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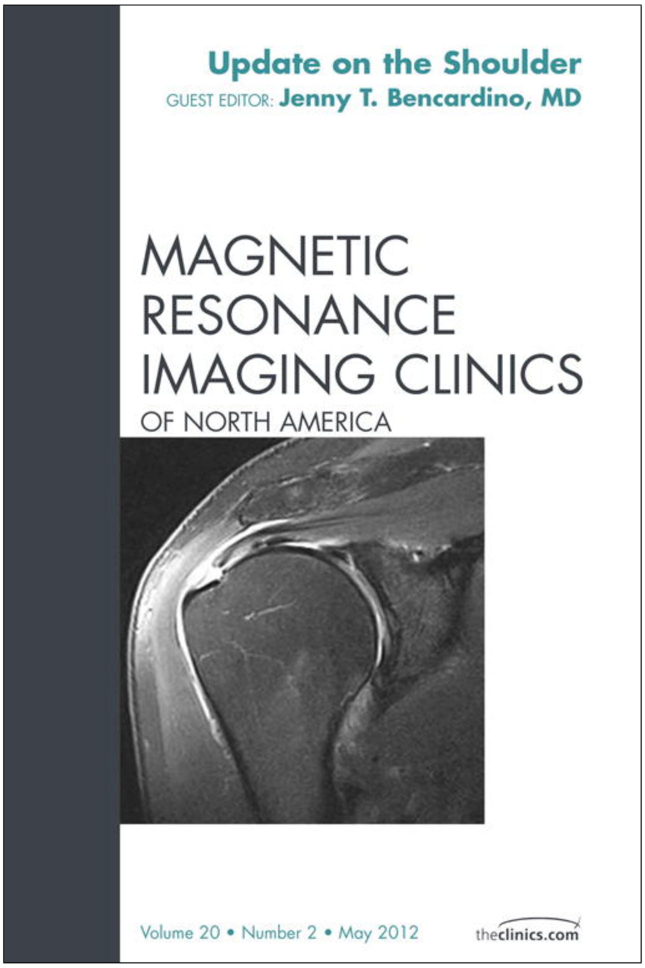
Update on the Shoulder
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Anatomic Variants and Pitfalls of the Labrum, Glenoid Cartilage, and Glenohumeral Ligaments

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KEYWORDS

• Shoulder • Variants • Labrum • Glenoid cartilage
• Glenohumeral ligaments

Magnetic resonance (MR) imaging is the primary diagnostic imaging modality for the evaluation of patients with suspected internal derangement of the shoulder joint. Awareness and understanding of the complex anatomy of the shoulder articulation and the ability to recognize normal anatomic variants and potential imaging pitfalls are critical to accurate interpretation of conventional and arthrographic MR imaging studies.[1,2] This review discusses the normal anatomy and anatomic variants of the glenoid labrum, articular cartilage, and glenohumeral ligaments (GHLs). An improved understanding of normal anatomy, biomechanics, and variants helps to avoid potential pitfalls in the interpretation of noncontrast and arthrographic shoulder MR examinations.

LABRUM

Function/Biomechanics

The glenoid labrum acts as a passive stabilizer to the glenohumeral articulation by adding depth to the shallow glenoid fossa.[3] It also serves as a primary attachment site for the GHLs, joint capsule, and long head of the biceps tendon. The labrum demonstrates considerable anatomic variability in its appearance, which may pose a diagnostic challenge to image interpretation.

The labral outline is ovoid in configuration, conforming to the underlying glenoid rim, and is most firmly attached to the glenoid posteriorly and inferiorly.[4] Previous reports have shown the labrum to be predominantly composed of fibrous tissue with some fibrocartilaginous components at the chondrolabral junction.[5,6] At the central interface of the glenoid labrum and the glenoid cartilage, 2 specific types of chondrolabral junctions have been described. There may be an abrupt transition with the labrum demonstrating a free edge margin (type A) or there may be a transition zone where the fibrous labrum blends with the glenoid hyaline cartilage (type B attachment) (**Fig. 1**). Initially the labrum was considered to normally be of low signal intensity on all MR pulse sequences; however, more recent studies have identified areas of increased linear or globular signal intensity in nearly a third of arthroscopically normal labral tissue.[7] In type B attachments, intermediate signal

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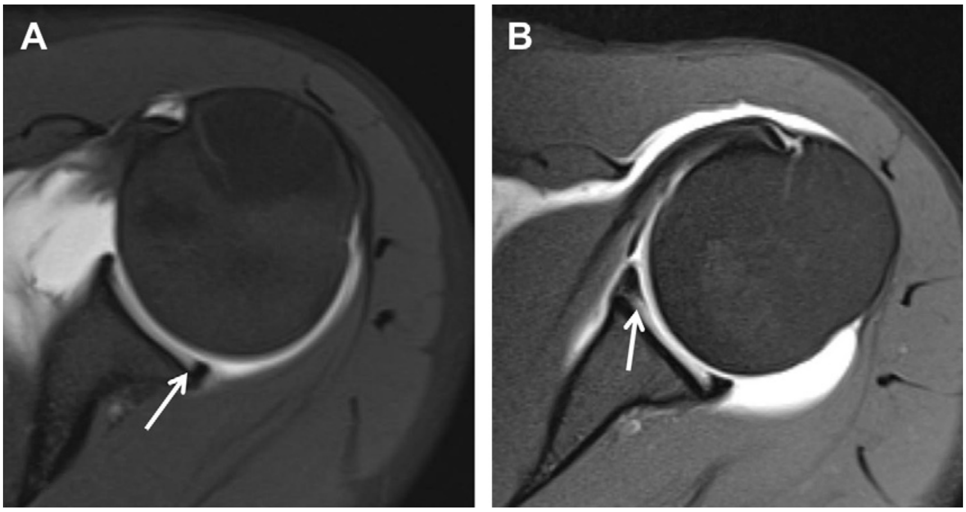

Fig. 1. Type A and B labrum. Axial fat-suppressed T1-weighted (repetition time/echo time, 514/8.6) MR arthrographic images demonstrate type A versus type B labrum. (*A*) Type A labrum characterized by abrupt chondrolabral transition and sharp marginated labral free edge is shown (*arrow*). (*B*) Ill-defined heterogeneous signal at the chondrolabral interface attributed to undercutting of the labral fibrocartilage by glenoid hyaline cartilage typical of a type B labrum is demonstrated (*arrow*).

intensity may be noted at the chondrolabral junction corresponding to the transitional zone of fibrocartilage, which should not be misinterpreted as a labral tear.[8]

Typically considered to be triangular or rounded in cross section, a range of glenoid labral morphologies has been described. Park and colleagues[9] evaluated labral shape on 108 arthrograms of asymptomatic volunteers and found a triangular shape to be most common (anterior, 64%; posterior, 47%) followed by rounded (17%, 33%). Flat, cleaved, notched, or absent labrum was also seen. The labrum typically measures approximately 4 mm in width and 3 mm in thickness; however, broad variation in labral size from 2 to 14 mm between normal individuals exist, thus rendering size criteria of little diagnostic utility.[7]

Superior Labrum

The labrum demonstrates its greatest variation in morphology and attachment above the equator. At the superior labrum, fibers from the proximal origin of the long head of the biceps tendon blend with the labrum forming the biceps labral complex (BLC). Three distinct types of complexes have been described (**Fig. 2**).[4] In a type I BLC, the labrum is firmly attached to the glenoid rim, with no intervening cartilage or central free edge. In a type II BLC, the attachment of the glenoid labrum and biceps tendon to the glenoid occurs more medially and there is continuation of the hyaline cartilage under the labrum accompanied by a small synovial-lined sulcus between the labral free edge and cartilage. In a type III BLC, a prominent triangular meniscoid labrum projects into the joint space and results in a deep recess that may be continuous with a sublabral foramen (**Fig. 3**).

