuff tendons, regardless of the etiology or injury mechanism [47]. Traumatic tears may extend anteriorly to involve the subscapularis (Fig. 17). Subscapularis ruptures can also occur after anterior shoulder dislocations [48], and typically progress inferiorly to reach the middle and inferior third, where the tendon becomes more muscular. Traumatic RCTs can be associated with biceps tendon pathology (tear, tendinosis, and dislocation) in 77% of cases [49].

4.2. Imaging

There can be subtle clues on radiographs that suggest rotator cuff pathology. The humeral head can present with superior subluxation, resulting in a decreased acromiohumeral interval (AHI) of < 7 mm on true AP view. If the humeral head articulates with the undersurface of

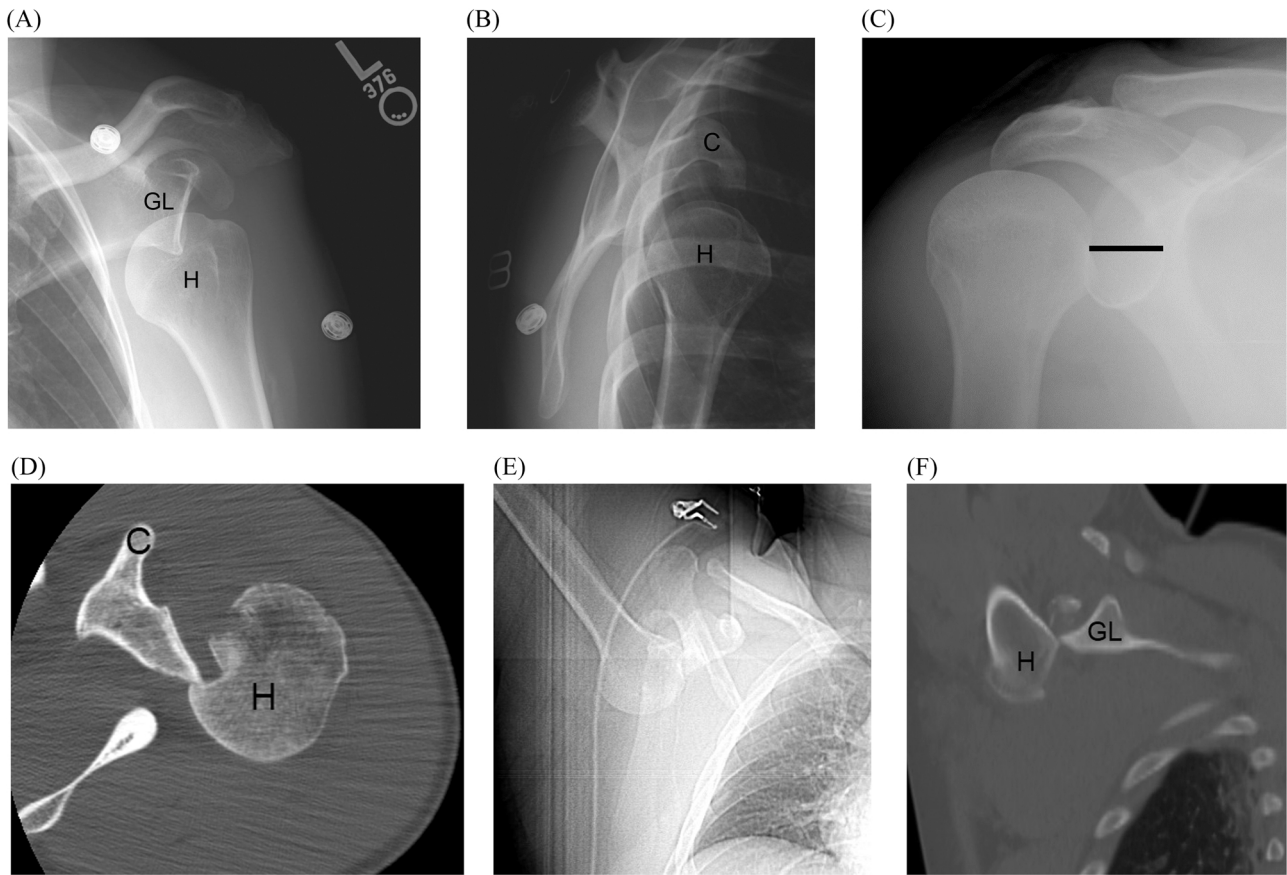


Fig. 7. Glenohumeral dislocation types as categorized by location of the humeral head (H) in relation to the glenoid (GL). Anterior dislocation seen on anteroposterior (A) and trans-scapular Y (B) views. The latter shows migration of the humeral head towards the coracoid process (C). Posterior dislocation shows widening of the glenohumeral distance (black line) on the internal rotation view (C) and posterior migration of the humeral head in relationship to the coracoid process on nonenhanced axial CT image (D). Inferior dislocation (luxatio erecta) showing abduction of the affected arm on CT scout image (E) and inferior dislocation of the humeral head relative to the glenoid on nonenhanced coronal CT image (F).

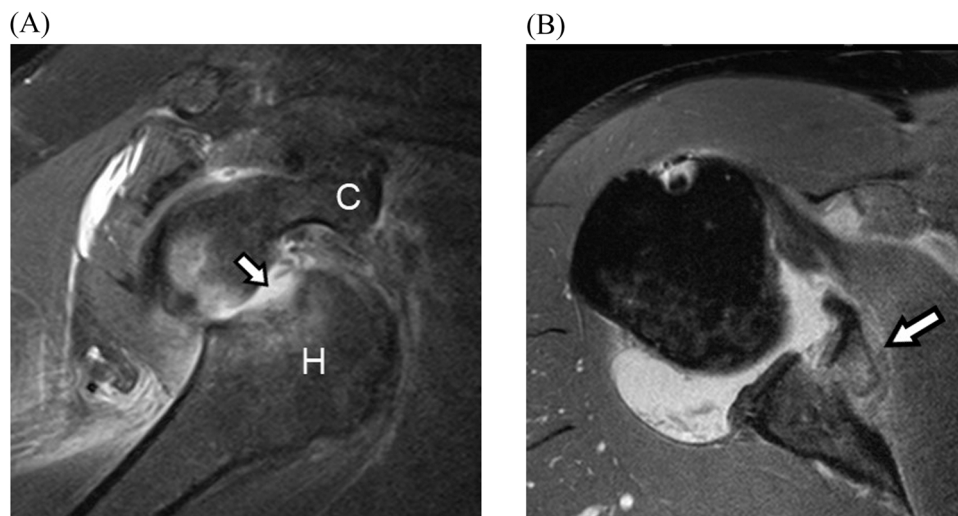


Fig. 8. A 37-year-old man with anterior shoulder dislocation. (A) Anterior dislocation of the humeral head (H) in relation to the coracoid process seen on sagittal T2 weighted fat-suppressed MR image with a Hill-Sachs fracture (arrow) at the posterior superior humeral head. (B) Post-reduction axial T2 weighted fat-suppressed MR image reveals a bony Bankart fracture (arrow) at the anterior inferior glenoid.

the acromion, there is complete rupture of the superior rotator cuff with retraction. However, in the immediate post-traumatic period, the rotator cuff, deltoid and peri-scapular musculature may become transiently atonic, and the humeral head is subluxed inferiorly by the weight of the

arm, increasing the AHI. In other cases of acute injury or degenerative RCT, the rotator cuff fails to center the humeral head in the glenoid, such that the humerus is elevated toward the acromion, which reduces the AHI. Radiographically on the AP projection, any change to the AHI is

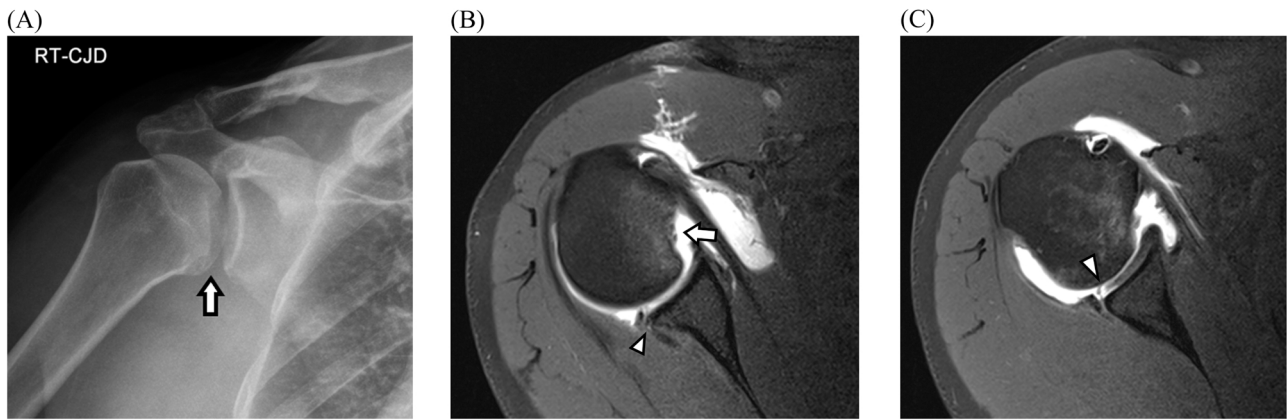


Fig. 9. A 59-year-old man with posterior shoulder dislocation after closed reduction. (A) Frontal shoulder radiograph shows a reverse Hill-Sachs defect (arrow) at the anteromedial aspect of the humeral head. (B and C) Axial T2 weighted fat-suppressed MR images better show the reverse Hill-Sachs defect (arrow) and a chondrolabral tear along the posterior labrum (arrowheads).

