Magnetic resonance imaging in glenohumeral instability

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INTRODUCTION

Shoulder joint is the most mobile and most commonly dislocated joint of the body[1]. Injuries to this joint leading to dislocation, subluxation and fracture are common, especially in young active individuals. Glenohumeral instability can be classified differently (Table 1) based on the etiopathogenesis (traumatic or atraumatic), direction of dislocation (anterior or posterior) or chronicity (acute or chronic). Traumatic anterior instability (often represented by the term TUBS; Traumatic, Unidirectional, Bankart, Surgical) is the most common clinical entity compared to atraumatic multidirectional instability[1]. Anterior dislocation comprises the majority (95%) of all cases; whereas posterior dislocation is less common[1].

In this article, we will review the anatomy, the magnetic resonance imaging (MRI) techniques and recent advancements in imaging of glenohumeral instability, and commonly encountered abnormalities in glenohumeral instability.

ANATOMY

The shoulder girdle is comprised of three joints, the...
glenohumeral joint, the acromioclavicular joint and the sternoclavicular joint. The glenohumeral joint, a ball-and-socket type of joint, is the main component of the shoulder girdle mechanism[1]. The glenoid labrum is a fibrocartilage located at the glenoid rim which increases the depth by 2-4 mm (50%)[2] and increases the articular surface of the socket by 1 cm. Normal glenoid labrum appears as a triangular structure at the glenoid margin, having hypointense signal intensity on all sequences (Figure 1)[1]. Principal stabilizing mechanisms of the shoulder joint are the rotator cuff tendons (dynamic stabilizers) and the glenoid labrum and the ligaments (static stabilizers)[2]. The rotator cuff tendons are comprised of four tendons arranged around the shoulder girdle: the subscapularis, supraspinatus, infraspinatus, and teres minor. Normal tendons appear hypointense on T1-weighted (T1W) as well as T2-weighted (T2W) images[1,2].

Glenohumeral ligaments (superior, middle and inferior) are thickenings of the capsule of the glenohumeral joint. Normal glenohumeral ligaments appear as hypointense linear bands, best documented after joint distension on magnetic resonance (MR) arthrography (Figures 2-4). The inferior glenohumeral ligament (IGHL) is made up of two components, the anterior and the posterior bands[2]. The anterior band of the IGHL is of prime importance in the stability of the shoulder joint. The anterior inferior labrum and the anterior band of

Table 1 Classification of glenohumeral instability

| Classification | Types of instability |
|----------------|---------------------|
| Anatomic       | Anterior            |
|                | Posterior           |
|                | Multidirectional    |
| Etiologic      | Traumatic (TUBS)    |
|                | Atraumatic (AMBRI)  |
| Clinical course| Acute               |
|                | Recurrent           |
| Degree of instability | Subluxation   |
|                | Dislocation         |
have been reported to be most closely correlated with anterior glenohumeral instability. The attachment of the anterior joint capsule and middle glenohumeral ligament (MGHL) shows significant variability. Three types of attachment have been described: type I refers to an attachment of the anterior joint capsule at the anterior labral tip or at the base of the labrum; in type II attachment, the capsule attaches to the glenoid close to the labral base; whereas type III refers to an attachment more medially along the scapular neck (Figure 5).

Rotator cuff interval (RCI) is defined as the discontinuity of the rotator cuff that occurs between the superior border of the subscapularis and the anterior border of the supraspinatus tendon. Articular cartilage and labrum are best evaluated on a proton density (PD) or gradient echo image on axial and oblique coronal planes. The rotator cuff tendons should be evaluated on oblique coronal and oblique sagittal planes. For evaluation of the signal intensity of the rotator cuff tendons, T2W fat-saturated images are ideal.

**Table 2 Arthrographic techniques and their drawbacks**

| Arthrographic technique | Procedure | Advantages | Drawbacks |
|------------------------|-----------|------------|-----------|
| Indirect               | Intravenous injection of gadolinium and imaging 10 min after active exercise of the joint | Simple | Joint cavity distension not achieved; ligamentous pathologies not well detected |
| Direct arthrography: anterior approach | Dilute gadolinium injected in the joint cavity through an anterior approach (US- or fluoroscopy-guided). Injection made through a point at the junction of the upper two-thirds and lower-third of anterior joint space | Adequate joint distension helps detection of labral and ligamentous pathologies better | Needs expertise |
| Direct arthrography: posterior approach | Dilute gadolinium injected in the joint cavity through a posterior approach (US- or fluoroscopy-guided) | Adequate joint distension helps detection of labral and ligamentous pathologies better | May cause injury to the posterior structures |
| Direct arthrography: anterosuperior approach | Dilute gadolinium injected in the joint cavity through an anterosuperior approach in the RCI (US- or fluoroscopy-guided) | Adequate joint distension helps detection of labral and ligamentous pathologies better | May cause injury to the rotator interval capsule |