The sublabral sulcus or recess present in type II and III BLCs represents the most frequent normal anatomic variant of the superior labrum. A cadaveric study by Smith and colleagues[10] demonstrated a recess deeper than 2 mm to be present in 39% of specimens. The recess can be identified on routine MR imaging and is enhanced by the presence of a joint effusion or an intra-articular contrast solution.[10] Mischaracterization of this finding as a superior labral anterior-posterior (SLAP) II tear is a potential diagnostic pitfall.[11] Tuite and Orwin[12] described 3 key features of the superior recess to help differentiate it from an SLAP tear: (1) location: a sulcus typically extends only to the most posterior insertion point of the biceps tendon attachment to the labrum and glenoid[13]; (2) contour: a sulcus should demonstrate smooth margins, any irregularity in the contour should be considered suspicious for SLAP tear; and (3) orientation: the direction of increased signal intensity/fluid should extend medially, paralleling the underlying glenoid cartilage; any extension laterally into the substance of the labrum should be considered pathologic. A shallow contrast-filled cleft can sometimes be depicted between the labrum and the biceps, the so-called bicipital labral sulcus (**Fig. 4**).[14]

A second normal anatomic variant of the superior labrum is the sublabral foramen that may be seen in association with a sublabral sulcus or in isolation. Present in 11% of normal patients,[15] the foramen represents a focal developmental

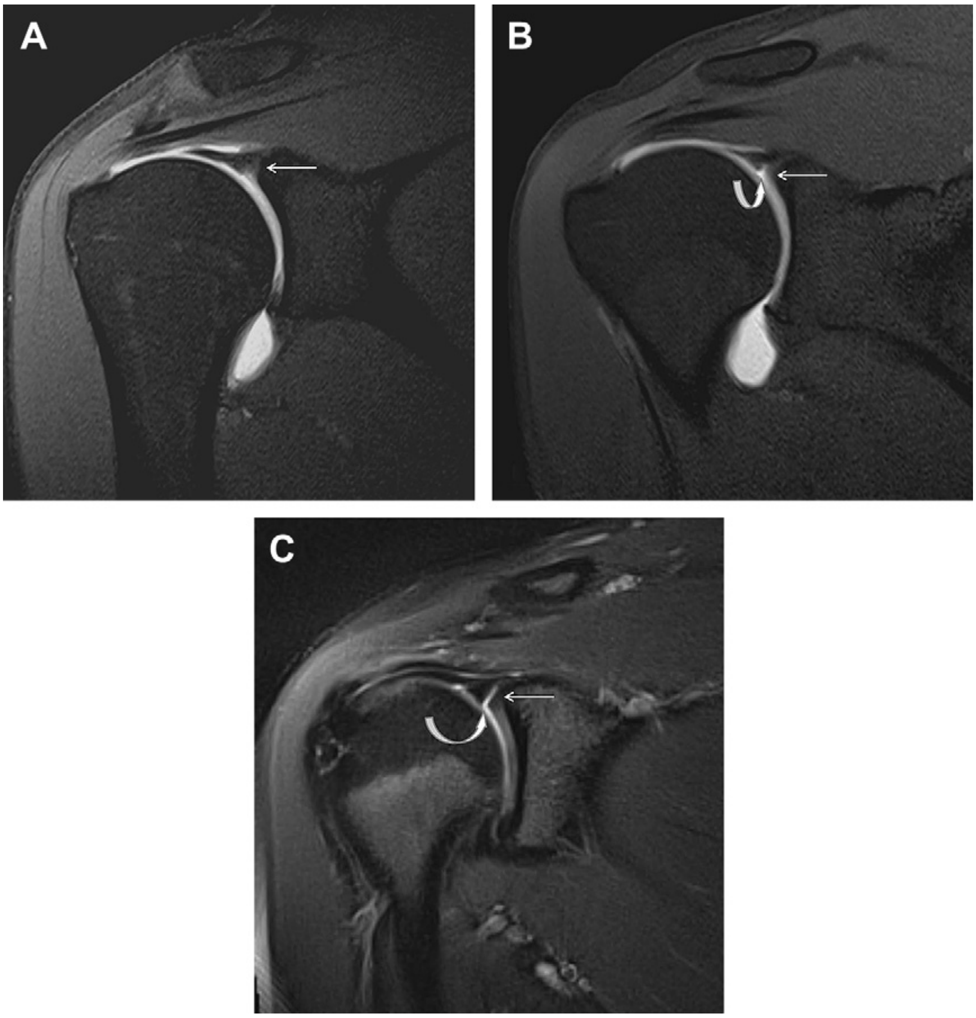

Fig. 2. BLC. Three distinct types of BLC have been described. (*A*) Type I BLC. Oblique coronal fat-suppressed T1-weighted (repetition time/echo time [TR/TE], 446/8.6) MR arthrographic image demonstrates a smooth, firm attachment of the labrum to the superior glenoid (*arrow*) with no intervening sulcus. (*B*) Type II BLC. Oblique coronal fat-suppressed T1-weighted (TR/TE, 446/8.6) MR arthrographic image demonstrates continuation of the hyaline cartilage under the labrum (*arrow*) accompanied by a contrast-filled sulcus between the labral free edge and cartilage (*curved arrow*). (*C*) Type III BLC. Oblique coronal fat-suppressed T2-weighted (TR/TE, 3410/72) image shows a prominent triangular meniscoid labrum outlined by fluid because of a deep sublabral sulcus (*curved arrow*) that parallels the underlying glenoid cartilage (*arrow*) extending through the superior labral base.

detachment of the anterosuperior labrum, which may be confused with an anterior labral tear if care is not taken to note features of this anatomic variant (**Fig. 5**). Again, location is a key factor because the normal foramen is identified along the anterosuperior quadrant between the 1-o'clock to 3-o'clock position. The sublabral foramen can vary in extent from a focal detachment to involvement of the entire anterosuperior quadrant. Initial descriptions of the location of the foramen stated that it should not extend below the level of the midglenoid notch that is present at the physeal line or junction of the superior and middle thirds of the glenoid; however, Tuite and colleagues[16] noted that in some patients a sublabral foramen may extend below the midglenoid notch. Smooth margins of the foramen, no significant displacement (<1–2 mm) of the detached labrum, and lack of associated traumatic injuries in the adjacent capsuloligamentous structures are additional helpful parameters to distinguish this variant from a labral tear. The sublabral foramen provides a communicating pathway between the glenohumeral joint and the subscapularis recess (**Fig. 6**). Loose bodies may extrude through a sublabral foramen and collect in the subscapularis recess.[17] Constricted joint fluid access to the subscapularis recess through the sublabral foramen should not be misconstrued as a type II SLAP tear with associated paralabral cyst. High origin of the middle and inferior GHLs (MGHL and IGHL) with narrowing of Weitbrecht foramen may promote extension of fluid and/or debris through the sublabral foramen as an alternative path to the subscapularis recess.[18] The presence of high origin of the anterior band of the IGHL

