MR Arthrography of the Shoulder: Variants and Pitfalls[1]

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Use of magnetic resonance arthrography to evaluate pathologic conditions of the shoulder is becoming widespread. However, normal anatomy or anatomic variations can cause interpretive errors. The most common variations occur at the origins of the glenohumeral ligaments (GHLs) and the insertion of the joint capsule. Among the GHL variants, common origin of the superior and middle ligaments is the most frequent followed by thinning, thickening, or absence of a ligament, most often the middle one. Absence or thinning of one ligament is sometimes associated with thickening of another or changes in the size and shape of the anterior capsular recesses. Common normal variants of the labrum include foramen sublabrum (detachment of the anterosuperior labrum from the glenoid margin) and the Buford complex (absence of the anterosuperior labrum in association with a thick middle GHL). Pitfalls related to the arthrographic technique include (*a*) visualization of a deep sulcus between the insertion of the long head of the biceps tendon and the superior labrum and (*b*) an apparent type III capsular insertion due to overdistention of the capsule by injected contrast material.

■ INTRODUCTION

The diagnostic accuracy of magnetic resonance (MR) arthrography of the shoulder may exceed that of conventional MR imaging of the shoulder. Intraarticular structures are better demonstrated if they are separated by means of capsular distention. Such separation can be achieved with intraarticular injection of contrast material (diluted gadopentetate dimeglumine) or saline or with preexisting joint fluid (joint effusion). The goal is to produce high contrast between the labrum, capsule, capsular recesses, glenohumeral ligaments (GHLs), and articular surface of the rotator cuff. It is essential

Abbreviations: FDA = Food and Drug Administration, GHL = glenohumeral ligament, IRB = institutional review board, SE = spin echo, SLAP = superior labral anterior and posterior

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See the commentary by Barr following this article.

to demonstrate these delicate structures in cases of derangement associated with glenohumeral joint instability.

There is controversy in the radiologic and orthopedic communities over use of MR arthrography. Costs, invasiveness, cumbersome scheduling, and legal considerations may be slowing more widespread use of this technique (1). Despite these problems, our institution implemented gadolinium-enhanced MR arthrography of the shoulder in January 1995 after approval of the protocol by our institutional review board (IRB).

Our experience indicates that a thorough knowledge of capsulolabral and ligamentous complex anatomy is essential for adequate evaluation of MR arthrograms (Fig 1). We have also found a significant number of variations of the normal anatomy that simulate pathologic conditions and represent diagnostic pitfalls at MR arthrography. Some of these have already been described in the radiology and orthopedic literatures (1-11). In this article, the anatomic variants and potential pitfalls seen in MR arthrography of the shoulder are presented.

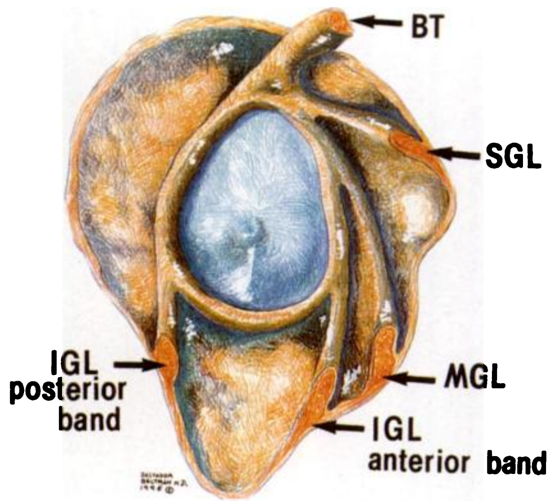


Figure 1. Labral-ligamentous complex. Drawing (lateral view) shows the superior GHL (*SGL*), middle GHL (*MGL*), and anterior and posterior bands of the inferior GHL (*IGL*). Note the insertion of the long head of the biceps tendon (*BT*) in the superior labrum.

■ TECHNIQUE

At our institution, fluoroscopic guidance is used for intraarticular placement of a 20-22-gauge needle; ultrasonographic guidance, blind placement, or guidance with an open MR system may also be used. Once the needle is in position, 0.1 mL of gadopentetate dimeglumine diluted in 20 mL of saline is injected, along with 0.3 mL of epinephrine diluted 1:1,000. Care should be taken not to inject air, which produces artifacts that may simulate pathologic conditions, such as loose bodies.