**Figure 5 Magnetic resonance arthrographic axial T1-weighted fat-saturated images showing different types of attachment of anterior joint capsule. A: Type I; B: Type II; C: Type III (arrows).**

**MRI TECHNIQUE IN SHOULDER INSTABILITY**

Routine imaging of the shoulder is done in three planes. The acquisition of images in the oblique coronal plane, which is the single most important imaging plane in the shoulder joint, is done parallel to the supraspinatus tendon. Oblique sagittal images are acquired at a plane perpendicular to the plane of the glenoid face, and best planned on an axial image.

Articular cartilage and labrum are best evaluated on a proton density (PD) or gradient echo image on axial and oblique coronal planes. The rotator cuff tendons should be evaluated on oblique coronal and oblique sagittal planes. For evaluation of the signal intensity of the rotator cuff tendons, T2W fat-saturated images are ideal. On oblique sagittal images, the entire rotator cuff tendons, muscles and RCI can be assessed. In the setting of trauma, T1W images are less helpful, and can be acquired in oblique coronal plane only.
MR ARTHROGRAPHY

MR arthrography has proven its utility in the evaluation of glenohumeral instability and cartilage abnormalities. MR arthrography can either be direct or indirect (Table 2). Direct MR arthrography procedure can be divided into two parts: injection of the dilute gadolinium contrast agent into the joint and imaging in a MR scanner. Usually fat-saturated T1W images are obtained in all three planes. The labrum and glenohumeral ligaments are well visualized after distension of the joint cavity by the intra-articular injection. The only drawback of this imaging protocol is that it can miss the presence of any intra-substance rotator cuff tear. To avoid this difficulty, additional T2W MRI with fat suppression can be done in the oblique coronal plane. Imaging with the shoulder in ABER position increases the sensitivity and specificity of detection of anterior inferior labral and glenohumeral ligament attachment abnormalities.

The injecting approach in MR arthrography has undergone several alterations since its introduction. Injection can be performed either through anterior, anteroinferior or posterior approach. Anterior approach is the most commonly adopted one. In 1975, Schneider et al described a simplified injection technique, which uses a straight anteroposterior approach with a 3.5 inch (8.8 cm), 22 gauge needle directed vertically at the junction of the middle and lower thirds of the glenohumeral joint under fluoroscopic guidance. After confirmation of needle placement using 1-2 mL iodinated contrast agent, 10-12 mL of a dilute gadolinium solution (1:200 dilution) is injected into the joint cavity. MR imaging is usually performed within 90 min to avoid absorption of the intraarticular contrast.

A posterior approach can also be adopted, especially when there is anterior instability as needle placement through an anterior route may distort the images of healthy anatomic structures. The patient lies prone with ipsilateral shoulder raised off the table with a pad. A 21 gauge spinal needle is advanced vertically through the intermedial aspect of the humeral head under fluoroscopic guidance.

For a long time, a modified Schneider technique (anteroinferior approach through rotator interval) has been in use, where the patient is kept supine with arm externally rotated and a 1.5 inch (3.8 cm), 20-22 gauge needle is inserted through an area medial to the superior third of the humeral head. The needle tip is advanced in an anteroposterior direction to the humeral head to avoid contact with the glenoid labrum. The utility of this procedure was established by Dépelteau et al.

In indirect MR arthrography, gadolinium is injected intravenously and imaging is done after it diffuses into the joint cavity through a highly vascular synovial lining (which takes a few minutes). However, it lacks the effect of joint distension (compared to direct MR arthrogram).

While performing MR arthrography, adequate precautions should be taken to avoid introduction of air in the joint cavity, which can mimic detached and torn labrum on imaging (Figure 7). The gadolinium concentration should also be properly checked, as injection of undiluted gadolinium may lead to diffuse low signal intensity in the joint cavity.

MRI FINDINGS IN SHOULDER INSTABILITY

MR imaging in anterior instability can reveal a large number of abnormalities affecting the bone and labroligamentous tissue.

Hill-Sachs lesion
Hill-Sachs lesion (Figure 8) is the most common injury associated with anterior glenohumeral instability. It consists of bony injury of the posterosuperior humeral head manifesting as cortical bony loss, impaction fracture or associated bone marrow edema in acute cases.