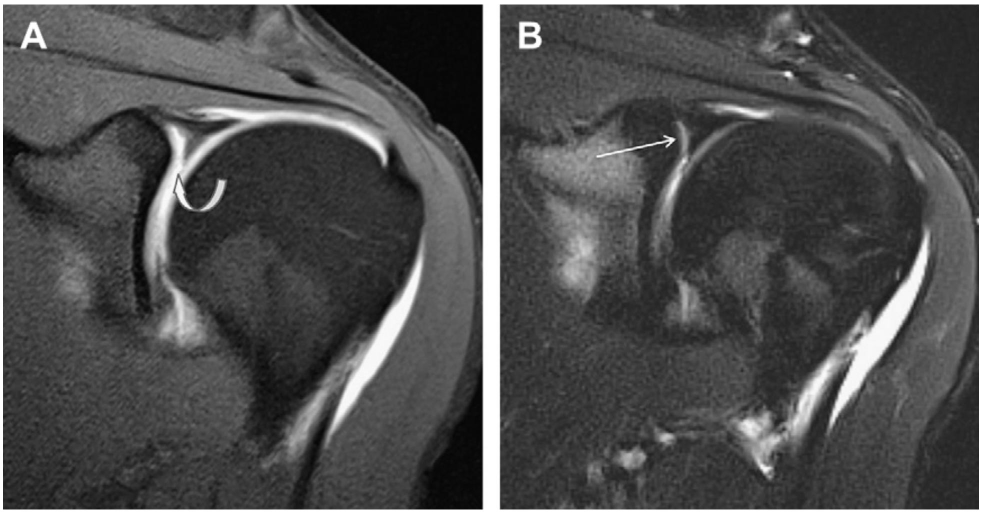

Fig. 3. Sublabral sulcus and meniscoid superior labrum: pseudo-SLAP. (*A*) Meniscoid attachment of the superior labrum is demonstrated on this oblique coronal fat-suppressed T1-weighted (repetition time/echo time [TR/TE], 698/8.6) MR arthrogram. Note a linear focus of contrast extending into the sublabral sulcus (*curved arrow*). (*B*) Corresponding oblique coronal fat-suppressed T2-weighted (TR/TE, 5880/79) image shows hyaline cartilage paralleling the glenoid margin manifested by linear intermediate signal intensity (*arrow*). The diagnosis of a sulcus is supported by the lack of lateral extension of contrast into the substance of the labrum, irregular labral margins, or extension of signal/contrast posterior to the biceps anchor.

was recently reported as a potential imitator of sublabral foramen.[19]

The anterosuperior labrum may also be diminutive or absent. The combination of an absent anterosuperior labrum and a thickened cordlike MGHL is termed the Buford complex; this is a relatively uncommon normal variant, occurring in approximately 1.5% of patients (**Fig. 7**).[20,21] This variant is important to recognize because it may also be misinterpreted as a labral tear or a displaced long head of the biceps tendon. Care should be taken to follow the cordlike structure on consecutive axial images cross-referencing them in the sagittal plane.

Fig. 4. Labral bicipital sulcus. Oblique coronal fat-suppressed T1-weighted (repetition time/echo time, 446/8.6) MR arthrogram demonstrates a labral bicipital sulcus manifested by a shallow cleft with smooth margins located between the undersurface of the proximal intra-articular biceps tendon and the superior labrum (*arrow*).

MR Imaging Technique

The labrum is routinely evaluated in all 3 planes on MR imaging, with the axial plane providing the most diagnostic information and the coronal plane serving an adjunctive role for evaluation of the superior labrum and inferior glenohumeral capsulolabral complex. Several reports have detailed the importance of proper shoulder positioning to optimize evaluation of its complex anatomy and specifically to aid in detection of subtle abnormalities of the glenoid labrum and GHLs. The shoulder is routinely imaged in neutral or slight external rotation. The degree of rotation can be assessed by noting the position of the bicipital grove on axial images. Significant internal rotation should be avoided for conventional MR imaging of the shoulder because it results in medial displacement of the joint capsule and contraction of the subscapularis tendon, both of which may obscure the subjacent anteroinferior labrum. MR imaging of the shoulder with the arm in alternate positions has been advocated to better assess the integrity of specific labroligamentous structures.