After injection of contrast material, the patient is escorted to the MR imaging room. MR imaging is performed within 45 minutes after contrast material administration; during this time, the patient is allowed limited arm movement. A routine shoulder study is performed with a shoulder coil and with the arm in the neutral position. The following sequences are used: axial and oblique sagittal T1-weighted spin-echo (SE) imaging (600-800/15-20 [repetition time msec/echo time msec]) and oblique coronal proton-density- and T2-weighted SE imaging (1,800-2,000/20-100). Fat suppression techniques may be used. The field of view is 16-18 cm, and the section thickness is 3 mm interleaved or 4 mm with 1-mm gaps.

Intraarticular administration of gadopentetate dimeglumine is not approved by the U.S. Food and Drug Administration (FDA). Approval by an IRB is required, and patients must sign a consent form. At our institution, all patients sign an informed consent form before undergoing the procedure.

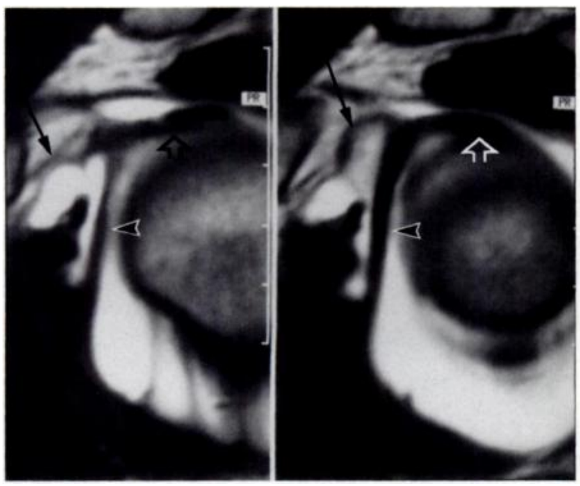
■ VARIANTS AND PITFALLS

• Superior GHL

The superior GHL extends from the superior glenoid margin, just anterior to the origin of the long head of the biceps tendon, to the lesser tubercle, where it blends with the coracohumeral ligament (2) (Fig 1). At arthroscopy, the superior GHL is found in 97% of patients (2). Palmer et al (6) identified the superior GHL in 47 of 48 patients (98%) with MR arthrography. The superior GHL may originate with the biceps tendon (Fig 2), alone, or with the middle GHL (Fig 3). Normally thin, the superior GHL can also be thick, in which case the middle GHL may be absent or underdeveloped (Fig 4).

2a.

2b.



3.

4.

Figures 2–4. **(2)** Superior GHL originating with the biceps tendon. **(a)** Axial MR arthrogram (SE 650/15) shows the superior GHL (arrowhead) originating with the long head of the biceps tendon (arrow). **(b)** Oblique sagittal MR arthrogram (SE 650/15) shows the superior GHL (arrowhead) in continuity with the biceps tendon (solid arrow). The middle GHL (open arrow) also originates from the biceps tendon. **(3)** Superior GHL originating with the middle GHL. Oblique sagittal MR arthrograms (SE 650/15) (left image obtained lateral to the right image) show the superior GHL (solid arrow) originating with the middle GHL (arrowhead). A small amount of contrast material (open arrow) is seen between the origin of the long head of the biceps tendon and the conjoined superior and middle GHLs. **(4)** Thick superior GHL. Oblique sagittal MR arthrogram (SE 650/15) shows a thick superior GHL (open arrow) below the coracohumeral ligament (solid arrow). Note the thin middle GHL extending inferiorly from the undersurface of the superior GHL.