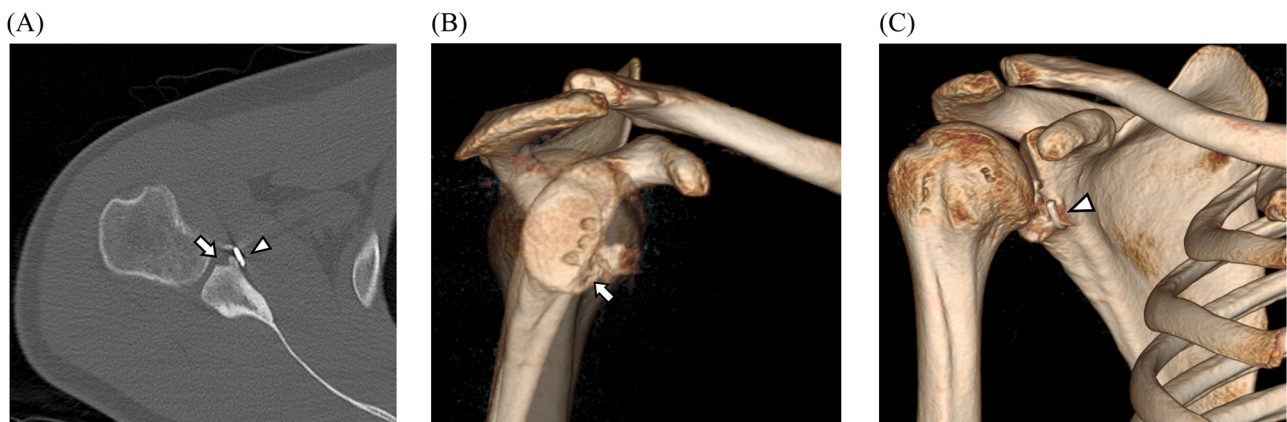


Fig. 10. A 21-year-old man with persistent pain after arthroscopic Bankart repair with retained surgical hardware. Nonenhanced axial CT (A) and 3D reformatted sagittal (B) and coronal (C) images show a bony Bankart injury at the anterior inferior glenoid (arrows) with a retained metallic suture anteromedially (arrowheads).

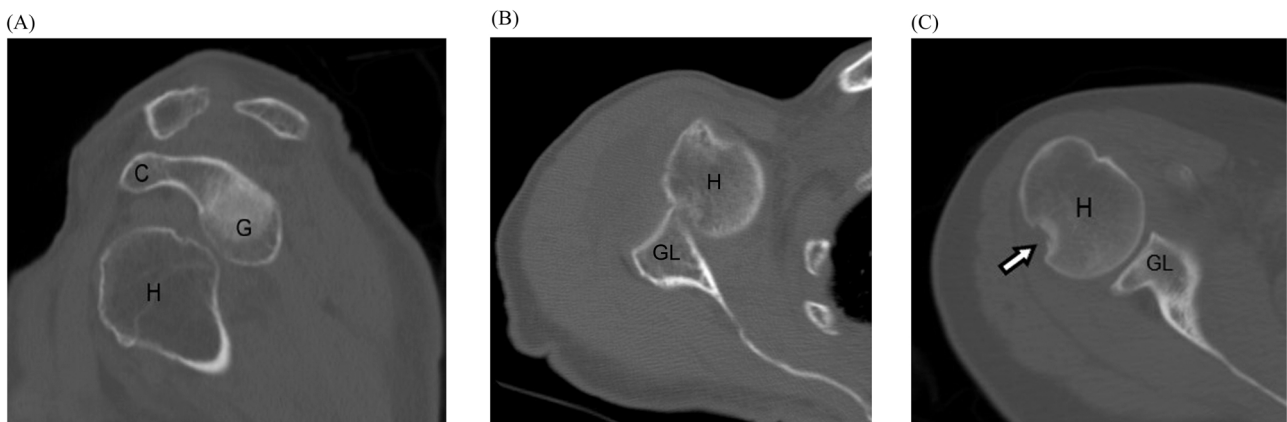


Fig. 11. A 45-year-old man with anterior shoulder dislocation. Nonenhanced sagittal (A) and axial (B) CT images show respective anterior and medial displacement of the humeral head (H) in relation to the coracoid process (C) and glenoid (GL). (C) Post-reduction nonenhanced axial CT image shows the humeral head in normal alignment with the glenoid and a Hill-Sachs deformity (arrow).

suspicious for supraspinatus injury. If the rotator cuff pathology is predominately chronic rather than due to acute trauma, interaction of the humeral head and the acromial undersurface will result in conformational changes, including rounding of the greater tuberosity (femorization of the humeral head) and concavity of the underside of the acromion (acetabularization).

Both US and MRI can provide accurate evaluation of the rotator cuff tendons [50]. US has the advantage of assessing individual tendons and tendon impingement with dynamic maneuvers. It is cost-effective, has 91% sensitivity, and 85% specificity for diagnosis of RCTs [15]. MRI has a higher sensitivity of 98% with 79% specificity [46,51], but more importantly, MRI provides a more comprehensive evaluation of the

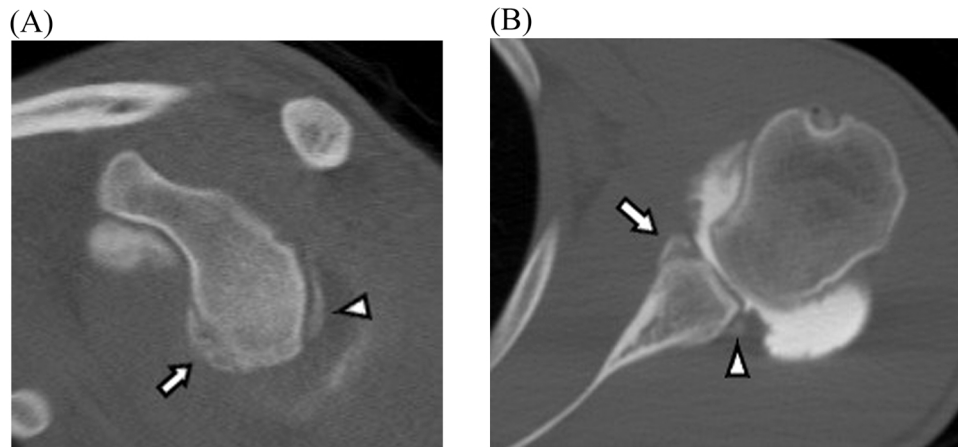


Fig. 12. A 23-year-old man with prior anterior and posterior shoulder dislocation. Sagittal (A) and axial (B) post arthrogram CT images demonstrate anterior (arrows) and posterior (arrowheads) glenoid fractures.



Fig. 13. A 42-year-old man with unsuccessful relocation attempts of anterior shoulder dislocation. Small osseous fracture fragments (arrow) are seen preventing relocation of the humeral head over the glenoid on nonenhanced axial CT image.

shoulder, including a detailed examination of the tendons, ligaments, muscles, and bone marrow, making it the imaging modality of choice.

CT arthrography can be performed using a single- or double-contrast technique for rotator cuff evaluation in patients who are not candidates for MR [39,41]. CT is a superior modality for evaluation of osseous structures that may cause rotator cuff impingement. Like MR arthrography, CT technique can also address the presence or absence of extravasation of contrast into the subacromial/subdeltoid space for diagnosis of full thickness RCT. Thin-sectioning and multi-planar reformatted images on CT arthrography can also allow detection of full or partial thickness tendon tears.