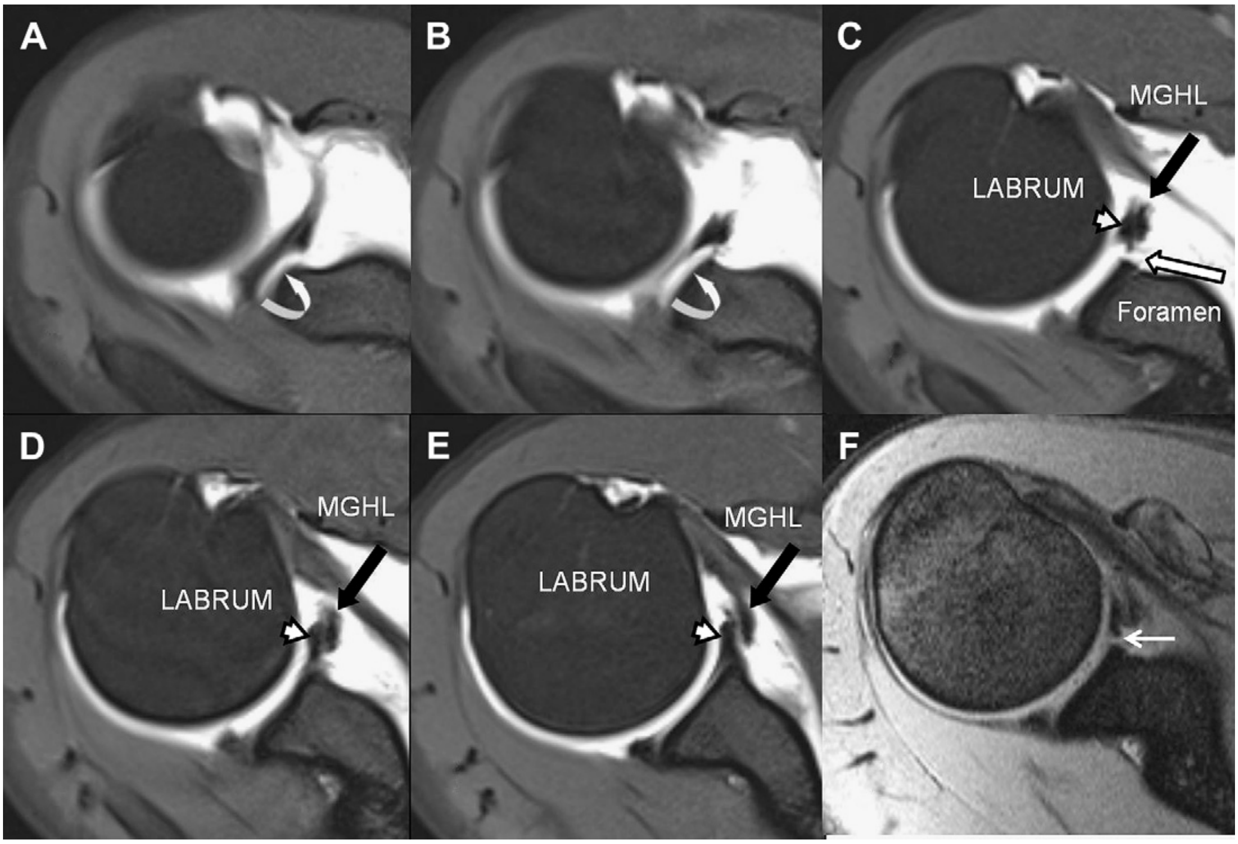

Fig. 5. Sublabral sulcus and foramen. Consecutive axial fat-suppressed T1-weighted (repetition time/echo time [TR/TE], 617/8.6) MR arthrographic images demonstrate the coexistence of a sublabral sulcus and sublabral foramen in a 21-year-old woman. (*A*, *B*) Note contrast located deep to a smooth superior labrum denoting the sublabral sulcus (*curved arrow*). (*C*) Continuing inferiorly, there is focal detachment of the anterosuperior labrum consistent with sublabral foramen (*open arrow*) with communicating neck of contrast extending from the glenohumeral joint to the subscapularis recess. Note the normal-appearing anterior labrum (*arrowhead*) and MGHL (*black arrow*) (*C–E*). (*F*) Conventional axial gradient echo (TR/TE, 610/15) image of the same patient at a comparable level to image C demonstrates the nonarthrographic appearance to the sublabral foramen (*arrow*) characterized by a smoothly marginated, nondisplaced anterosuperior labrum.

Abduction and External Rotation

Tirman and colleagues[22] originally described the use of abduction and external rotation (ABER) positioning for evaluation of the rotator cuff. Other investigators have since noted improved detection of anteroinferior labral pathology with the ABER technique.[23,24] Imaging is performed using a flexible coil, with the arm above the head, the elbow flexed, and palm facing upward, thus placing tension on the anteroinferior capsulolabral complex and potentially revealing otherwise-occult pathology of the labrum or IGHL (Fig. 8). Kwak and colleagues[24] described the ABER position as optimal for evaluation of the IGHL and advocated it as an adjunct to routine imaging examination. In a recent publication, Schreinemachers and colleagues[25] retrospectively compared the sensitivity and specificity of conventional arthrograms with single arthrographic series in ABER position. After reviewing 250 arthrograms with arthroscopic correlation in 92 patients, the investigators found no significant difference in detection of anteroinferior labroligamentous injury. The investigators concluded that limited study with images acquired only in the ABER position could replace the more time-consuming complete examination if there was only a clinical concern for anteroinferior labroligamentous pathology. In another recent investigation, Takubo and colleagues[26] evaluated the nonarthrographic MR imaging technique in ABER position and found comparable sensitivity and specificity to arthroscopy for the identification of a biomechanically intact IGHL. A recognized downside to this and other adjunctive positions is prolonged examination time. In addition, some patients experience discomfort and/or a sensation of instability, particularly with the ABER position, and may not be able to tolerate this portion of the examination.

Flexion, Adduction, and Internal Rotation

Imaging of the shoulder in flexion, adduction, and internal rotation (FADIR) has been advocated to

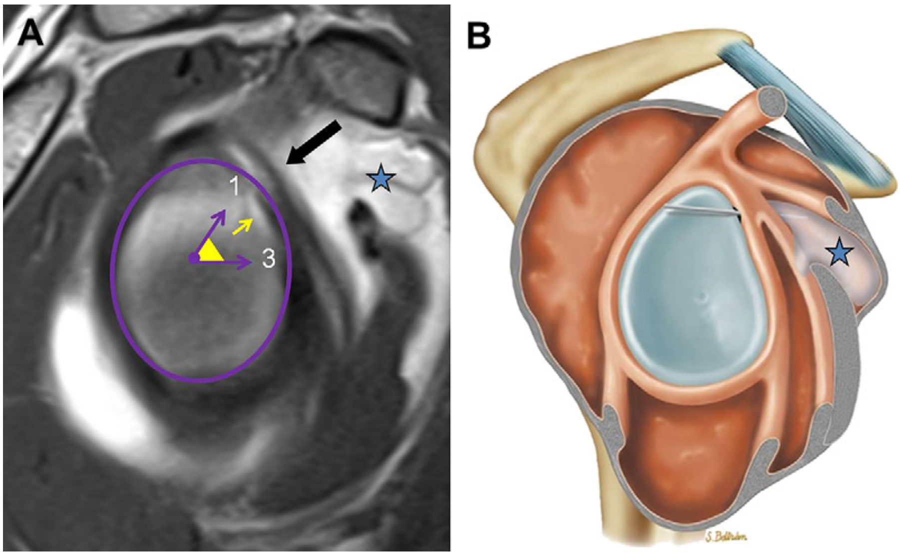

Fig. 6. Sublabral foramen anatomy. (*A*) Oblique sagittal T1-weighted (repetition time/echo time, 512/9.4) MR arthrographic image from same patient in Fig. 5 demonstrates typical location of the sublabral foramen (*yellow arrow*) between the 1-o'clock and 3-o'clock positions of the anterosuperior labral quadrant, at the site of attachment of the MGHL (*black arrow*), subscapularis recess (*blue star*). (*B*) Anatomic illustration shows the sublabral foramen as a communicating pathway from the glenohumeral joint into the subscapularis recess (*blue star*). (*Courtesy of* Salvador Beltran, MD.)

better evaluate the posterior capsulolabral complex. The FADIR position is achieved by placing the patient's arm across the chest with the hand on the contralateral shoulder. Chiavaras and colleagues[27] evaluated the impact of FADIR position in the detection of posterior labral tears in a recent small preliminary retrospective review and found it to be a useful adjunct to conventional imaging (Fig. 9).

Adduction and Internal Rotation

Nonarthrographic MR imaging with the arm in internal rotation may cause redundancy of the anteroinferior capsular structures and obscuration of the underlying labrum, potentially leading to false-negative interpretations.[28] With the administration of intra-articular contrast and distension of the joint, capsular apposition becomes less problematic. Song and colleagues[29] introduced the adduction and internal rotation (ADIR) position at MR arthrography and evaluated its diagnostic performance compared with ABER and neutral position in the assessment of anterior inferior labral lesions. In their retrospective review of patients found to have anteroinferior labroligamentous injury at arthroscopy, the investigators reported that ADIR was superior to ABER and neutral position in the discrimination between subtypes of Bankart injuries.