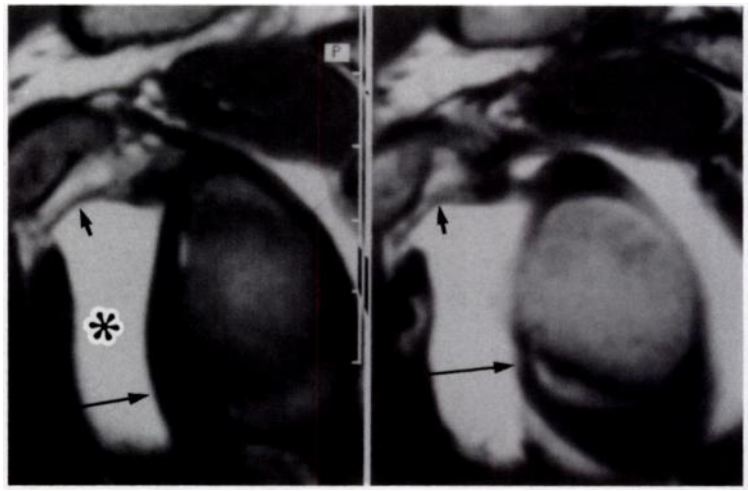
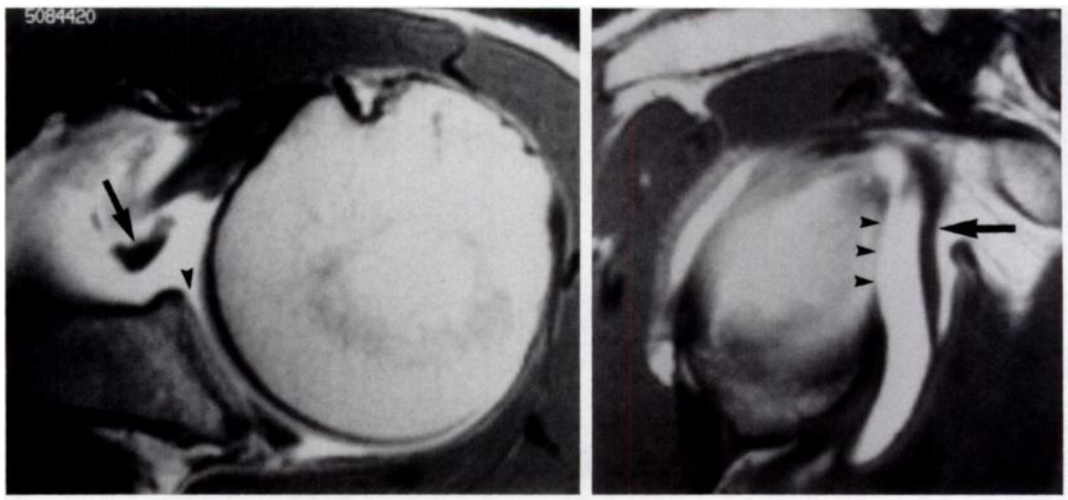
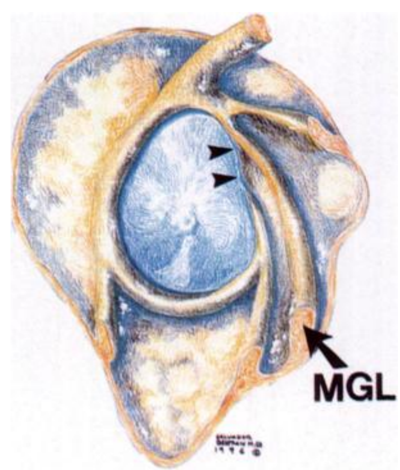


Figure 5. Absent middle GHL. Oblique sagittal MR arthrograms (SE 650/15) (left image obtained medial to the right image) show absence of the middle GHL. Normal superior (short arrow) and inferior (long arrow) GHLs are present. Marked distention of the subscapular recess is noted (*).