4.3. Surgeon’s perspective

Traumatic full-thickness RCTs often require surgery to restore anatomic function of the rotator cuff and should be performed in a timely fashion. Without surgery, the torn rotator cuff muscle will atrophy, reducing the function of the shoulder and precluding future surgical intervention [49,52]. Rotator cuff tears are best assessed on MRI and it is important to describe the key findings that will guide surgical management (Fig. 18): (1) location (anterior, mid, posterior fibers), (2) full or partial thickness (bursal, articular, intrasubstance), (3) degree of tendon retraction from the anatomic footprint, (4) integrity of the distal tendon attachment (tendon stump or avulsed bone), and (5) appearance

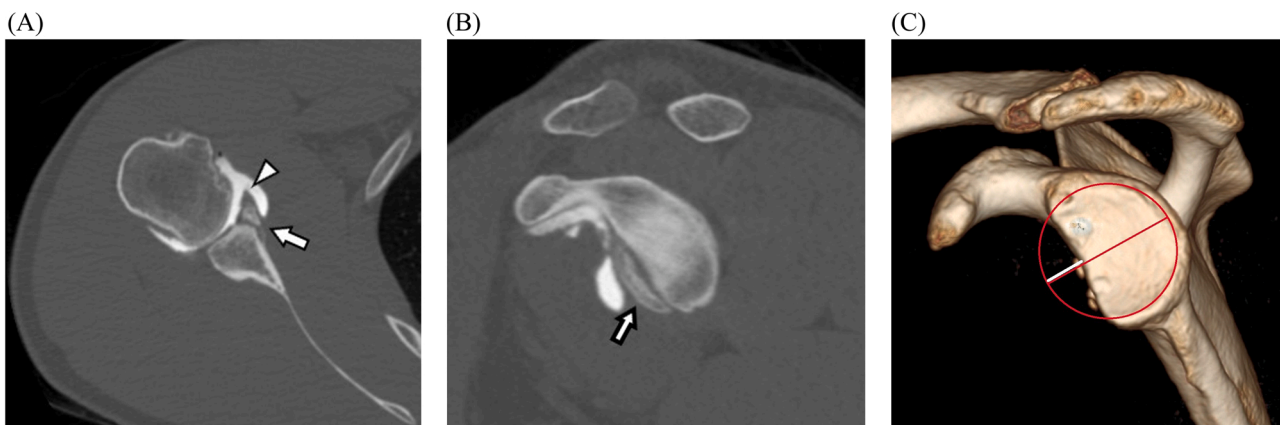


Fig. 14. A 37-year-old woman with anterior glenoid fracture after anterior shoulder dislocation. (A) Axial post arthrogram CT image shows a bony bankart fracture (arrows) with normal attachment of the anterior labrum (arrowhead) to the fracture fragment. The size of the bankart fracture fragment is better shown on sagittal post arthrogram CT image (B) which helps in surgical planning. (C) 3D reformat image can estimate the degree of glenoid bone loss using a best-fit circle (red) that approximates the normal glenoid articular surface. The distance measured between the anterior margin of the circle and the anterior margin of the glenoid (white line) is divided by the circle diameter to calculate the percentage bone loss, which is 28% in this case.

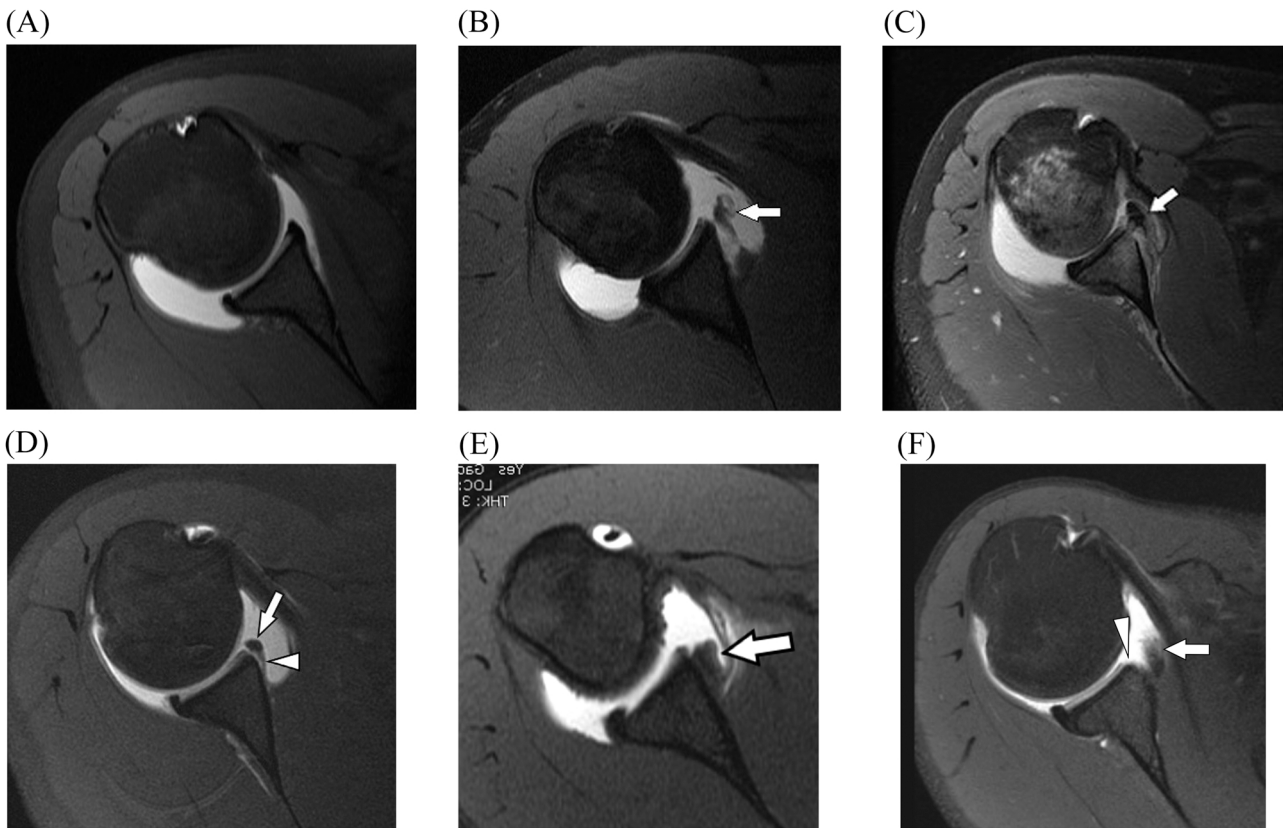


Fig. 15. Arthrographic MRI appearances of Bankart variants at the anterior inferior labrum as indicated by labral defects (arrows) and osseous or periosteal defects (arrowheads). (A) normal, (B) labral Bankart, (C) osseous Bankart, (D) Perthes, (E) ALPSA, (F) GLAD. ALPSA, anterior labral periosteal sleeve; GLAD, glenolabral articular disruption.



Fig. 16. ABER MRI sequence. T1 weighted fat-suppressed MR arthrogram image with the arm in the ABducted and External Rotated position shows displacement of the anteroinferior labral ligamentous complex (arrow). (Case courtesy of Dr. Andrew Haims, New Haven CT).

of the tendon free edge (frayed, delaminated, rounded, wavy).

Special attention should be directed towards evidence of muscle atrophy and/or fatty infiltration. The tangent sign for evaluation of muscle atrophy is positive if the mid-belly of the supraspinatus muscle lies inferiorly to a tangential line drawn between the superior aspect of the coracoid and scapular spine on sagittal oblique MRI images (Fig. 19) [53]. The Goutallier grading system is commonly used for assessment of



Fig. 17. 55-year-old man with traumatic subscapularis tendon tear and biceps tendon dislocation sustained while skiing. Axial T2 weighted fat-suppressed MR images show complete tearing of the subscapularis tendon (arrow) with retraction. The long head of the biceps tendon (arrowhead) is dislocated medially due to subscapularis tendon disruption.

muscle quality, in which fatty infiltration as a proportion of total muscle volume is translated to grades 0 through 4, and patients with > 50% fatty infiltration (grade 3 or 4) are considered poor surgical candidates [54].

In general, MRI provides a more complete assessment of rotator cuff tears than US for preoperative planning. Although both modalities can assess the size and location of the tendon tear, US cannot evaluate additional injuries of the labrum, articular cartilage, and bone marrow.

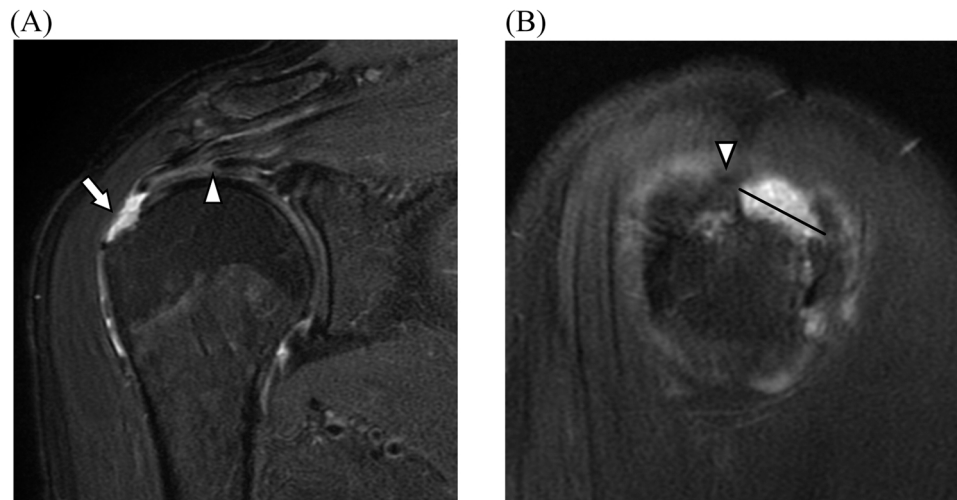


Fig. 18. A 60-year-old female with traumatic supraspinatus rotator cuff tear. Coronal (A) and sagittal (B) T2 weighted fat-suppressed MR images demonstrate a full-thickness (arrow), partial width (black line) tear of the supraspinatus tendon involving the anterior fibers with retraction of the frayed proximal tendon edge. There are intact posterior fibers (arrowheads) of the supraspinatus tendon. No tendon stump or osseous avulsion is seen.