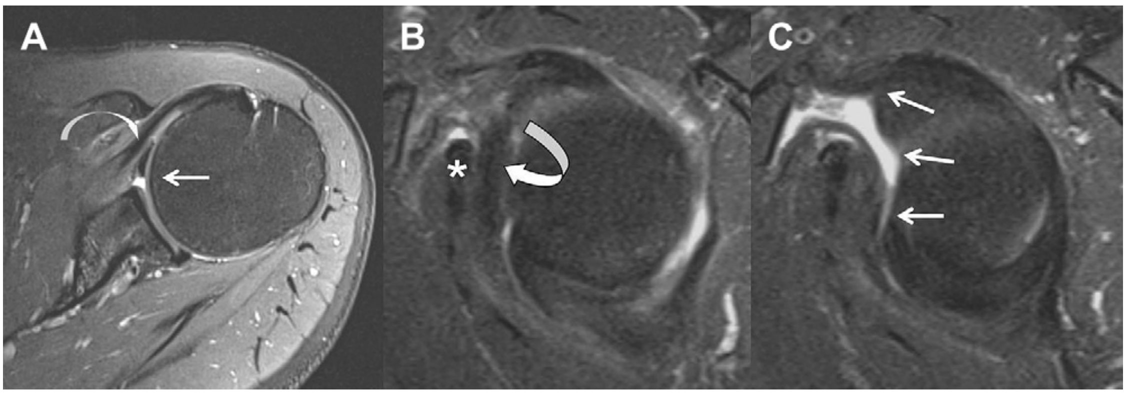

Fig. 7. Buford complex. (*A*) Axial fat-suppressed proton density (repetition time/echo time [TR/TE], 3030/33) image demonstrates cordlike thickening of the MGHL (*curved arrow*) and absence of the anterosuperior labrum (*arrow*) compatible with a Buford complex. (*B*, *C*) Consecutive oblique sagittal fat-suppressed T2-weighted (TR/TE, 5000/62) images confirm the findings of cordlike thickening of the MGHL (*curved arrow*) coursing deep to the subscapularis tendon (*asterisk*) associated with an absent anterosuperior labrum (*arrows*).

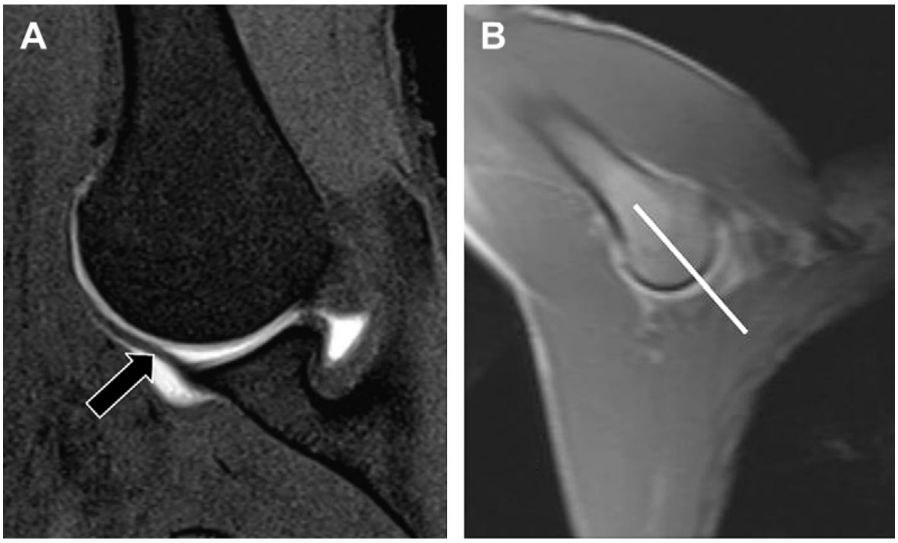

Fig. 8. IGHL in ABER position. (*A*) Oblique axial T1-weighted (repetition time/echo time, 583/8.6) fat-suppressed MR arthrogram with the arm in ABER position demonstrates an intact anterior band of the IGHL under tension (*arrow*). (*B*) Localizer image obtained specifically for the ABER series acquisition with overlying scout line demarcates plane of section in (*A*).

CARTILAGE

Anatomy and Histology

The articular surfaces of the glenoid fossa and the humeral head are lined by hyaline cartilage. Articular congruity of the glenohumeral joint is improved by normal alterations in the cartilage thickness. There is relative thinning of the articular cartilage of the glenoid centrally and thickening along the periphery. In contradistinction, the

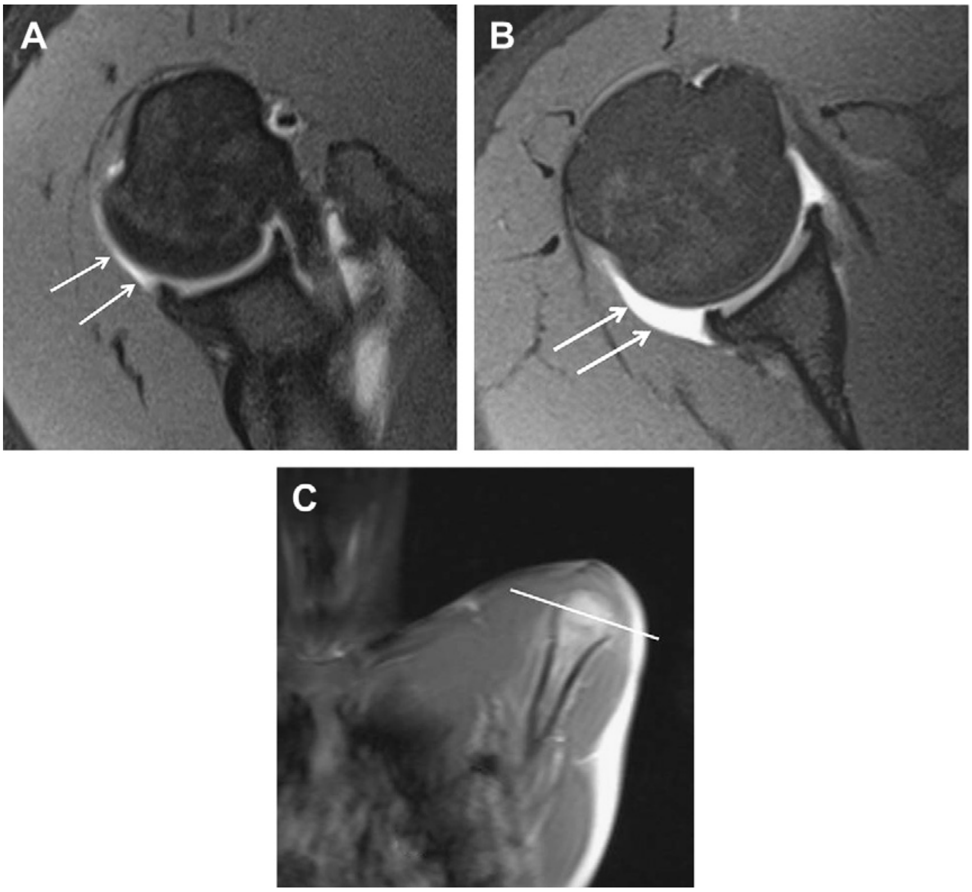

Fig. 9. FADIR position. (*A*) Oblique axial T1-weighted (repetition time/echo time, 619/11) fat-suppressed MR arthrogram with the arm in FADIR position demonstrates increased tension placed on an intact posterior capsulolabral complex (*arrows*) relative to neutral rotation (*B*). (*C*) Localizer image obtained specifically for the FADIR series acquisition with overlying scout line demarcates plane of section in (*A*).

articular cartilage of the humeral head is thicker centrally and thinner near its margins.