Classic bankart lesion
Bankart lesion (Figure 9) is the commonest labral injury, manifesting as tear of the anterior inferior labrum with associated periosteal tear. It can be purely cartilaginous or may involve the bony glenoid rim (bony Bankart
Bankart lesion is usually accompanied by Hill-Sachs lesion. Several other variants of Bankart lesion have been described, including the Perthes lesion, anterior labroligamentous periosteal sleeve avulsion (ALPSA) lesion, glenolabral articular disruption (GLAD) lesion.

On conventional MR imaging in Bankart lesion, the anteroinferior labrum is seen to be attenuated or absent. The signal intensity on T2* gradient-echo or PD FS FSE MR images may be increased secondary to degeneration of the labrum. On T1 turbo spin echo fat saturation (TSE FS) post-arthrographic MR images, contrast is seen between the labrum and the glenoid margin.

Perthes lesion (Figure 11), described by Perthes in 1905, is defined as a tear of the glenoid labrum with intact scapular periosteum. The torn anterior labrum is often undisplaced and visualized in its normal location on conventional MR imaging. MR arthrography, especially when imaging is performed with the arm in ABER position, improves the detection rate of Perthes lesion, as it puts the anterior band of the IGHL and anteroinferior capsule under stress. This is a difficult lesion to detect, both on conventional MRI and even on arthroscopy.

ALPSA lesion
ALPSA lesion (described by Neviaser) is defined as an avulsion and medial rolling of the inferior labroligamentous complex along the scapular neck secondary to a chronic injury (Figure 12). The main differentiating point of ALPSA from a Perthes lesion is the displacement of the torn labroligamentous tissue, which is undisplaced or shows minimal displacement in Perthes lesion. An ALPSA lesion differs from a Bankart lesion in that an ALPSA lesion has an intact anterior scapular periosteum (it is ruptured in Bankart lesion) that allows the labroligamentous structures to displace medially and rotate inferiorly on the scapular neck.

GLAD lesion
This lesion also described by Neviaser consists of a superficial anterior inferior labral tear associated with an anterior inferior articular cartilage injury (Figure 13). The use of intra-articular contrast in MR arthrogram helps to visualize the small tears at the level of the anterior inferior glenoid rim. When a GLAD lesion is seen on MRI, one should look for loose bodies, which can occur from...
a detached articular cartilage fragment¹⁸.

**Superior labrum anterior and posterior type 5 lesion**

Superior labrum anterior and posterior (SLAP) lesion, described by Snyder et al.¹⁹, is an injury involving the superior aspect of the glenoid labrum that includes the biceps tendon anchor. SLAP tears were initially classified by Snyder et al.¹⁹ into 4 distinct but related lesions; Maffet et al.²⁰ added three more types, and currently 10 types or patterns have been recognized. Though SLAP lesions often present with nonspecific symptoms such as pain, locking and snapping, type 5 SLAP lesion (type 2 or 3 SLAP lesion with superior extension of a Bankart lesion) is often associated with anterior shoulder dislocation. Sagittal MRI or MR arthrogram can demonstrate the complete extent of labral tear.

**Humeral avulsion of anterior glenohumeral ligament lesion**

Humeral avulsion of anterior glenohumeral ligament (HAGL) lesion (Figure 14) is a less commonly encountered abnormality (9.3%) in anteroinferior instability²¹. It may coexist with an anterior labral tear in patients with anterior instability. In patients with documented anterior instability without a demonstrable “primary” Bankart lesion, a HAGL lesion should be ruled out²¹. For detection of HAGL, the glenohumeral joint cavity should be well distended, either by contrast agent (direct MR arthrogram) or joint effusion. On coronal MR image, normal distended axillary pouch is seen as a U-shaped structure, which changes into a J-shape in a HAGL lesion as the IIGHL drops inferiorly (J sign)²².

**Bony humeral avulsion of glenohumeral ligaments lesion**

Bony humeral avulsion of glenohumeral ligaments (BHA-
GL) lesion is less common than HAGL. In BHAGL, there is a small avulsed osseous fragment attached to the torn end of the humeral attachment of the IGHL.

**GAGL lesion**
This uncommon lesion implies an avulsion of the IGHL from the inferior pole of glenoid without associated disruption of the inferior labrum (Figure 15).

**Rotator cuff tears**
These tears (Figure 16), associated with anterior and inferior glenohumeral dislocation, are commoner in the elderly rather than the younger age group (30% incidence in patients less than 40 years of age and 80% incidence above 60 years of age).

