Shoulder: Instability

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Learning Objectives

- To know the types of glenohumeral instability and anatomic factors for the development of glenohumeral instability.
- To understand the concept of the glenoid track and the engaging Hill-Sachs lesion.
- To understand the MR appearance of SLAP tears, overhead thrower labral tears, and the labral tears associated with spinoglenoid notch cysts.
- To understand how to distinguish labral tears from normal labral variants.

1.1 Glenohumeral Instability

Glenohumeral instability is the inability to keep the humeral head centered in the glenoid fossa. Glenohumeral instability can be classified according to etiology and direction of instability.

Glenohumeral instability can be classified into static instabilities, dynamic instabilities, and voluntary dislocation [1].

Static instability is associated with significant structural alteration of the shoulder, for example, large rotator cuff tears or a glenoid dysplasia with consecutive static decentering of the humeral head.

Dynamic instability is the classic form of instability, commonly caused by trauma, and is usually associated with injuries to the labrum, to the glenohumeral ligaments, and often with fractures of the glenoid rim. Dynamic instability may also be associated with general hyperlaxity.

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Glenohumeral instability may be *unidirectional* (anterior instability or posterior instability) or *multidirectional*. Multidirectional instability is affecting a minority of patients.

The classification in *traumatic instability* and *atraumatic instability* is important from an imaging perspective. Both instabilities are characterized by recurrent dislocations of the glenohumeral joint. However, in traumatic instabilities, structural changes such as labral, ligamentous, and bony lesions are highly prevalent. In atraumatic instabilities the glenohumeral joint may not exhibit any injuries [2].

Key Point

- In atraumatic instabilities the glenohumeral joint may be normal at imaging.

The labrum, the ligaments, and the bony structures contribute to the stability of the glenohumeral joint. Usually, the labrum receives the highest attention at imaging. However, the glenoid labrum only contributes about 10% to the stability glenohumeral joint. Therefore, it is important to also include the glenohumeral ligaments and the bony structures into a comprehensive imaging assessment.

1.2 Anterior Instability

1.2.1 Labral Lesions in Anterior Instability

Bankart lesion: The “Bankart lesion” was described by A. S. Blundell Bankart in the *British Medical Journal* in 1923 [3]. The Bankart lesion consists of a tear of the anteroinferior labrum. The labrum and the periosteum are completely detached. Therefore, the labrum seems to float distant to the glenoid rim when viewed at arthroscopy or on transverse MRI sections (Fig. 1.1).

Fig. 1.1 Bankart lesion

Axial fluid sensitive fat-saturated MR arthrography image shows a Bankart lesion (red arrow) consisting of a tear of the antero-inferior labrum. The labrum and the periosteum are completely detached. Therefore, the labrum seems to float distant to the glenoid rim

Fig. 1.3 ALPSA lesion

Axial fluid sensitive fat-saturated MR arthrography image shows an ALPSA lesion (red arrow). The detached labrum is medially displaced and scarred to the glenoid neck

Fig. 1.2 Perthes lesion

Axial fluid sensitive fat-saturated MR arthrography image shows the antero-inferior labrum (red arrow) detached from the edge of the glenoid but still attached to the intact periosteum

Perthes lesion: The Perthes lesion was described some years earlier than the Bankart lesion in 1906 [4]. The antero-inferior labrum is detached from the edge of the glenoid but still attached to the intact periosteum. Often the labrum may be almost normally positioned at imaging. However, functionally the labrum no longer adds to the stability glenohumeral joint (Fig. 1.2).

ALPSA lesion: In 1993 Neviaser [5] described the anterior labro-ligamentous periosteal sleeve avulsion (ALPSA) lesion as a cause for anterior instability of the shoulder. In the ALPSA lesion, the periosteum between the labrum and glenoid remains intact. The detached labrum displaces medially and inferiorly. The labrum and the periosteum heal on the scapular neck (Fig. 1.3).