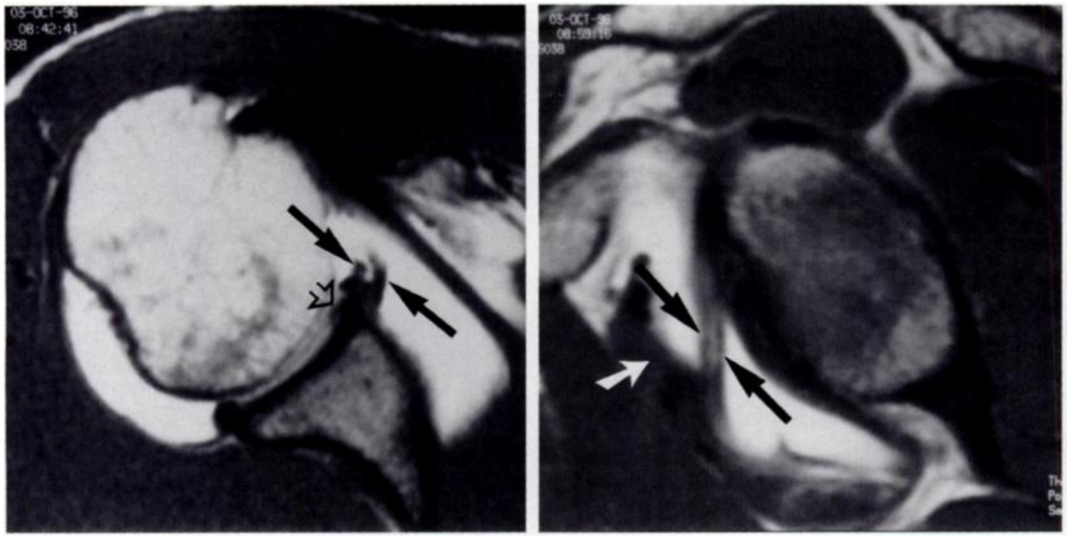


b. c.

Figure 6. Buford complex. **(a)** Drawing (lateral view) shows the Buford complex. Note the absence of the anterosuperior labrum (arrowheads). *MGL* = middle GHL. **(b)** Axial MR arthrogram (SE 650/15) shows absence of the anterosuperior labrum (arrowhead); the posterior labrum is normal. The middle GHL (arrow) is unusually thick. **(c)** Oblique sagittal MR arthrogram (SE 650/15) shows a thick middle GHL (arrow). Absence of the anterosuperior labrum is also evident (arrowheads).



a.



a. b.

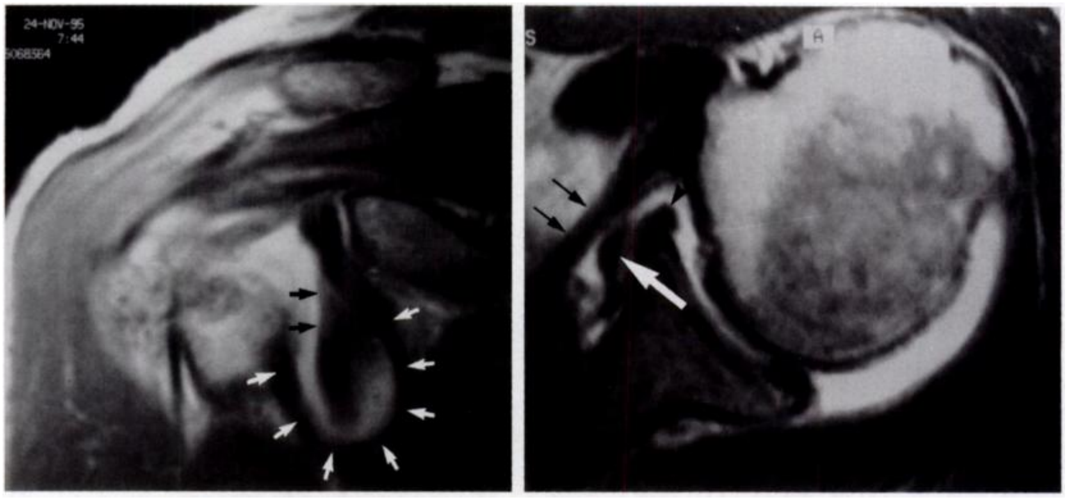
Figure 7. Double middle GHL. **(a)** Axial MR arthrogram (SE 650/15) shows a normal anterior labrum (open arrow) and two ligamentous structures (solid arrows) in its vicinity that correspond to a double middle GHL. **(b)** Oblique sagittal MR arthrogram (SE 650/15) shows a double middle GHL (black arrows) arising from the superior bicipital-labral complex and blending with the capsule behind the subscapular muscle (white arrow).

• Middle GHL

The middle GHL shows the greatest variation of all the GHLs (2). It is absent in up to 30% of cadaveric dissections (6) and was not identified in 12% of patients evaluated with MR arthrography (6) (Fig 5). It arises most frequently from the anterosuperior aspect of the labrum and may originate with the superior GHL (Fig 3), alone, or with the inferior GHL. The middle GHL inserts in the humerus at the base of the lesser tubercle and can also blend with the capsule before reaching the tubercle.