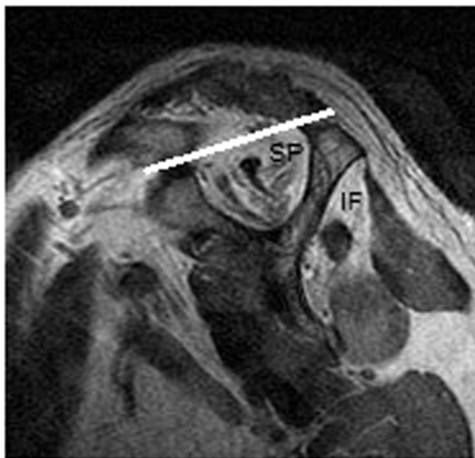


Fig. 19. 73-year-old man with rotator cuff atrophy. Sagittal T1 weighted MR image shows severe fatty atrophy of the supraspinatus (SP) and infraspinatus (IF) muscles. The “tangent sign” shows most of the supraspinatus muscle belly is below a tangential line (white line) between the coracoid and scapular spine.

Moreover, MRI provides better assessment of fatty atrophy of the muscle belly which helps to define whether surgery is warranted.

4.4. Complications

Surgical repair of RCTs generally have good outcomes, with US showing a healed rotator cuff tendon in 64% of patients at one year postoperatively, up to 75% at two years, and 81% at five years, as well as restoring function [55,56]. The rate of complication after arthroscopy is approximately 11% [57], and the most common cause of failure is poor healing of repaired tissue, leading to suture pull out (Fig. 20) [58]. Risk factors for failure to heal include massive RCT involving multiple tendons, large size of tear, age > 65 years, muscle atrophy, retraction of torn tendon medial to the glenoid, and concomitant repair of other shoulder structures [59,60]. A “massive” rotator cuff tear is present if there is rupture of least two of the four rotator cuff tendons and/or retraction away from the attachment site of > 5 cm and should be described in the report (Fig. 21) [46]. Failed RCT repair can be treated with a revision rotator cuff repair or a reverse total shoulder arthroplasty, in older patients. Other complications of surgery include axillary

and suprascapular nerve injury, deltoid detachment or denervation (Fig. 22) after open repair, shoulder stiffness, and infection [57].

Report checklist

1. Is there a decreased acromiohumeral interval (AHI) of < 7 mm on shoulder AP view?
2. Is there an excess widening of the AHI (muscle atony)?
- 3 Which rotator cuff tendon(s) are injured?
4. Is there a partial thickness, full thickness, or complete (full-thickness, full-width) tear?
5. What is the size of the tear in the anterior to posterior (AP) dimension? Does the tear involve the anterior, central or posterior fibers?
6. Does the tear involve the adjacent tendon(s) (i.e., extension of a posterior supraspinatus tear to the anterior fibers of infraspinatus)?
7. What is the extent of the tendon retraction, if present?
8. How is the tendon free edge (frayed, tendinosis, interstitial tearing)? Is there a tendon stump on the humerus?
9. Is there muscle atrophy or fatty infiltration of rotator cuff muscles?
10. Is there an injury of the biceps tendon (tear, tendinosis, subluxation)?
11. Is there a “massive” RCT tear (2 or more tendons ruptured and/or retraction by >5 cm)?

5. Acromioclavicular joint separation

5.1. Anatomy and main considerations

Acromioclavicular joint (AC) separation refers to injuries of the AC ligament, coracoclavicular (CC) ligament, and other structures in the superior shoulder suspensory complex (SSSC). The AC joint is supported by the AC and CC ligaments, with the latter being more important for joint’s stability [61–63]. The superior and inferior AC ligaments partly form the AC joint capsule, which maintain the joint’s horizontal alignment [61]. The CC ligament is the major vertical stabilizer of the AC joint and is comprised of the conoid and trapezoid ligaments, inserting medially and laterally along the clavicle, respectively. Severe trauma with an AC joint injury can also be associated with injury to the trapezius and deltoid attachments at the acromion.

AC joint injuries account for 10% of all shoulder injuries and are most common in young adult men, resulting from a direct blow to the acromion with the shoulder adducted [7,61]. The mechanism of trauma is often low energy impact, such as a sports injury or fall from a height, compared to high-energy trauma which tend to cause fractures of the shoulder girdle. There is a predictable pattern of AC injury that increases with the amount of force. Initially, there is tearing of the AC ligaments, followed by the joint capsule, the CC ligaments, and lastly the

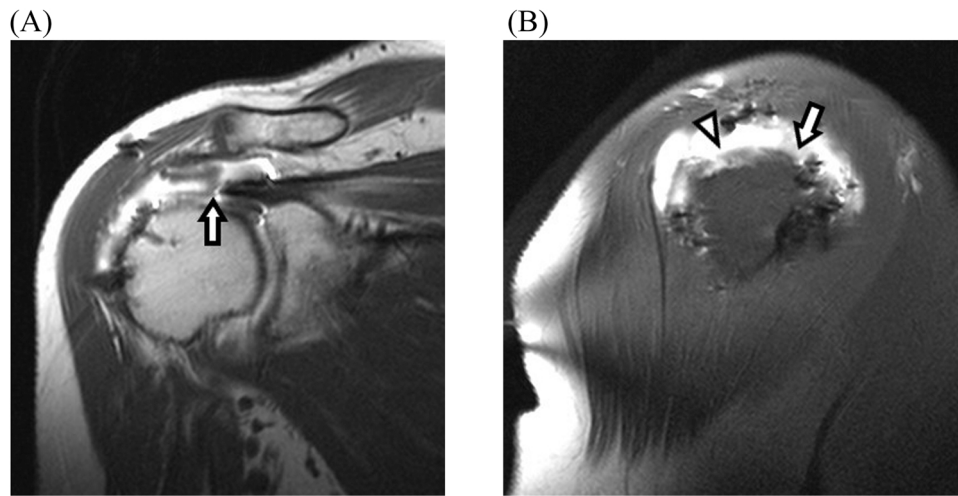


Fig. 20. 69-year-old female with history of prior open supraspinatus tendon repair found to have retear. (A) Coronal T1 weighted MR arthrogram image show complete tearing of the supraspinatus tendon (arrow) with retraction to almost the glenoid rim. (B) Sagittal T1 weighted fat-suppressed MR arthrogram image marks the expected locations of completely torn supraspinatus (arrow) and infraspinatus (arrowhead) tendons.