A focal well-demarcated articular cartilage defect at the central aspect of the glenoid termed the bare spot has been reported in the surgical and radiologic literature (**Fig. 10**). Burkhart and colleagues[30] reported its consistent location at the central aspect of the inferior glenoid and noted that it provided a useful landmark at arthroscopy to quantify the degree of glenoid bone loss. However, in a subsequent study by Kralinger and colleagues[31] in which 3-dimensional computed tomography of cadaveric specimens was performed, the investigators discovered variation in the location of the bare spot. Evaluation in the pediatric population using MR imaging has also shown some slight but significant variability in the location of the bare spot. Kim and colleagues[32] also noted a considerable lower incidence in the pediatric population supporting the hypothesis that this may be an acquired finding.

Focal thickening of the subchondral bone along the central aspect of the glenoid fossa is an additional normal variant termed the Ossaki tubercle. This is typically accompanied by thinning of the overlying cartilage. These variants should not be mischaracterized as osteochondral injuries. The absence of subchondral bone marrow signal abnormality and lack of intra-articular loose bodies are pertinent negative findings.

A bare area of the humeral head devoid of articular cartilage or sulcus has also been described.

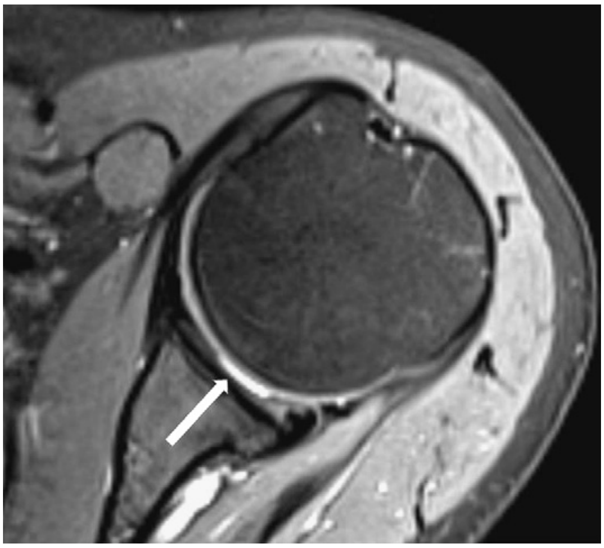

Fig. 10. Bare area of the glenoid. Axial fat-suppressed proton density (repetition time/echo time, 2700/33) image through the midglenoid demonstrates a focal well-demarcated articular cartilage defect (*arrow*) located at the central aspect of the glenoid compatible with bare area. Debate remains whether this represents a normal variant or an acquired lesion.

Located posteriorly between the posterior insertion of the joint capsule and synovial membrane and the adjacent articular cartilage, this bare area may be confused with a Hill-Sachs impaction injury (**Fig. 11**). An additional bare area has been described between the supraspinatus insertion on the greater tuberosity and the adjacent articular cartilage. This bare area is used by surgeons to quantify partial-thickness articular surface tears. Failure to recognize and account for the bare area at imaging may lead to erroneous diagnosis or overestimation of partial thickness supraspinatus tendon tears. In contradistinction, widening of the bare area may be due to loss of the articular cartilage and/or undersurface supraspinatus tear.[33]

Assessment of glenohumeral articular cartilage abnormalities using routing MR imaging and MR arthrography has yielded only moderate diagnostic accuracy, in part because of the curved morphology and relative thinness of the glenohumeral articular cartilage.[34] Improvements in accuracy in identifying cartilage injury and loss have been made by application of advanced cartilage imaging techniques. Dietrich and colleagues[35] retrospectively reviewed performance of 3-dimensional water-excitation true fast imaging with steady-state precession sequence in 75 shoulder MR arthrograms with arthroscopic correlation and found good diagnostic performance. However, this technique was not compared directly with conventional imaging sequences, so it remains unclear if there is a diagnostic advantage. T2 mapping and delayed gadolinium-enhanced MR imaging of cartilage have been recently used to image the glenohumeral joint. These advanced imaging techniques may provide a mechanism to detect degenerative changes of glenohumeral articular cartilage before they are evident on anatomic imaging and theoretically at a stage where they may be reversible.[36,37]

LIGAMENTS

The large size discrepancy between the small glenoid and the large humeral head affords the shoulder joint the largest range of motion in the human body.[3] However, it also renders the joint inherently unstable and susceptible to dislocation and subluxation. Active and passive stabilizers serve to maintain stability of the shoulder.

The GHLs serve as important static stabilizers of the shoulder joint over a wide range of positions. Formed by localized thickenings of the glenohumeral joint capsule, the ligaments extend from the anterior and inferior margins of the capsule to the anatomic neck of the humerus. Three main

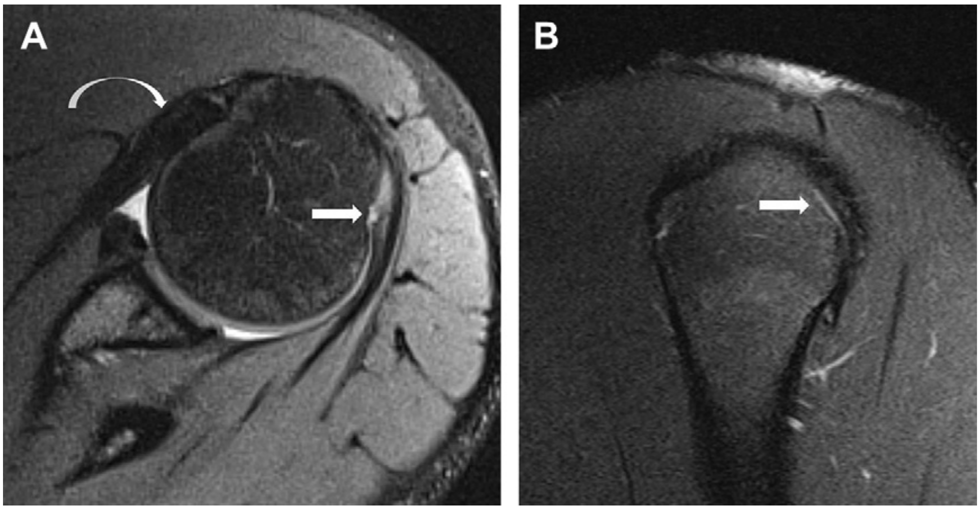

Fig. 11. Bare area of the humerus. (*A*) Axial proton density (repetition time/echo time [TR/TE], 3030/33) fat-suppressed image through the proximal humerus at the level of the subscapularis tendon (*curved arrow*) shows normal bare area of the humerus (*arrow*) close to the posterior capsular insertion and synovial membrane. This finding should not be mistaken for a Hill-Sachs impaction lesion, which would be located more superiorly at and above the level of the coracoid process. (*B*) The bare area (*arrow*) can also be appreciated in the oblique sagittal plane as demonstrated on this T2-weighted (TR/TE, 5000/62) image in the same patient.

ligaments have been described: superior GHL (SGHL), MGHL, and IGHL complex, the IGHL complex formed by anterior and posterior bands and intervening axillary recess.