Occasionally, the middle GHL is thick and cordlike and may be associated with absence of the anterosuperior labrum, the so-called Buford complex (7,8) (Fig 6). Williams et al (7) noted this variation in three of 200 patients (1.5%) studied with arthroscopy. In cases of Buford complex, axial MR images at the level of the superior half of the glenoid cavity show a cross section of the thickened middle GHL close to the glenoid margin with an absent labrum, simulating a labral tear (Fig 6). Identification of a thick middle GHL on oblique sagittal images helps one avoid this pitfall.

Rare cases of a double middle GHL have been reported (1). In these cases, oblique sagittal MR images demonstrate a double parallel line and axial images show a U-shaped structure that may simulate a labral cleft or tear (Fig 7).



a. b.

Figure 8. Redundant middle GHL. **(a)** Oblique coronal MR arthrogram (SE 650/15) shows a middle GHL (white arrows) running adjacent to the anterior labrum (black arrows). **(b)** Axial MR arthrogram (SE 680/15) shows a redundant middle GHL (white arrow) medial to the anterior labrum (arrowhead) and posterior to the subscapular tendon (black arrows).

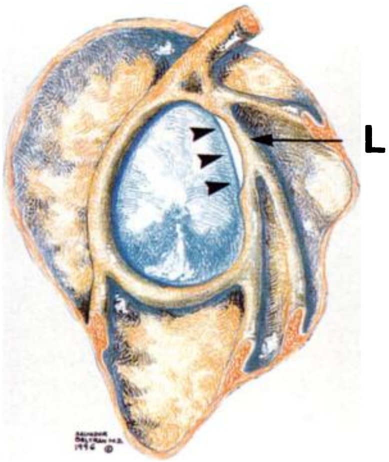
a. b.

Figure 9. Rough-looking inferior GHL at its origin in the humeral neck. **(a)** Axial MR arthrogram (SE 650/15) shows the origin of the inferior GHL as irregular tendinous slips (arrowheads). **(b)** Oblique sagittal MR arthrogram (SE 650/15) shows the fan-shaped insertion of the inferior GHL in the humeral neck (arrowheads). The anterior and posterior bands are indicated by the most anterior and posterior arrowheads, respectively.

Sometimes the middle GHL is redundant, running medial to the labrum where the capsule is well distended (Fig 8) (5). The position of the middle GHL is closely related to the degree of rotation of the arm during imaging (1). With the arm in external rotation, the middle GHL becomes stretched and blends with the capsule.

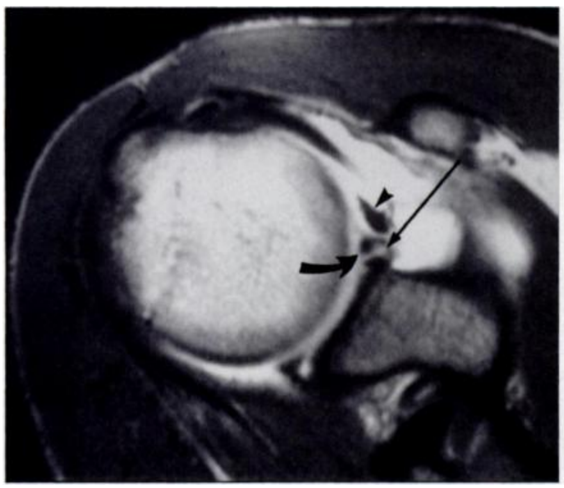
• Inferior GHL

The inferior GHL complex consists of an anterior band, a posterior band, and the axillary recess of the capsule between these bands (2). The anterior band extends from the anteroinferior aspect of the labrum to the surgical neck of the humerus. The posterior band extends from the posteroinferior aspect of the labrum to the surgical neck of the humerus. The anterior band is usually thicker than the posterior band. The insertion of the axillary recess and the anterior and posterior bands in the



a.

Figure 11. Foramen sublabrum or anterior fenestration. **(a)** Drawing (lateral view) shows the foramen sublabrum (arrowheads). *L* = anterior labrum. **(b)** Axial MR arthrogram (SE 650/15) shows a normal middle GHL (arrowhead), a normal anterior labrum (curved arrow), and a small fenestration between the anterior labrum and the anterior margin of the glenoid rim (straight arrow). This variant should not be misinterpreted as complete detachment of the labrum. **(c)** Oblique sagittal MR arthrogram (SE 650/15) of a patient without a middle GHL shows the fenestration as a small pocket of contrast material (white arrow) extending under the anterior labrum (black arrow).