Fig. 1.4 GLAD lesion

Axial fluid sensitive fat-saturated MR arthrography image shows a GLAD lesion. A portion of the anterior inferior glenoid articular cartilage is avulsed associated with a partial labral tear. The labrum is not detached or dislocated

GLAD lesion: GLAD stands for “glenolabral articular disruption” and was also described by Neviaser in 1993 [6]. The GLAD lesion consists of an antero-inferior glenoid articular cartilage injury associated with a partial labral tear. The labrum is not detached or dislocated. Patients with GLAD lesions usually have a stable glenohumeral joint and present with anterior shoulder pain (Fig. 1.4).

1.2.2 Ligament Lesions in Anterior Instability

One of the most important stabilizers for the glenohumeral joint is the inferior glenohumeral ligament (IGHL). The IGHL connects the glenoid to the humerus and has the shape

of a hammock with a strong anterior and posterior bundle. Two distinct patterns of the attachment of the IGHL to the glenoid are described [7]. In most joints (80%) the IGHL attaches directly to the labrum with some fibers extending onto the glenoid neck. Less commonly (20%) the IGHL attaches only to the glenoid neck. Therefore, a detachment of the glenoid labrum is a detachment of the IGHL in most cases. Most frequently the failure of the IGHL is on the glenoid side. Failure on the humeral side is termed “humeral avulsion of glenohumeral ligament” or HAGL lesion. HAGL lesions may be difficult to be diagnosed at arthroscopy. The J sign (the axillary recess is normally U-shaped—conversion to a J shape is called the J sign) and axillary fluid extravasation at MR arthrography are suggestive of a HAGL lesion. However, a false-positive diagnosis of HAGL lesions is not uncommon at MRI [8]. Fluid extravasation at MR arthrography may occur with an intact IGHL or also in a mid-substance tear of the IGHL.

Key Point

- The inferior glenohumeral ligament attaches directly to the labrum in most joints. Therefore, a detachment of the glenoid labrum is a detachment of the IGHL in most cases.

1.2.3 Bony Lesions in Anterior Instability

1.2.3.1 Glenoid

A bony defect of the glenoid rim is probably the most important factor for the development of an unstable glenohumeral joint. Bony defects of the glenoid that are more than half of the maximal AP diameter of the glenoid in length lead to a significant loss of dislocation resistance. This may not be compensated for by a Bankart repair or labral reconstruction alone. A bony procedure such as a Latarjet procedure or bone grafting procedure to augment the anterior glenoid rim is often necessary.

A bony defect can be congenital, can be a result of a glenoid rim fracture, or can be the result of the chronic instability. Repetitive anterior subluxations of the humeral head lead to glenoid bone loss without the presence of a fragment at the glenoid rim.

1.2.3.2 Humerus

In 1940 Harold A. Hill and Maurice D. Sachs described the grooved defect of the humeral head in the journal *Radiology*. The presence of a Hill-Sachs lesion confirms the diagnosis of anterior instability of the glenohumeral joint. The prevalence of Hill-Sachs lesion that needs to be treated is about 7% [9].

Therefore, the size, location, and relation to the glenoid need to be addressed.

Some types of Hill-Sachs are at risk for an engaging lesion and need to be treated: risk factors are a large and wide Hill-Sachs lesion, a medially located Hill-Sachs lesion, or a Hill-Sachs lesion with an oblique orientation on neutral position of the humerus. Cases with an engaging Hill-Sachs lesion present with a large bony defect of the glenoid at the same time (bipolar lesion).

1.2.3.3 Glenoid Track Theory, On-Track and Off-Track Lesions

In the abduction and external rotation (ABER) position of the shoulder, patients with glenohumeral instability experience subluxation and apprehension. Apprehension is the fear of imminent dislocation of a patient anterior instability with when placing the arm in an ABER position.

The “glenoid track” is the contact area of the glenoid surface onto the posterosuperior humeral head in the ABER position (Fig. 1.5).

The contact area between the glenoid and the humeral head, e.g., the “glenoid track,” measures approximately 84% of the glenoid transverse diameter, whereas remainder of glenoid (16%) contacts with the medial margin of the rotator cuff footprint [10].

- On-track: Hill-Sachs lesion remains within the glenoid track.
- Off-track: Hill-Sachs lesion extends past the glenoid track medially and is therefore at risk for engaging.