**RCI tear**
A tear of the RCI typically does not appear as complete disruption of the fibres of its components. Instead it is seen on imaging as thinning, irregularity or focal discontinuity of the rotator interval capsule. Arthroscopy is considered the gold standard in diagnosing RCI lesions. MR arthrography, particularly the T2W sagittal or axial images, may be useful in diagnosing RCI pathologies.

**ANATOMIC VARIATIONS MIMICKING LABRAL TEARS**
Sublabral foramen is a normal detachment of the anterosuperior labrum (usually at 2 o’clock location) from the glenoid rim that needs to be differentiated from a Bankart lesion (28). Bankart lesion usually involves the anteroinferior labrum (isolated anterosuperior labral involvement is rare and seen in throwing athletes presenting with pain on overhead abduction). The margins of a labral tear are usually irregular as compared to the sublabral foramen.

Buford complex (Figure 17) is defined as congenital absence of the anterosuperior labrum and thickened cord-like MGHL. The thickened MGHL, when visualized on axial MR images, can mimic detached labrum of a Bankart lesion. However, on oblique sagittal arthrographic images, the superior insertion of a cord-like MGHL is usually visible and misdiagnosis can be avoided.

**IMAGING FINDINGS IN POSTERIOR DISLOCATION**
**Reverse hill-sachs lesion**
This lesion (Figure 18) consists of an anteromedial superior humeral head impaction fracture which is often associated with a reverse Bankart lesion (posterior glenoid labral disruption).
Reverse hagl lesion
In posterior instability, there is sometimes a complete avulsion of the posterior attachment of the shoulder capsule from the posterior humeral neck, associated with tear of the posterior band of the IGHL.

Posterior glad lesion
This lesion is a newly described entity in posterior gleno-humeral instability, which can be seen as focal posterior articular cartilage defect (between 7 and 9 o’clock location).

Bennett lesion
This is an extra-articular crescentic posterior ossification associated with posterior labral injury and capsular avulsion, sometimes secondary to the posterior subluxation. The ossification is best visualized on CT, and often missed by arthroscopy as it is extra-articular.

Posterior superior labral tear
This occurs (Figure 19) as a part of posterior SLAP 2 or posterosuperior to a posterior labral tear in association with a paralabral cyst and may be seen in patients with posterior instability. Posterior superior labral tear may be associated with repetitive microtrauma, as in throwers, and can even be seen in anterior instability. The cysts are almost always associated with labral tears, but the communication with the joint space is often not visualized on MRI.

POST-OPERATIVE IMAGING
Anatomic repair of the labrum and capsule using metallic suture anchors is being increasingly employed in gleno-humeral instability using an arthroscopic approach. On post-operative MR imaging, susceptibility artifacts from the metallic implants may degrade the image quality. A few important points should be kept in mind to overcome this problem: gradient echo sequences should be avoided and replaced by spin echo sequences when possible; fast spin echoes are preferable over standard spin echo sequences; and inversion recovery sequences should be preferred over chemical fat suppression. After an anatomic apposition of the labrum to the articular margin in suture-anchor repair, no hyperintensity should be visible between the two. MR arthrography is more useful in post-operative shoulders as a problem solving tool in suspected recurrent labral tear. Contrast-enhanced T1W sequences should always be acquired in addition if there is a suspicion of septic arthritis.

Non-anatomic repairs (Putti-Platt repair, Bristow-
Helfet procedure) are usually not preferred for primary instability surgery. Following capsular shift or shrinkage procedures, thickening of the joint capsule can be visualized on imaging.

Complications during arthroscopic repair include inadvertent injury to the axillary nerve (lying in close relation to the inferior joint capsule) and subscapularis muscle injury, hematoma, infection, septic arthritis, heterotopic ossification.

**RECENT ADVANCES IN SHOULDER MRI**

Virtual MR arthroscopy of the shoulder joint has been described in a few reports using 3D gradient echo sequences after intra-articular injection of dilute gadolinium. The technique can act as a useful adjunct tool to MR arthrography in the assessment of labral tears, by providing helpful visual information similar to arthroscopy.

**CONCLUSION**

To conclude, MRI and MR arthrography are routinely used investigations in glenohumeral instability and have very high sensitivity in detecting labroligamentous injuries. An MR arthrogram plays a crucial role in the imaging of post-operative shoulder. While diagnosing various labral lesions, anatomic variations should be kept in mind.

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