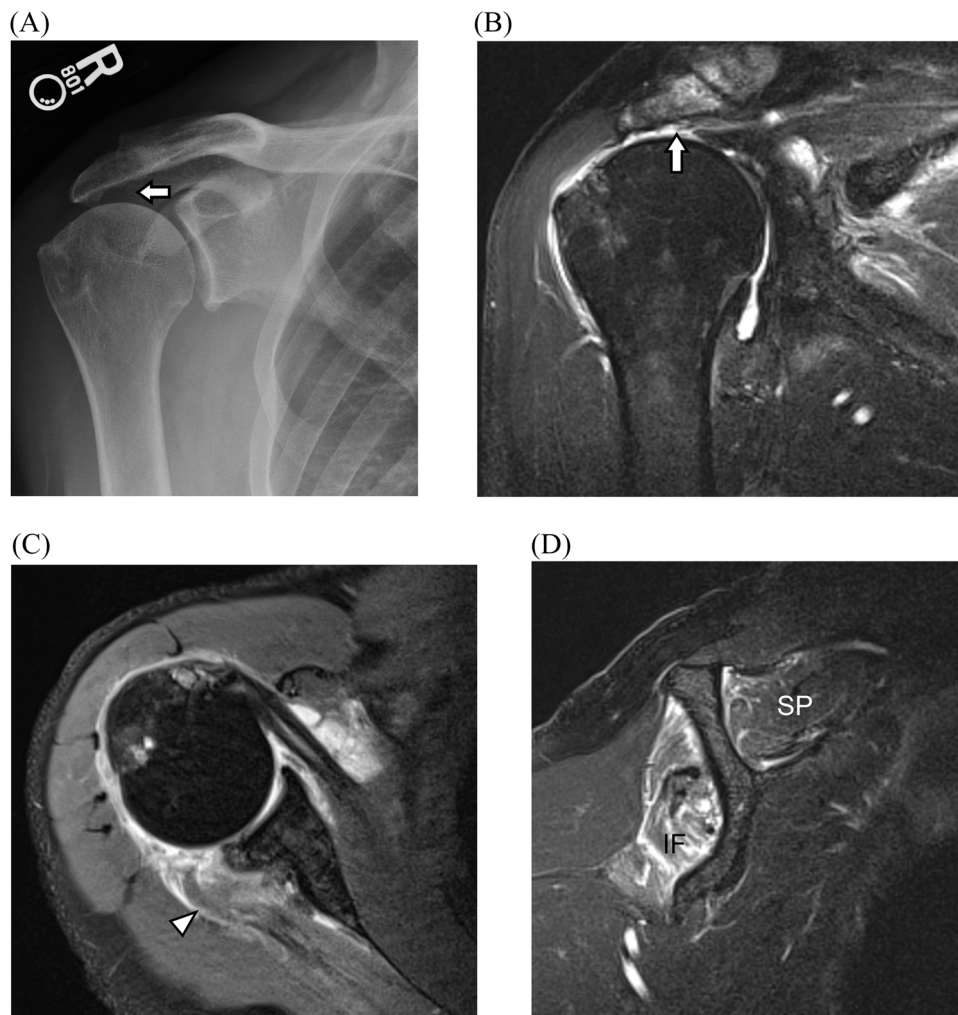


Fig. 21. A 56-year-old man with traumatic massive rotator cuff tear. (A) Frontal right shoulder radiograph shows narrowing of the acromiohumeral interval (arrow) that is suggestive of supraspinatus tendon tear. Coronal (B) and axial (C) T2 weighted fat-suppressed MR images show complete rupture of the supraspinatus (arrow) and infraspinatus (arrowhead) tendons. (D) Intramuscular edema within the supraspinatus (SP) and infraspinatus (IF) muscles can be consistent with acute trauma.

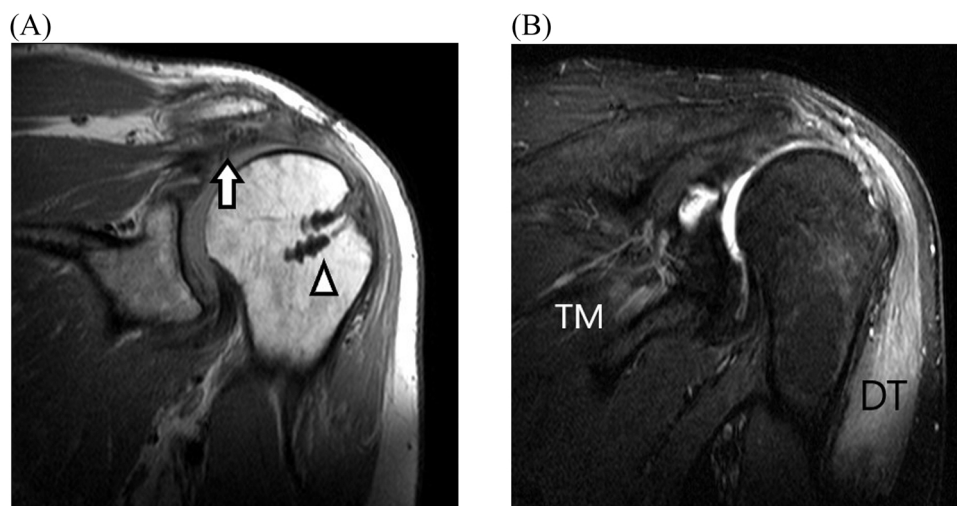


Fig. 22. 44-year-old man with history of prior rotator cuff repair found to have postoperative denervation injury. (A) Coronal T1 weighted MR image shows suture anchors (arrowhead) attaching the repaired distal supraspinatus tendon (arrow) to the greater tuberosity. (B) Coronal T2 weighted fat-suppressed MR image shows diffuse intramuscular edema involving the deltoid (DT) and teres minor (TM), suggestive of denervation injury to the axillary nerve.

aponeurosis of the deltoid and trapezius muscle attachments (deltotrapezial fascia) [61].

The Rockwood classification is the most commonly used system for grouping AC joint injuries (Table 1). A type I injury presents with normal radiographic findings or has mild widening (>5 mm) of the AC interval due to sprain of the AC ligaments. In a type II injury, the AC ligaments and deltotrapezial fascia are both torn with the AC interval ≥ 3 mm compared to the contralateral shoulder; however, the coracoclavicular ligaments remain intact (Fig. 23) [61–63]. The AC ligaments, CC ligaments, and deltotrapezial fascia are torn in a type III injury with the coracoclavicular distance > 14 mm. Types IV–VI have the same pathology as type III injuries; however, the clavicle is displaced posteriorly into the trapezius, superiorly ($>100\%$ of the acromion thickness), and inferiorly below the coracoid, respectively.

5.2. Imaging

In most cases, shoulder radiographs can identify AC joint separations [64]. However, the degree of injury may be underestimated without CT or MR imaging. On a standard AP projection, the inferior border of the clavicle should be aligned with the inferior border of the acromion for a normal AC joint. A difference of ≥ 3 mm in comparison to the contralateral side is considered a widened joint interval (Fig. 24) [32]. The addition of a Zanca view with 10- to 15-degree cephalic tilt and axillary view can improve diagnostic accuracy for AC joint separation [65]. AC and CC distances can be accentuated by weight-bearing radiographs, obtained by tying 15–20 lbs. weights to each wrist during imaging [63,

65]. Type I injuries are frequently missed on radiographs; however, they are treated conservatively. For higher grade AC joint injuries, MRI can evaluate the integrity of the CC ligaments to determine the need for definitive operative management (Fig. 25).

5.3. Surgeon's perspective

Even though low grade (type I and II) AC joint injuries are managed conservatively, there may be a concurrent CC ligamentous sprain without full disruption [66]. It is important to search for radiographic evidence of CC and AC ligament injury, and, if suspected, MRI should be considered. High grade injuries (type IV, V, and VI) are typically treated with surgical internal fixation [61,66]. There remains considerable debate regarding the management of type III injuries, which can be tailored to the patient's needs. Surgery can be considered for competitive athletes to restore overhead shoulder function and for patients with cosmetic concerns [61,66]. Most other patients with type III injuries do not require surgical intervention, with some data showing more favorable outcomes after conservative treatment than the surgical cohort for < 2 cm AC joint displacement [67].

Surgery for AC joint dislocation attempts to address both the AC and CC ligaments. In the acute traumatic setting, surgical repair re-approximates the clavicle to the coracoid, thus reducing the CC distance, and the distal clavicle to the acromion, thus bridging the AC joint. Delayed repair can use autograft or allograft to reconstruct the AC and CC ligaments to achieve reduction. Both techniques require integrity of the distal clavicle and the coracoid process. Therefore, bony injury to these structures may affect surgical planning and should be included in the imaging report.

5.4. Complications

The most common complication of AC joint dislocation is residual pain, which may be partially attributed to development of posttraumatic arthritis. Persistent pain and disability may even affect low grade injuries [68]. Posttraumatic distal clavicular osteolysis is another complication of AC joint injuries, manifesting as pain with arm abduction and flexion, but is frequently self-limited. A Zanca view radiograph or technetium bone scan can facilitate diagnosis of this condition, if needed. Patients with severe joint arthritis and osteolysis who are refractory to conservative treatment may be candidates for distal clavicle resection. Additionally, chronic joint instability may lead to neurovascular compromise with brachial plexopathy [69].

Table 1

Rockwood classification of AC joint separation.

Type	AC ligaments	CC ligaments	CC distance	Clavicle displacement
I	Sprained but intact	Intact	Normal	None
II	Disrupted	Sprained but intact	Increased $< 25\%$	50% superior
III	Disrupted	Disrupted	Increased 25–100%	100% superior
IV	Disrupted	Disrupted	Normal or increased	Posterior
V	Disrupted	Disrupted	Increased 100–300%	$> 100\%$ superior
VI	Disrupted	Disrupted	Decreased	Inferior to coracoid

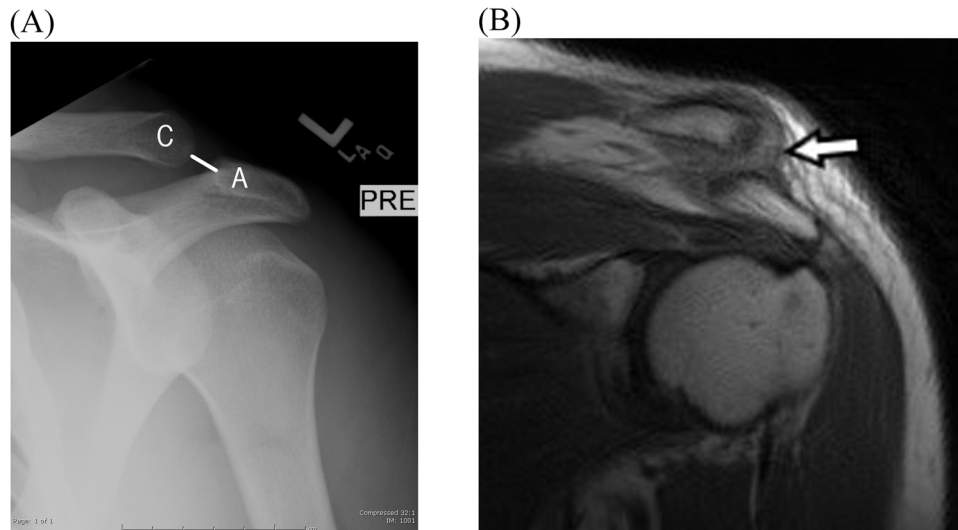


Fig. 23. A 24-year-old man with grade 2 acromioclavicular joint separation. (A) Frontal radiograph shows abnormal widening of the acromioclavicular interval (white line) between the acromion (A) and clavicle (C). (B) Coronal T1 weighted MR image shows disruption of the acromioclavicular joint capsule (arrow).