Key Point

- Reasons for the “off-track” lesion are a large Hill-Sachs lesion, a medially located Hill-Sachs lesion, and/or a bony defect of the glenoid rim.

1.3 Posterior Instability

1.3.1 Labral Lesions in Posterior Instability

Posterior instability of the glenohumeral joint is common in young active patients. Posterior instability of the glenohumeral joint is most prevalent in young men, for example, the military population. Posterior instability of the glenohumeral joint is often caused by repetitive microtrauma. Repetitive pushups, pullups, or heavy weightlifting (bench press) may promote posterior instability of the glenohumeral joint. Also, in swimming and golf which puts stress on the posterior capsule, posterior instability of the glenohumeral joint may be seen.

Fig. 1.5 Glenoid track theory, on-track situation, and off-track situation. The “glenoid track” is the contact area of the glenoid surface onto the humeral head in the ABER position (a). On-track situation: the Hill-Sachs lesion remains within the glenoid track, and the Hill-Sachs lesion is not engaging (b). Off-track situation: the Hill-Sachs

lesion extends past glenoid track medially, and the Hill-Sachs lesion is engaging (c). Off-track situation: the bony defect of the glenoid rim narrows the glenoid track humeral head. Hill-Sachs lesion extends past glenoid track medially, and the Hill-Sachs lesion is engaging (d).

Key Points

Anatomic risk factors for posterior instability of the glenohumeral joint include:

- Increased glenoid retroversion.
- Increased humeral head retroversion.
- Posterior glenoid dysplasia (brachial plexus birth palsy).

The Kim lesion, named after the author who first described this lesion, represents a posteroinferior labrum avulsion [11]. Often the labral lesion is concealed. Adjacent a marginal chondrolabral junction, lesion caused by repetitive posterior subluxations of the humeral head is observed (Fig. 1.6).

Kim’s triad includes:

- Concealed posteroinferior labral tear.
- Marginal chondral lesion.
- Retroversion of the glenoid.

1.4 Labral Tears Without Overt Instability

1.4.1 Superior Labrum Anterior-Posterior (SLAP) Tears

SLAP tears are superior labral tears that occur in the region of the biceps anchor. SLAP tears are one of the more common tears of the glenoid labrum, with a prevalence at arthros-

Fig. 1.6 Kim’s lesion

Axial fluid sensitive fat-saturated MR arthrography image shows a posteroinferior labrum avulsion lesion (red arrow)

copy of 5–38% [12]. Although SLAP tears are often painful, smaller tears can be asymptomatic and identified incidentally at surgery or on a shoulder MR scan done for other reasons. SLAP tears can occur acutely after a fall on an outstretched hand or from either acute or repetitive biceps traction on the superior labrum. The SLAP tears in overhead throwing athletes will be discussed further in the next section on Overhead Thrower Injuries.

SLAP tears can have a variety of tear orientations, so are often subdivided into several types. A type 1 SLAP tear refers to a frayed free edge of the superior labrum and is a common finding in older individuals. Type 1 SLAP tears are usually degenerative or from overuse and may be minimal or asymptomatic.

The higher-type SLAP tears are longitudinal tears of the superior labrum, and these tears may require surgery to alleviate symptoms. The most common higher-type SLAP tear is a type 2 SLAP tear, which is a partial-thickness longitudinal tear of the superior labrum. These tears can have either a stable or unstable biceps anchor depending on their size and specific site of involvement. Distinguishing a stable from an unstable type 2 SLAP tear can be difficult on MR images, but in general larger tears at the base of the labrum that weaken the biceps anchor are more unstable.

The anterior to posterior length of type 2 SLAP tears varies in different individuals. Some have subcategorized type 2 SLAP tears as 2A (anterosuperior), 2B (posterosuperior), or 2C (involving the entire superior labrum from anterior to posterior). The posterosuperior type 2B SLAP tears are sometimes seen in overhead throwing athletes and in patients with a spinoglenoid notch paralabral cyst, both discussed in a later section.

A type 3 SLAP tear is a full-thickness tear resulting in a bucket handle torn labral segment. Type 3 SLAP tears tend to have a stable biceps anchor. A type 4 SLAP tear extends into the biceps tendon. There are currently some 12 types of SLAP tears described, and the type 5 and above tears mainly involve extension to other parts of the labrum or adjacent structures.