The capsular mechanism provides the most important contribution to the stability of the glenohumeral joint. The anterior stabilizing structures include the fibrous capsule, GHLs, synovial membrane and recesses, fibrous glenoid labrum, subscapularis muscle and tendon, and scapular periosteum. Three types of anterior capsular insertions have been described according to the proximity of the insertion to the glenoid margin. In a type I configuration, the capsule inserts at the glenoid margin; type II inserts at the glenoid neck; and type III inserts more medially along the scapula. A direct relationship between the degree of medial insertion and glenoid instability has been suggested, with type III capsular insertions being associated more frequently with unstable shoulders.[2] However, care should be taken when evaluating MR arthrograms to not misinterpret overdistention of the joint capsule as a type III capsular insertion.

The posterior stabilizing structures include the posterior capsule, synovial membrane, glenoid labrum and periosteum, and posterior superior tendinous cuff and associated muscles (supraspinatus, infraspinatus, and teres minor). The long head of the biceps tendon and triceps tendon provide additional stability to the glenohumeral articulation as they course about the anterosuperior and inferior aspect of the capsule, respectively.

Several studies have examined the relative contribution of each GHL to stability depending on the position of the arm. Matsen and colleagues[38] and Caspari and Geissler[39] reported the absence of the SGHL and MGHL in a relative high percentage of individuals as an argument against the importance of these structures in maintaining joint stability. By selectively releasing these structures in cadaveric specimens, Turkel and colleagues[40] studied the individual contribution of each GHL at various degrees of abduction and rotation. The investigators concluded that the IGHL is critical in preventing anterior dislocation over a range of positions, especially with the arm abducted at 90°.[40] The validity of these results has been called into question, however, by other researchers who argue that the capsular structures work as a unit, and disrupting even a single component to assess its role in isolation disrupts the synergistic effect of the structures and the unit as a whole.[41]

Others have sought a different approach to study the GHLs. O'Connell and colleagues[41] measured tension of the GHLs in cadavers after application of controlled external torque and concluded that at 90° abduction, the IGHL and MGHL developed the most strain. At 45° abduction, the most strain was also developed by the IGHL and MGHL, but the SGHL was also somewhat tensed. At 0° of arm abduction, the SGHL was found to play a role limiting inferior translation of the humeral head with respect to the glenoid.

There also remains debate in the surgical literature regarding arthroscopic evaluation of the

GHLs. The question posed is whether the capsular structures identified at arthroscopy represent the classically described ligaments versus mere infolding of the joint capsule. In a combined cadaveric live subject study, Pouliart and Gagey[42] systematically examined a total of 300 shoulders for which arthroscopy, open dissection, or both were performed. The investigators reported that in neutral position or low degrees of abduction, the classically described capsular infoldings were identifiable in nearly all cases; however, with higher degrees of ABER, the capsule appeared smooth without distinct ligamentous structures. The investigators concluded that given the positional dependence, the infoldings seen at arthroscopy may not represent the true glenohumeral capsular ligaments.

Moore and colleagues[43] investigated the strain distribution of the IGHL at varying degrees of ABER using strain grid markers in cadaveric specimens. Although these investigators found that the strain on the anterior IGHL increased with external rotation, their results suggest that the capsule acts more as a complex fibrous sheet in a synergistic manner rather than as discrete components.[44]

SGHL

The SGHL extends from the superior glenoid margin and base of the coracoid, just anterior to the biceps tendon and courses inferolaterally to the anterior humerus just superior to the lesser tuberosity at the anatomic neck. The SGHL is nearly invariably present, identified at arthroscopy in 97% of patients[3] and in an arthrographic series by Palmer and colleagues[45] in 98% of patients. On MR imaging, the SGHL can be well visualized on axial planes as a low–signal intensity structure arising from the superior glenoid tubercle and paralleling the coracoid process. Oblique sagittal projection is also useful for demonstrating the normal course of the SGHL just inferior to the coracohumeral ligament and coracoid process.[46]

Variants

Variant origins of the SGHL reported in the radiologic literature include a common origin with the MGHL and/or direct origin from the biceps tendon.[14] Pradhan and colleagues[47] issued a case report of a rare variant in which the SGHL arises from the posterior labrum and overrides the biceps tendon origin without attaching to the anterior labrum or MGHL. The SGHL is normally thin but can become thickened in patients with an underdeveloped or absent MGHL.

MGHL

Of all the GHLs, the MGHL demonstrates the most variability.[3] The ligament may be absent in up to 30% of patients.[48] Initial arthroscopic studies of MGHL anatomy described an origin from the anterior margin of the scapula, just medial to the articular surface. The ligament then courses in an oblique inferolateral direction along the posterior margin of the subscapularis tendon and inserts on the neck of the humerus. In some patients, the ligament may blend with the joint capsule before inserting on the humerus just below the insertion of the SGHL. On MR arthrography, a distinct origin of the MGHL from the anterosuperior labrum has been described.[14] This origin is well demonstrated on axial MR arthrographic images in which the MGHL appears as a hypointense structure separated from the labrum by a small cleft. As the MGHL courses along the labrum, it may be mistaken for an anterior labral tear if care is not taken to follow the structure on continuous axial slices.[14] On more inferior axial images, the MGHL may appear as a rounded or flat hypointense structure that blends with the capsule or may be separate from the capsule. The inferolateral oblique course of the ligament across the anterior capsular space as well as its labral origin and distal capsular merging points are well demonstrated on oblique sagittal MR arthrographic images. Oblique coronal images are less helpful, and the MGHL is not routinely visualized in this plane unless thickened and redundant.[2]

The position and appearance of MGHL on MR imaging is greatly affected by patient positioning. With the arm in internal rotation, the ligament may appear redundant along the anterior margin of the scapular neck and simulate a loose body or capsular stripping (**Fig. 12**). With the arm imaged in external rotation, the MGHL is under tension and more likely to blend with the anterior joint capsule.[24]

Variants

The MGHL demonstrates the largest multiplicity of normal variants. Awareness of the normal anatomic variants is critical to preventing diagnostic errors. The MGHL may be absent in a significant proportion of patients. In anatomic studies by Moseley and Overgaard,[49] the MGHL was absent in up to 30% of specimens. Subsequent arthroscopic series by Wall and O'Brien[50] confirmed this finding. The MGHL was not visualized in 12% to 21% of patients on MR arthrography.[9,14,45] Absence or attenuation of the MGHL is often associated with a prominent subscapularis recess.