Fig. 24. 36-year-old man with grade 3 left acromioclavicular joint separation. Anteroposterior radiograph shows abnormal widening of both acromioclavicular (black line) and coracoclavicular (white line) intervals.

Surgical approach for AC joint injuries is most commonly achieved with a hook plate, which needs to be removed. Surgical pins, such as K-wires, can also be used for internal fixation. However, wire migration (Fig. 26) into the pleural space, spinal canal, and adjacent vascular structures is a potential complication that dissuades prevalent use [70]. If pins are used for stabilization, their position should be checked with frequent radiographs, and they should be removed after initial healing [71]. Common complication following AC joint reconstruction is loss of

reduction (Fig. 27), occurring in 15–80% of patients [71].

Report checklist

1. Is there widening of the AC interval (measured from inferior margins of lateral clavicle and acromion)?
2. If AC widening is unclear, get contralateral side (>3 mm) or stress views.
3. Is there widening of the CC interval (>14 mm)?
4. Which Rockwood type of AC joint separation is present?
5. Are there fractures of the clavicle or coracoid which can impact surgical repair?

6. Clavicle fracture

6.1. Anatomy and main considerations

Clavicle fractures are common due to its superficial location [72]. Moreover, as one of the last bones to fuse, clavicle fractures are common in children, accounting for 5% of all pediatric fractures and 85% are due to sports or recreational injuries [32,73,74]. In adults, they are typically seen in the setting of high energy trauma, either from a fall on an outstretched hand or from direct impact onto the clavicle, especially in elderly females with osteoporosis [75].

Clavicular fractures are grouped anatomically by the Allman

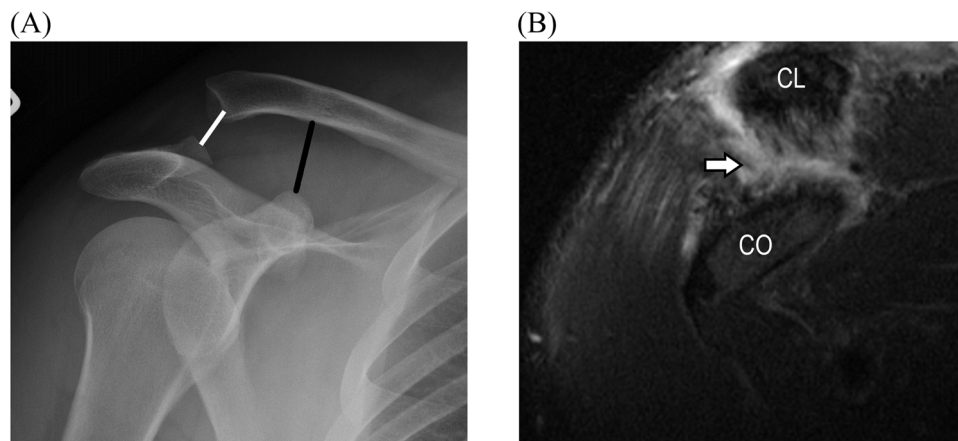


Fig. 25. A 31-year-old man with grade 3 acromioclavicular joint separation. (A) Frontal radiograph shows abnormal widening of both the acromioclavicular (white line) and coracoclavicular (black line) intervals. (B) Coronal T2 weighted fat-suppressed MR image shows rupture of the coracoclavicular ligament (arrow) between the coracoid (CO) and clavicle (CL). (Case courtesy of Dr. Jennifer Nimhurchearthaigh, Limerick Ireland).

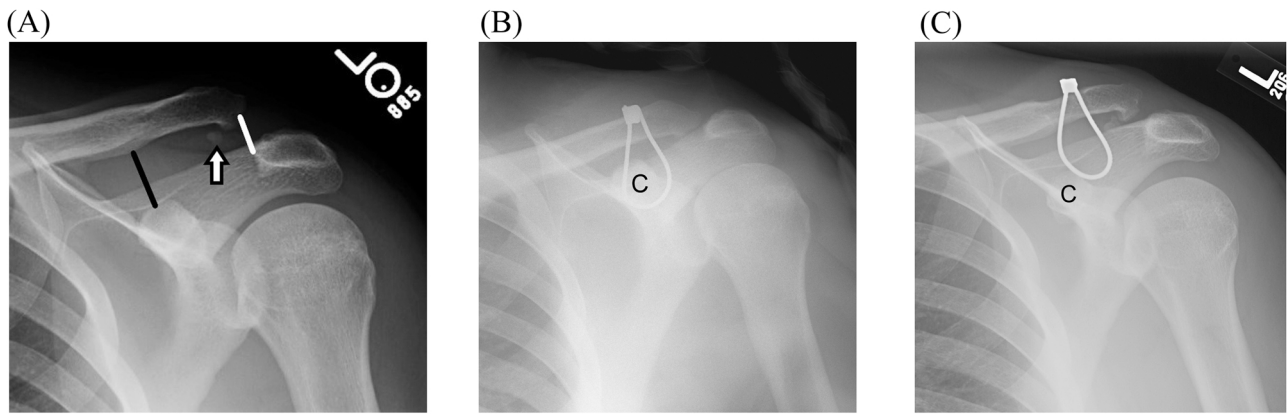


Fig. 26. 28-year-old male with surgical hardware migration after AC joint reconstruction. (A) Frontal left shoulder radiograph shows widening of the AC (white line) and CC (black line) intervals consistent with grade 3 AC joint separation. Small osseous fragment (arrow) represents a fractured bone fragment. (B) Postoperative radiograph after AC joint reconstruction and placement of a surgical wire approximating the clavicle and coracoid (C) shows improved AC joint alignment. (C) The patient returns with persistent shoulder pain 2 month after surgery and repeat radiograph demonstrates superolateral displacement of the surgical wire, which no longer encircles the coracoid (C). The AC and CC intervals are again increased. AC, acromioclavicular; CC, coracoclavicular.

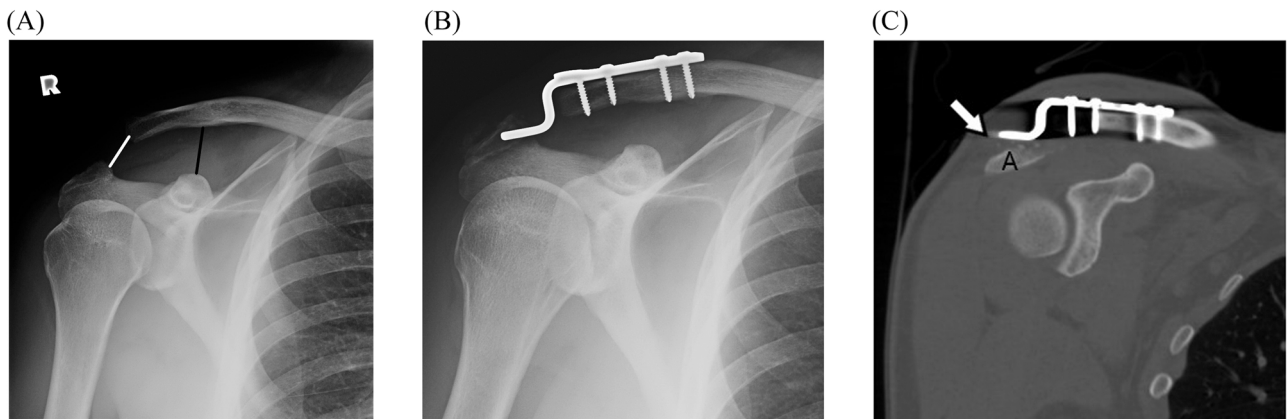


Fig. 27. 50-year-old male with AC hook plate migration after AC joint injury. (A) Frontal right shoulder radiograph shows widening of the AC (white line) and CC (black line) intervals that is consistent with grade 3 AC joint separation. (B) Postoperative radiograph shows improved AC joint alignment after AC hook plate placement. (C) The patient returns with persistent postoperative pain and nonenhanced CT study demonstrates superior migration of the distal hardware in relation to the acromion (A). AC, acromioclavicular; CC, coracoclavicular.