SLAP tears appear on MR images as linear increased signal extending to an articular surface of the labrum between the 11:00 and 1:00 position of the glenoid rim [13] (Fig. 1.7). Because some patients have a superior recess normal variant in this region of the labrum, there are several MR signs that have been proposed to help distinguish a SLAP tear from a normal recess. The findings of a SLAP tear include the lin-

ear increased signal being irregular, extending across the entire labrum on an oblique coronal image, curving laterally, there being two increased signal lines (a recess that is more medial, and the tear which is located more laterally, also called the “double oreo” sign), or signal width > 2 mm on MR or 3 mm at MR arthrography. High signal at the labral-chondral junction posterior to the biceps anchor has been proposed as a possible MR sign of a SLAP tear; however several studies have found that at MR arthrography a normal superior recess can extend posterior to the biceps in up to 90% of individuals.

Key Point

- For SLAP tears the linear increased signal usually curves laterally, in distinction from a normal labral variant superior sublabral recess which curves medially.

1.4.2 Overhead Thrower Labrocapsular Injuries

Overhead throwing athletes can develop an overuse injury of the shoulder that includes a superior labral tear. There are two related etiologies that have been described for why labral tears occur in these athletes, glenohumeral internal rotation deficit (GIRD) and internal impingement. GIRD results from thickening and fibrosis of the posterior band inferior glenohumeral ligament and capsule and results from repetitive traction during the deceleration phase of

Fig. 1.7 Superior labrum anterior–posterior (SLAP) tear
Two consecutive oblique coronal fat-suppressed T2-weighted images show irregular, laterally curving high signal (arrow) in the superior labrum

throwing. Internal impingement presents as pain in the late cocking phase of throwing with decreased throwing velocity. Internal impingement is felt to be a shoulder microinstability condition due to a posterosuperior shift of the humeral head contact point with the glenoid due to GIRD, a stretched anterior capsule, and muscle fatigue that allows increased contact of the under surface of the rotator cuff with the posterosuperior labrum [14].

There are two main mechanisms that are believed to lead to labral injury in patients with GIRD and internal impingement. The first is repetitive forceful contact between the greater tuberosity and the posterosuperior glenoid rim during abduction and external rotation, which causes fraying or tears of the posterosuperior labrum. The other is longitudinal twisting of the long head biceps tendon at full external rotation of the humerus, which twists the biceps anchor resulting in a “peel-back” SLAP tear. The biceps muscle also contracts late in the throwing motion during deceleration so as to slow the extension of the elbow, and this applies repetitive traction forces on the superior labrum and may exacerbate tears.

The posterosuperior labral tears with internal impingement appear similar on MR to SLAP tears from other mechanisms. Overhead throwers can develop free edge fraying in the posterosuperior labrum, which other than their distinctive posterosuperior location appear similar to other type 1 SLAP tears on MR with blunting and irregularity of the free edge. The other common SLAP tear in overhead throwers is a type 2B SLAP tear which will appear as irregular laterally curved high signal (Fig. 1.8). Other throwers may have a smaller focal tear of the posterosuperior labrum that does not extend to the 12:00 position of the glenoid. Because these

Fig. 1.8 Overhead thrower labral tear
Oblique coronal fat-suppressed T1-weighted MR arthrogram image in a 21-year-old baseball pitcher who has pain with throwing shows a tear of the posterosuperior labrum (arrows). There is also an articular surface partial thickness rotator cuff tear (arrowhead)

tears can be small, they are often better seen on MR arthrography with abduction and external rotation (ABER) images.

There are several other lesions of the labrocapsular complex that can be seen in throwing athletes. Patients with GIRD can have focal thickening of the posterior band inferior glenohumeral ligament near the labral insertion, with loss of the normal labrocapsular recess in this region. These athletes can also have an exostosis in this region, the Bennett lesion, which is felt to result from repetitive traction leading to ossification of the posterior band inferior glenohumeral ligament at the glenoid insertion. Throwers often develop a chronically stretched anterior capsule which allows the increased external rotation in the late cocking phase of the throwing motion that is associated with increased throwing velocity, although this can be difficult to diagnose on MR images. They can also develop tears of the anterior capsule due to tensile overload; these tears are more common in older overhead throwing athletes where the capsule has become less pliable.