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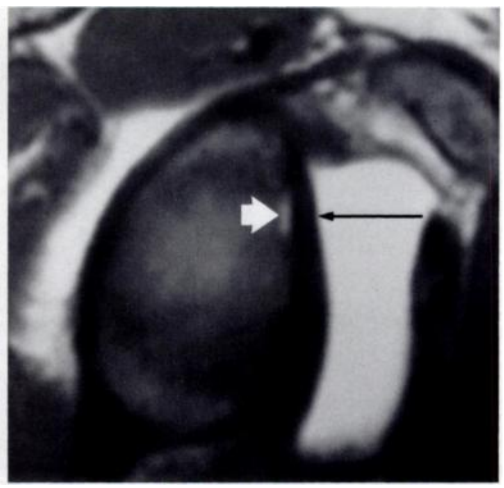

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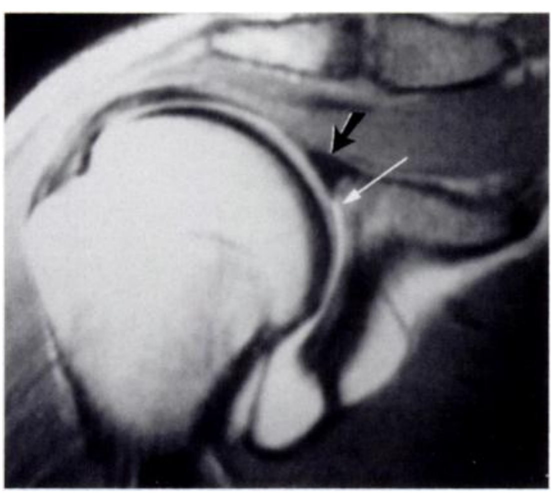


Figure 10. Sulcus under the anterosuperior labrum. Oblique coronal MR arthrogram (SE 650/15) shows a small, contrast material–filled sulcus (white arrow) under the superior labrum (black arrow). This normal variation should not be confused with partial labral detachment.

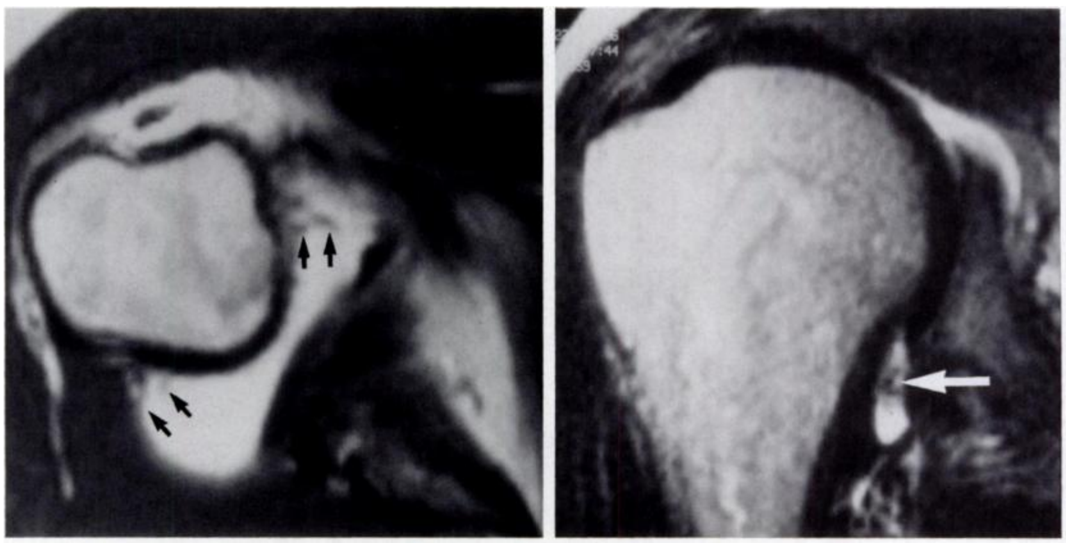
neck of the humerus creates a jagged appearance on axial MR images (Fig 9).