classification and based on the frequency of occurrence (Fig. 28–29) [66]. Group 1 fractures are the most common, at 80%, and located in the mid shaft, the thinnest part of the clavicle [7,32,72]. Group 2 fractures are the next most common at 10–15% and involve the lateral clavicle [63,75]. These fractures can be further subdivided by the Neer modification of the Allman classification based on the integrity of the CC ligaments and AC joint [76,77]. These classification systems focus on

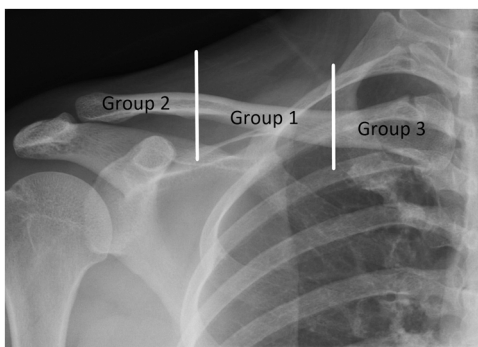


Fig. 28. Allman Classification of clavicular fractures based on their location: group 1, middle third; group 2, lateral third; group 3, medial third.

injury of the CC ligaments in determining need for surgery; however, they do not take into account fracture comminution and degree of displacement, which also affects surgical planning. Group 3 fractures are rare at 5% of fractures, involve the medial clavicle, and are due to direct trauma near the sternoclavicular joint [75].

Group 1, midshaft, clavicular fractures are typically treated conservatively with immobilization using a sling or figure-of-eight brace. However, two-thirds of patients with persistent pain or patients with fracture instability will eventually undergo ORIF [78]. Surgical intervention is recommended for patients at risk for non-union, such as significant displacement or angulation, the elderly, distal fractures, or for cosmetic deformity [79]. Shortening > 2 cm or > 10% leads to abnormal scapular position, biomechanics, and cosmetic alterations and may be another indication for surgery [78]. Operative strategies include plate and screw fixation or intramedullary pinning. In comparison, CC screw fixation can be performed for group 2 lateral clavicle fractures.

6.2. Imaging

Clavicular fractures can be well assessed on radiographs; however, a true orthogonal view of the clavicle is hard to be obtained due to its anatomic shape and position. The AP projection is best for assessment of the medial and middle clavicle, whereas the AP cephalic view directed

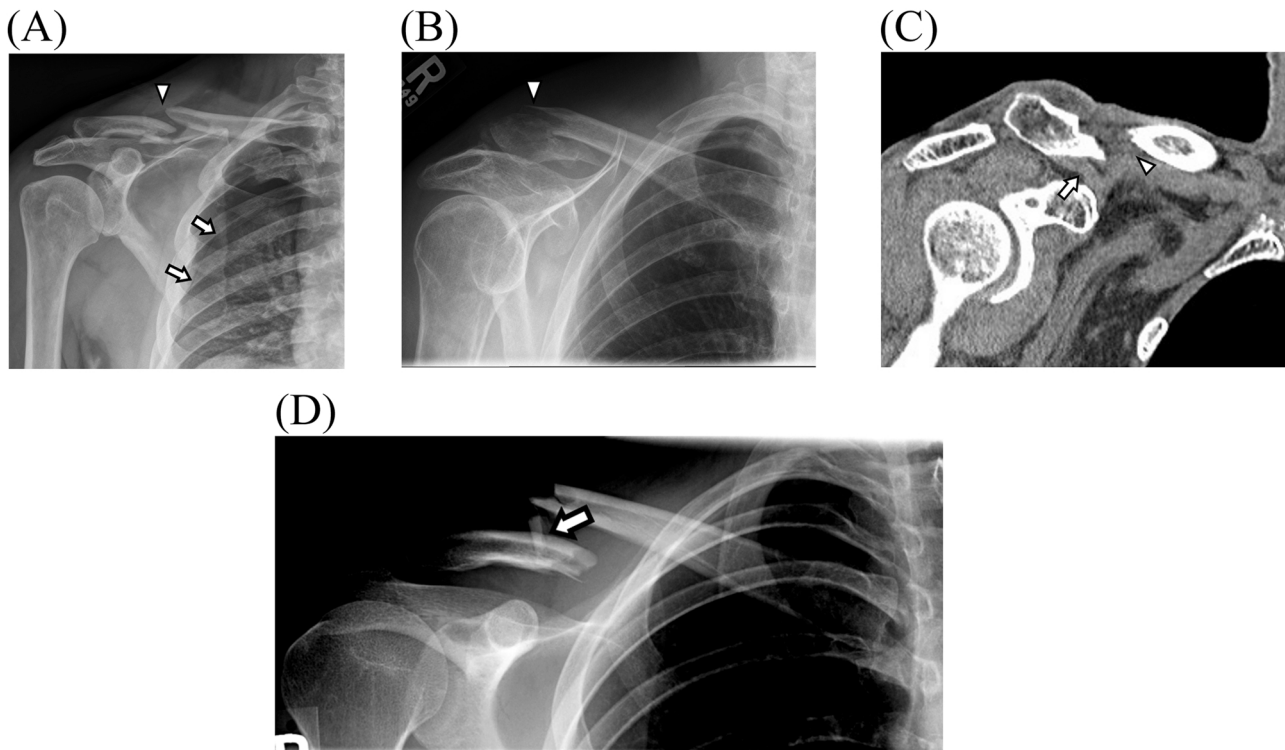


Fig. 29. Various types of clavicular fractures. (A) Comminuted group 1 midshaft fracture (arrowhead) with associated moderate sized pneumothorax (arrows). Comminuted group 2 lateral clavicular fracture (arrowhead) in the region of the coracoclavicular ligaments seen on frontal radiograph (B), with coronal non-enhanced CT image (C) showing an intact lateral trapezoid ligament (arrow); however, the medial conoid ligament is disrupted (arrowhead). (D) Comminuted lateral clavicular fracture with a displaced vertical “zed” fragment (arrow), which carries a higher rate of non-union, and acromioclavicular joint separation.

15–30 degrees towards the head is helpful in evaluating the lateral aspect [79]. Radiographs should be taken upright to allow gravity to stress the injured shoulder structures. In cases of suspected glenohumeral joint involvement or ligamentous injury, 3D reconstructed CT can be performed to better evaluate the degree of injury. CT imaging should also be considered if there is concern for underlying neurovascular injury in patients with medial clavicular fractures or sternoclavicular joint injury [72]. Additionally, MR imaging can better evaluate ligamentous injury, such as the integrity of the CC ligaments, which can alter patient management.

6.3. Surgeon's perspective

For clavicular fractures, it is important for radiologists to describe the number, size, and location of intercalary fragments to help with pre-operative planning. Higher degrees of comminution are associated with higher energy injuries and have a greater likelihood of additional injuries. Thus, intercalary, or “butterfly,” fragments correlate with severity of the injury, resulting deformity, and complexity of surgical reconstruction. Fractures that are completely displaced (no cortical contact), comminuted, or have a transverse Z-shaped (“zed”) fragment have higher rates of non-union [74]. Another important consideration is fracture shortening due to traction forces from the sternocleidomastoid, pectoralis, trapezius, and deltoid muscles [74]. A foreshortened clavicle results in an abnormal scapular position, altered scapulothoracic motion, and changed appearance of the affected forequarter. These changes are most pronounced if quantified using upright images, as opposed to supine or semi-recumbent radiographs.

Group 2 clavicular fractures that involve the CC ligaments carry a worse prognosis [20,71,75]. Any radiographic evidence of AC joint or ligamentous injury should also be emphasized and accompanied by a recommendation for additional evaluation with MRI or CT since delays in diagnosis may translate into an under appreciation of the injury's

complexity or severity. Upright x-rays can provide a valuable perspective because they magnify any osseous or ligamentous injury by applying gravity and the weight of the injured extremity. Visualizing a change in the position fracture fragments between upright and supine radiographs can suggest fracture instability and may be an indication for surgery. Clavicular fractures can be associated with other injuries including rib, scapular, and vertebral fractures and pneumothoraces; which should be assessed for and described in the radiology report [1, 65].

6.4. Complications

Non-union is a major complication with clavicular fractures. Most group 1 fractures are treated conservatively; however, 15% of cases treated conservatively will have non-union as opposed to 2% of those treated surgically [80]. Group 2 fractures at the lateral clavicle have a higher rate of non-union, 10–44%, than group 1 fractures [81]. Additional postoperative complications include wire and screw migration (Fig. 30), pain, and hardware irritation (8% of patients) requiring removal, infection (5%), and transient brachial plexus neuropathy (13%) [82]. Other complications regardless of operative or non-operative treatment include complex regional pain syndrome and thoracic outlet syndrome [20,72].