There are several additional findings in the shoulder associated with internal impingement. The most important is an articular surface partial thickness cuff tear of the posterior supraspinatus or anterior infraspinatus tendon (Fig. 1.8). Another common finding in throwers is prominent posterior humeral head cysts. These have been sometimes called a “pseudo Hill-Sachs” lesion, but they occur more posterior than a true posterolateral Hill-Sachs lesion. A partial tear of the inferior subscapularis muscle-tendon junction has also been described in throwing athletes.

1.4.3 Spinoglenoid Notch Cyst and Posterosuperior Labral Tear

Shoulder paralabral cysts are pseudocysts that result from a labrocapsular tear that allows joint fluid to extravasate into the paralabral soft tissues. Paralabral cysts can occur at any point around the glenoid rim, but are most common adjacent to the posterosuperior region of the glenoid rim. The posterosuperior location is common because cysts can form here easily in the fat plane between the supraspinatus and infraspinatus muscles lateral to the scapular spine, an area known as the spinoglenoid notch.

The labral tears associated with spinoglenoid notch paralabral cysts can be type 2B SLAP tears (superior labral tears that extend posteriorly) or focal posterosuperior labral tears. Focal tears in the posterosuperior labrum can occur after acute trauma such as a fall on an outstretched hand or from repetitive trauma. Labral tears in this region are not uncommon in overhead throwers, but most are not associated with a paralabral cyst in this group of athletes.

Spinoglenoid notch paralabral cysts are symptomatic because they often compress the suprascapular nerve, which

Fig. 1.9 Spinoglenoid notch cyst
(a) Oblique sagittal T1-weighted and (b) oblique sagittal fat-suppressed T2-weighted images show a paralabral cyst in the spinoglenoid notch (arrows) and denervation edema (arrowheads) within the caudal portion of the infraspinatus muscle

courses through the fat plane between the supraspinatus and infraspinatus muscles. The suprascapular nerve contains sensory fibers that supply the posterior joint capsule and acromioclavicular joint and motor fibers that innervate the infraspinatus and supraspinatus muscles. The most common presentation of a spinoglenoid notch paralabral cyst is pain, and half the patients who are symptomatic will have only pain due to the sensory fibers being primarily affected. Motor

symptoms are usually external rotation weakness from denervation of the infraspinatus muscle; large cysts that extend superiorly into the suprascapular notch can also involve the motor branch to the supraspinatus muscle causing arm abduction weakness.

On MR, paralabral cysts appear as a well-defined T2 high signal mass medial and adjacent to the posterosuperior labrum (Fig. 1.9) [15, 16]. On MR arthrography, there is variable filling of the cyst with intraarticular contrast. Although 85% of cysts are associated with a labral tear, the tear often partially heals so that fluid in the glenohumeral joint and the paralabral cyst may not have a bidirectional communication.

The infraspinatus muscle may appear normal on MR even if the patient is experiencing pain, possibly due to nerve impingement affecting the sensory fibers more than the motor fibers. Other spinoglenoid notch cysts will have associated increased T2 signal in the infraspinatus muscle, termed denervation edema. If the cyst is left untreated, the patient may develop fat replacement and atrophy of the muscle. If a cyst is large and extends up to the suprascapular notch region, there may also be T2 high signal in the supraspinatus muscle. Again, if the cyst is long-standing, there may be fat replacement atrophy of both the infraspinatus and supraspinatus muscles.

1.5 Normal Labral Variants

One of the difficulties with accurately diagnosing labral tears on MR imaging is the normal labral variants, which can sometimes appear similar to tears. The most common location for the labral variants is from 11:00 posterosuperiorly to the 3:00 anteriorly on the glenoid rim. The labral variants are mainly sections of the labrum that are partially or completely unattached to the glenoid rim.