• Labrum

The labrum may demonstrate multiple variations in size and configuration (8). Articular cartilage is frequently present between the labrum and the glenoid cortex, predominantly in the superior half of the joint. This interface can simulate a labral tear on axial MR images or a superior labral anterior and posterior (SLAP) lesion on oblique coronal images (Fig 10) (1,5, 11). In general, superior labral tears are oriented laterally, whereas the cartilage interface is oriented parallel to the glenoid cortex.

Another important variation is the so-called foramen sublabrum or labral fenestration (8). It consists of normal detachment of the anterosuperior labrum from the glenoid rim and has no clinical significance. This variant can easily be misinterpreted as a labral tear (Fig 11). Isolated tears of this region of the labrum are rare.

Figure 12. Pseudo-SLAP lesion. Oblique coronal MR arthrograms (SE 650/15) (left image obtained posterior to the right image) show a small sulcus (arrowhead) between the superior labrum (white arrow) and biceps tendon (black arrow). This variant should not be misinterpreted as a type 2 SLAP lesion.



a. b.

Figure 13. Pseudo-loose bodies of the axillary pouch. Axial MR arthrogram (SE 2,200/90) **(a)** and oblique coronal MR arthrogram (SE 650/15) **(b)** show synovial folds within the axillary pouch that simulate loose bodies (arrows).

At the origin of the biceps tendon just above the superior aspect of the labrum, a small, contrast material–filled sulcus with different degrees of depth may be observed on oblique coronal MR images (Fig 12). A deep sulcus may simulate a SLAP lesion (5). Normally, the sulcus is oriented medially, whereas labral tears in this location are oriented laterally on oblique coronal images.

Complete absence of the anterosuperior labrum in association with a thick middle GHL (Buford complex) has already been discussed (7,8) (Fig 6).

• Capsular Recesses

Synovial folds of the axillary recess may be prominent, simulating loose bodies or intra-articular debris on axial and oblique coronal MR images (Fig 13).

The subscapular recess is a normal extension of the capsule under the coracoid process, above the superior margin of the subscapular muscle. This recess demonstrates many variations, which depend on the configuration of the GHLs. Absence of the middle GHL is often associated with a large subscapular recess (see Fig 5).

Variations of the anterior capsular insertion in the scapula have been described. In a type I insertion, the capsule inserts at the glenoid margin. In a type II insertion, the capsule in-

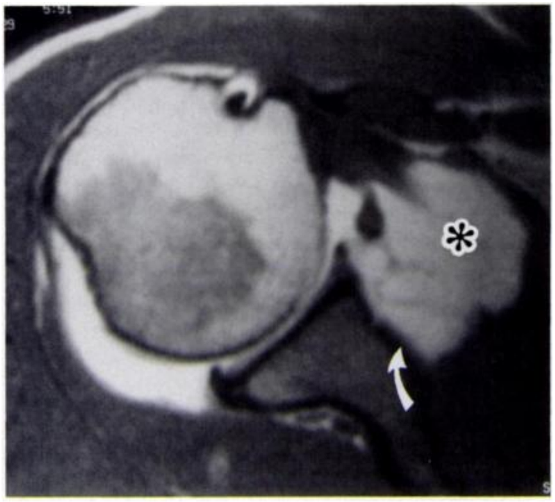


Figure 14. Variation of the anterior capsular recess. Axial MR arthrogram (SE 650/15) shows a large anterior capsular recess (*). When the joint is overdistended, the anterior capsular insertion may appear to be stripped away from the glenoid margin (arrow).

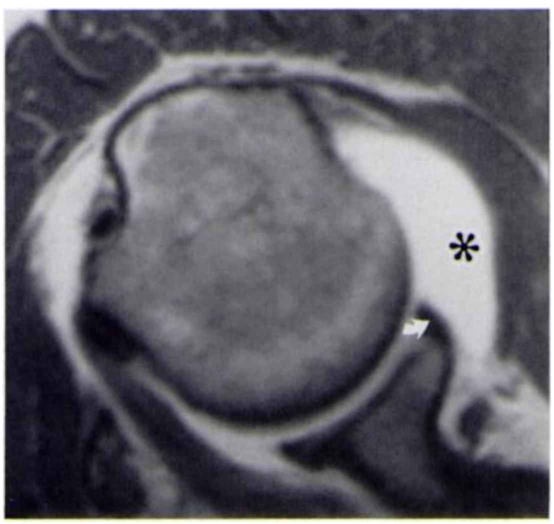


Figure 15. Variation of the posterior capsular recess. Axial MR arthrogram (SE 650/15) shows a mildly distended posterior capsular recess (*) that is related to the degree of capsular distention. The capsular insertion is actually in the posterior labrum (arrow).