Report checklist

1. Where is the clavicular fracture (midshaft, lateral, medial)?
2. Is there displacement of the fracture fragments?
3. Are there intercalary (butterfly) fragments? Describe number, size, location of fragments.
4. Is there foreshortening of the clavicle?
5. Does fracture displacement change with supine and upright films?
6. Is there fracture extension into the AC joint?
7. Is there involvement of the CC ligaments?
8. Are there other injuries (rib, scapular, and vertebral fractures; or pneumothoraces)?



Fig. 30. A 32-year-old man with clavicular fracture plate failure. (A) Frontal right shoulder radiograph shows a midshaft clavicular fracture (arrow) with apex superior angulation that is corrected by a surgical fixation plate (B). (C) The patient returns with postoperative shoulder pain and deformity, and repeat radiograph demonstrates displacement of the fixation plate allowing recurrent angulated deformity of fracture fragments.

7. Scapula fracture

7.1. Anatomy and main considerations

Scapular fractures are rare, accounting for only 3–5% of all shoulder girdle fractures [83]. However, because the scapula is the primary anchor for the upper extremity, scapular fractures can lead to chronic pain and disability if not diagnosed and treated [32]. Moreover, since the scapula is protected by several large surrounding muscles, high energy trauma is needed to produce a scapular fracture and this is typically due to motor vehicle accidents [84]. Most scapular fractures occur at the neck or body; however, it is also important to assess if the fracture involves the glenoid, coracoid, spine, or acromion as these fractures often require surgery since they are at muscle attachments.

Glenoid fractures (Fig. 31) deserve special mention as these intra-articular fractures can greatly affect shoulder function. The Ideberg classification of glenoid fractures takes into account the orientation of the fracture(s) along the glenoid and involvement of the medial, lateral, and superior scapular borders [85]. However, this method is primarily used in research and does not correlate well with clinical prognosis and lacks strong interobserver reliability [85,86]. Moreover, due to the high forces needed to fracture the scapula, other chest wall injury can occur. Rib and clavicle fractures or pneumothoraces are seen in 95% of scapula fracture [3]. Hence, it is critical to conduct a thorough search for additional injuries when scapular fractures are seen or suspected.

7.2. Imaging

Scapular body and neck fractures are best assessed on the transscapular Y-view [7,66]. If there is high suspicion for a scapular

fracture, a tangential, axillary view with the arm in 90-degree abduction may provide additional evaluation [32]. If a scapula fracture is seen, CT can be helpful in identifying additional chest wall injuries and for pre-operative planning. If initial radiographs are non-diagnostic, or if there is a question regarding the extent of injury, CT imaging with 3D reconstructions should be obtained and can provide additional characterization of fractures for operative planning (Fig. 32) [31,87].

7.3. Surgeon's perspective

It is essential to determine how the scapular fracture will affect future shoulder function since the scapula is the primary anchor for the upper extremity to the chest and has 18 muscular attachments [32]. Most scapular fractures can be treated conservatively. For instance, fractures of the scapular body rarely require surgical intervention except in cases of severe displacement [88]. Fractures involving the glenohumeral joint should be described in detail, including the comminution, degree of displacement, and angulation. Minimally displaced (less than 2 mm) intra-articular fractures without comminution can typically be managed conservatively, with greater degrees of fracture complexity requiring surgical fixation [87,89,90]. Articular displacement > 5 mm, which is the maximum thickness of the glenoid cartilage, can lead to development of posttraumatic degenerative joint disease, and is another criterion for surgery [88,91]. In addition to restoring the glenoid articular surface, alignment of the glenoid relative to the scapular body will influence the shoulder's function upon recovery. Therefore, extra-articular fractures of the glenoid neck should be described in reference to the normal scapular version with emphasis on any resulting angulation, rotation, or translation of the joint's surface. Surgical treatment is also indicated if there is recurrent instability of the humeral

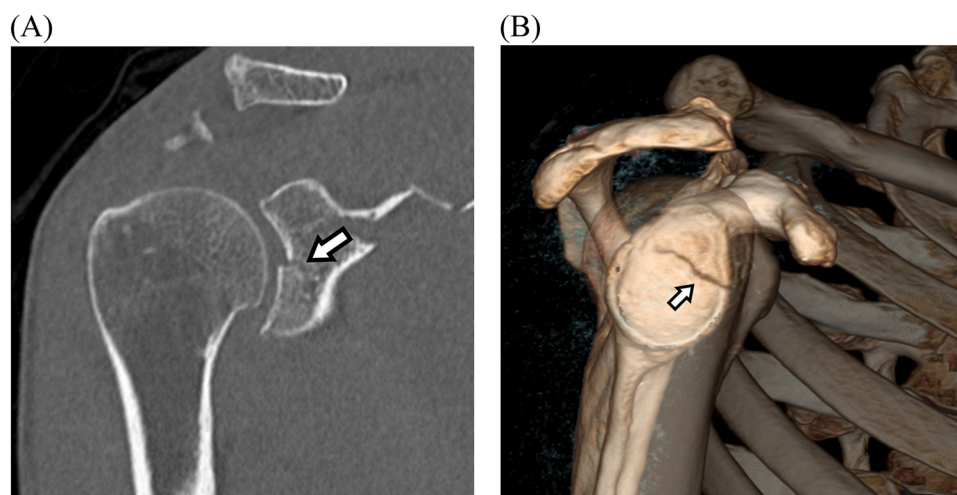


Fig. 31. A 37-year-old man with glenoid fracture. Nonenhanced coronal CT (A) and 3D reformatted sagittal (B) images show a fracture of the middle portion of the glenoid with articular stepoff (arrows).

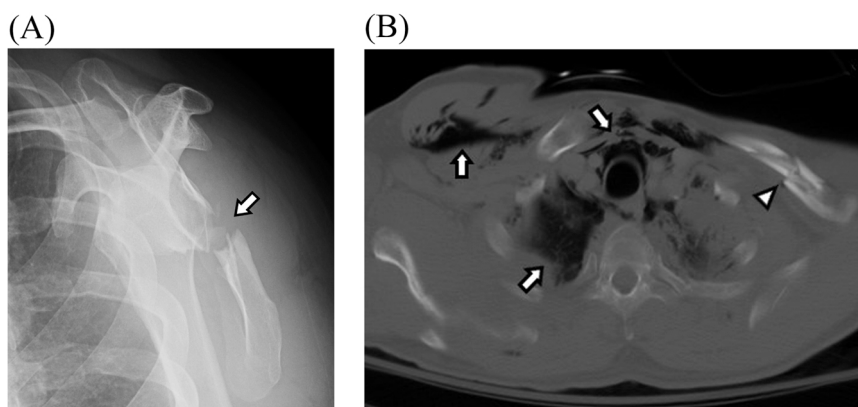


Fig. 32. A 45-year-old man with scapular fracture. (A) Trans-scapular Y view shows a displaced scapular body fracture (arrow). (B) Nonenhanced axial CT image shows associated extensive pneumomediastinum (arrows) and left clavicular fractures (arrowhead).

head resulting from the glenoid fracture.

Scapular fractures involving the coracoid, acromion, or scapular spine can lead to functional shoulder imbalance if not treated. The scapular processes are subjected to tensile forces by their muscle attachments and the weight of the upper extremity; therefore, they have a high risk for non-union. Restoration of their normal alignment with rigid compression can restore shoulder function and promote fracture healing. Even with the best available surgical techniques, treatment of complex scapular fractures is challenging.

7.4. Complications

Tensile forces on the scapular fracture fragments from muscular attachments can lead to malunion or non-union [87,89]. Management of complex scapular fracture is therefore challenging and can be prone to failure. Other complications from scapular fractures include neurovascular injury and recurrent shoulder dislocations and instability. Long-term complications in patients with displaced fractures but managed non-operatively include poor function, pain, weakness with abduction, and decreased range of motion [92].

Report checklist

1. Where is the scapular fracture (neck, body, glenoid, spine, acromion, coracoid)?
2. Is there fracture displacement and is it at a muscle attachment?
3. For glenoid fractures, is it intra- or extra-articular? Is there displacement of articular surface (>5 mm)?
4. For scapular body fractures, does the fracture involve the medial, lateral, and/or superior scapular border? Is there malalignment of the glenoid with respect to the scapular body?
5. Is there normal alignment of the glenohumeral joint?
6. Are there additional chest wall injuries (rib fracture, clavicle fracture, pneumothorax)?

8. Conclusion

Acute shoulder trauma is common, and the type of injury varies with the age of the patient and the severity of the trauma. Determining the need for surgery can be difficult and is best performed with imaging. Thus, it is crucial for the radiologist to understand and report the imaging findings that help the orthopedic surgeon determine conservative versus surgical treatment. Additionally, the surgeon relies on radiology to assist with preoperative planning and the imaging assessment of complications. Working together, the radiologist and surgeon can optimize care in patients with traumatic shoulder injuries.

Declaration of Competing Interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

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