The most common labral variant is a superior sublabral recess, which is a partially unattached superior labrum between 11:00 and 1:00 that is seen in 74% of people [17]. The recess formed by the partially unattached superior labrum occurs at the articular surface of the labral-chondral junction; the peripheral superomedial margin of the superior labrum remains adherent to the glenoid rim. Some have classified the attachment of the superior labrum to the glenoid rim into one of three “biceps-labral complexes”: type 1 (entire medial base of the labrum adherent to the glenoid rim), type 2 (superior recess ≤ 2 mm), or type 3 (superior recess > 2 mm) [18]. On MR images, a superior sublabral recess will appear as smooth medially curving linear high signal at the labral-chondral junction which does not extend outward across the entire base of the labrum.

The next most common location for labral variants is in the anterosuperior (1:00–3:00) labrum between the origins

of the middle and inferior glenohumeral ligaments. There are three labral variants that can occur in the anterosuperior labrum. One is a sublabral foramen, where the labrum is focally unattached to the glenoid rim, and is present in 10–15% of individuals [19]. The second is a Buford complex where the anterosuperior portion of the labrum is absent and there is a thick, cord-like middle glenohumeral ligament, and this is seen in 1–2% of individuals. The third is an anterosuperior sublabral recess where the labrum is only attached to the glenoid rim at its outer margin, similar to a superior sublabral recess. There is an increased association of these anterosuperior labral variants with the more common superior sublabral recess.

The sublabral foramen and anterosuperior recess will appear on MR images as high signal between the labrum and glenoid rim. The Buford complex appears on MR images as a segment of the anterosuperior glenoid rim where no labrum is visible, although the patient also has a thick middle glenohumeral ligament which may lie against the glenoid rim and mimic the unattached labrum of a sublabral foramen (Fig. 1.10).

Key Point

- On MR, increased signal between the labrum and glenoid rim isolated to the anterosuperior labrum is more likely to be a sublabral foramen normal variant than to be a tear.

Although less common than in the 11:00–3:00 region, a shallow recess at the inner labral-chondral junction can also occur at other regions around the glenoid rim [20]. These smooth, less than 2 mm deep recesses should not be confused with a labral tear.

There is controversy whether these labral variants are congenital or developmental such as from prior post-traumatic detachment. For the superior recess, De Palma found these recesses were more prevalent with increasing age and therefore believed they were an acquired lesion possibly from chronic repetitive traction [21]. Tena-Arregui et al. found that a superior recess was not present in still-born fetal specimens and came to the same conclusion but did observe that 10% of fetuses had a sublabral foramen, a similar prevalence to adults [22]. It may be that some variants are congenital and others acquired. In any case, most believe that a superior recess or an anterosuperior labral variant is an incidental finding and if “repaired” at surgery will only worsen symptoms.

Finally, there is a finding on oblique coronal MR images called a “pseudoSLAP,” where T2 high signal fluid is present between the long head biceps tendon and the anterosuperior labrum on oblique coronal images. This occurs because the long head biceps tendon can pass over the antero-

Fig. 1.10 Buford complex normal labral variant (a) Axial T1-weighted and (b) oblique sagittal fat-suppressed T2-weighted images show an absent anterosuperior labrum (arrow) and a thick, cord-like middle glenohumeral ligament (arrowheads), known as a Buford complex

osuperior labrum to insert directly onto the supraglenoid tubercle in some individuals. This pitfall should not be mistaken for a biceps-labral junction tear.

1.6 Concluding Remarks

MR is the best modality for imaging the glenoid labrum and instability, but even with high-quality images, accurately diagnosing pathology can be challenging. Learning the varied MR appearances of labral tears and injuries to the capsule is important to help confirm the clinical findings and guide

presurgical planning. Recognizing labral tears above the midpoint of the glenoid, and distinguishing them from the normal labral variants, is important in identifying several of the causes of shoulder pain.

Take Home Messages

- The classification in traumatic instability and atraumatic instability is very important because the examination in a patient with an atraumatic instability of the glenohumeral joint may be normal.
- All structures (labrum, ligament, bone) contributing to glenohumeral instability must be addressed.
- The increased signal on MR seen in SLAP tears is often irregular, directed cranially or curves laterally, and extends into the superior labrum.
- The increased signal on MR of a normal variant superior sublabral recess is smooth, curves medially, and occurs at the labral/glenoid junction.

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