Normal Features and Variants of the Labral-Ligamentous Complex

- Superior GHL (2)
  - Absent (10% of cases)
  - Originates with biceps tendon (Fig 2)
  - Originates distinct from biceps tendon
  - Originates with middle GHL (Fig 3)
  - Normally thin
  - Occasionally thick (Fig 4)
- Middle GHL (2)
  - Absent (27% of cases) (Fig 5)
  - Originates with superior GHL, with inferior GHL, or alone
  - Distal insertion in capsule instead of lesser tubercle
  - Normally thin
  - Cordlike middle GHL (Buford complex) (7,8) (Fig 6)
  - Double middle GHL (Fig 7)
  - Redundant middle GHL (5) (Fig 8)
  - Position related to degree of rotation (1)
- Inferior GHL (2)
  - Anterior band normally thicker than posterior band
  - Posterior band occasionally thicker than anterior band
  - Rough looking at its origin in humeral neck (Fig 9)
- Labrum
  - Normal sulcus under anterosuperior labrum (1,5) (Fig 10)
  - Foramen sublabrum (fenestration) (9) (Fig 11)
  - Pseudo-SLAP lesion (sulcus between biceps tendon and superior labrum) (5) (Fig 12)
  - Absence of anterosuperior labrum (Buford complex) (7,8) (Fig 6)
- Capsular recesses
  - Axillary pouch simulates loose bodies (3) (Fig 13)
  - Variations of subscapular recess (10)
  - Enlarged subscapular recess when middle GHL is absent (Fig 5)
  - Variations in insertion of anterior capsule (3) (Fig 14)
  - Variations in insertion of posterior capsule (3) (Fig 15)
  - Bicipital sheath usually fills with contrast material (1)

serts at the glenoid neck. In a type III insertion, the capsule inserts more medially along the scapula (3). It is generally agreed that type III insertions are often associated with anterior instability. The capsule is overdistended during MR arthrography, which often produces a false appearance of a type III insertion (Fig 14). A similar effect can be seen in the posterior capsular recess (Fig 15). The anterior capsular recess is even more redundant when the arm is in internal rotation.

■ CONCLUSIONS

The Table summarizes the normal variants and pitfalls described in the literature or encountered in our experience with MR arthrography of the shoulder. The most common variants and pitfalls include variations in the sizes, shapes, and insertions of the GHLs, capsule, and biceps tendon. Most of the pitfalls can be

avoided by following the anatomic structures in adjacent sections and inspecting them in all three imaging planes. Familiarity with these normal variants is essential for accurate interpretation of MR arthrograms of the shoulder.

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Invited Commentary

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MR arthrography is becoming more popular for the evaluation of shoulder pain and instability as the greater sensitivity and specificity of this technique over those of conventional arthrography, computed tomographic arthrography, or conventional MR imaging become apparent. Intraarticular injection of gadopentetate dimeglumine improves visualization of labral tears and degeneration, the anatomy and tears of the GHLs, complete and partial rotator cuff tears, and possibly abnormal articular cartilage (1-10). The enhanced diagnostic accuracy provided by MR arthrography enables the radiologist to assist clinicians in establishing a treatment plan and in directing a surgical approach when repair is necessary.

In the preceding article, Beltran et al describe the routine use of MR arthrography to evaluate pathologic conditions of the shoulder. To my knowledge, the information and increased accuracy provided by MR arthrography have not been proved to justify the added cost of routine use of this technique in the evaluation of shoulder pain. In addition, the preceding article does not clearly explain how one can confidently distinguish pathologic conditions from normal anatomic variants. The ability to consistently distinguish between normal anatomic structures, normal anatomic variants, and pathologic conditions is vital to maintaining the diagnostic accuracy of any imaging technique and ultimately is important in justifying the benefits and cost-effectiveness of that technique.

If radiologists are unable to prove the cost-effectiveness of MR arthrography, it is unlikely