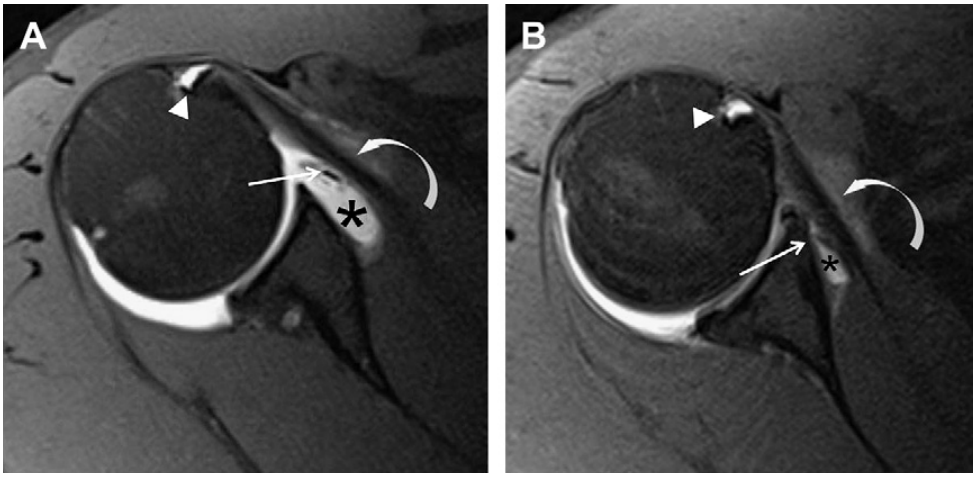

Fig. 12. MGHL deviation between neutral and internal rotation. Axial fat-suppressed T1-weighted (repetition time/echo time, 514/8.6) MR arthrographic images in neutral (*A*) and internal rotation (*B*) in a patient with a history of prior labral repair. Note medial deviation of MGHL (*arrow*) along the articular surface of the subscapularis tendon (*curved arrow*) as well as decreased volume of the subscapularis recess (*asterisk*) in internal rotation. The migrated MGHL may be potentially misinterpreted as a displaced labral fragment or scapular stripping. The position of the intertubercular grove (*arrowhead*) is used to assess rotation.

Variants involving the origin of the MGHL are also frequently identified. The most common of theses variants is a conjoint origin with either the SGHL or IGHL. Variants in which there is a common origin with the SGHL and biceps tendon or conjoined origin with the biceps tendon alone and absent SGHL may also be observed.[2]

The MGHL may be diminutive or thickened, even cordlike. A well-recognized and frequently cited normal variant is the Buford complex, which includes a cordlike thickening of the MGHL and an absent anterosuperior glenoid labrum.[20,21] Present in 1.5% of patients, this variant may be mistaken for detachment of the anterosuperior labrum on axial images at the level of the superior glenoid.[21] Evaluation of the structure on consecutive axial images helps to demonstrate the superior origin and distal capsular merge and to differentiate it from a labral tear. A thickened cordlike MGHL can also be identified on oblique sagittal images. The MGHL more frequently appears thickened in association with a normal superior labrum or in association with a sublabral foramen.[20] Cases of longitudinal splitting or duplication of the MGHL have been reported (**Fig. 13**). In these cases, oblique sagittal images show a double parallel line along the course of the MGHL, and axial images demonstrate a U-shaped

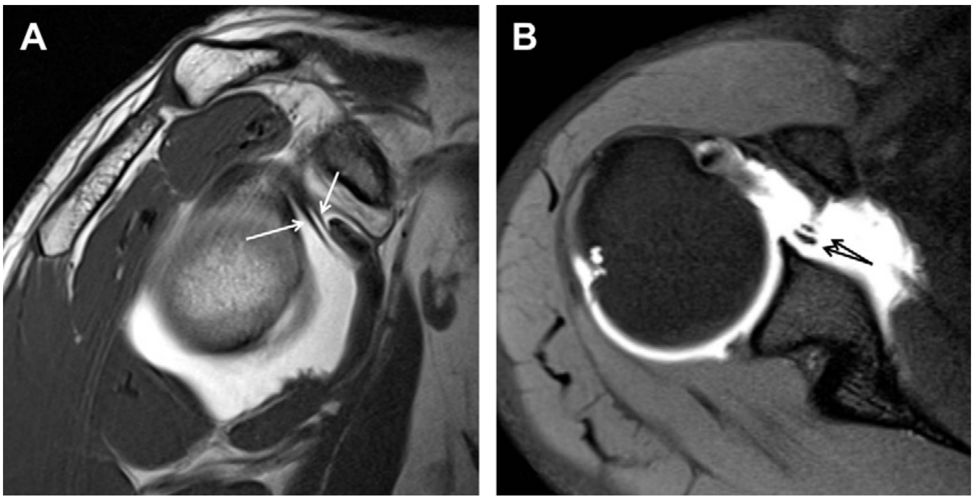

Fig. 13. Duplicated MGHL versus remote longitudinal split tear. (*A*) Oblique sagittal T1-weighted (repetition time/echo time [TR/TE], 491/9.4) MR arthrogram image shows 2 parallel low–signal intensity structures along the course of the MGHL (*arrows*). (*B*) Corresponding axial T1-weighted (TR/TE, 514/8.6) fat-saturated arthrogram in the same patient demonstrates contrast extending between the 2 distinct portions of the MGHL. A duplicated configuration of the ligament in the axial plane has also been described (*arrows*).

structure that may simulate a labral cleft or tear. Debate exists as to whether this represents a normal variant or a partially healed longitudinal split tear of the MGHL.[2]

Previous investigators have noted an association between the presence of a sublabral foramen, Buford complex, and SLAP lesions.[51,52] In the largest series to date, Ilahi and colleagues[53] prospectively analyzed 334 shoulder arthroscopies for association between anatomic variants of the anterosuperior labrum with pathology. These investigators found a significantly higher incidence of SLAP lesions in patients with variants involving partial detachment from the glenoid (sublabral foramen with or without cordlike MGHL and Buford complex), whereas in patients with more standard anatomy or only a thickened MGHL, no such association was found. The investigators hypothesized that the presence of anterosuperior labral variant anatomy may result in higher stresses on the superior BLC, predisposing to injury.

The foramen of Weitbrecht represents a normal communication between the glenohumeral joint capsule and the subscapularis bursae located between the SGHL and MGHL. Another communication, the foramen of Rouvière, exists slightly more inferior and is located between the MGHL and IGHL.[46] When the MGHL is absent, a single large communication between the glenohumeral joint and subscapularis bursa may be present, rendering the latter redundant (**Fig. 14**).[14,54] Conversely, in a recent report, Bencardino and colleagues[18] postulated that a high riding and thickened MGHL may result in constriction of the foramen of Weitbrecht, which in the presence of a sublabral foramen may render the latter as a constricted communicating pathway between the glenohumeral joint and the subscapularis recess, thus promoting the formation of a pseudoparalabral cyst about the anterosuperior quadrant.

IGHL COMPLEX

The IGHL complex is composed of an anterior and posterior band and an intervening portion, the axillary recess. The complex is consistently present.[55] The anterior band arises from the anterior glenoid rim/labrum at approximately the level of the midglenoid notch, between the 2-o'clock to 4-o'clock positions, which is more cranial than the origin of the posterior band, arising at the 7-o'clock to 9-o'clock position. The posterior band also inserts more medially than the anterior band and may be identified inserting along the glenoid neck. Distally, the IGHL inserts at the surgical neck of the humerus. Two distinct patterns of humeral insertion have been described: (1) a collarlike attachment in which the entire IGHL inserts slightly inferior to the articular edge of the humeral head and (2) a V-shaped attachment in which the anterior and posterior bands of the IGHL attach adjacent to the articular edge of the humeral head, and the axillary pouch attaches at the apex of the V distal to the articular edge.[56] As discussed previously, when the arm is imaged in an ABER position, the anterior band of the IGHL becomes taut and is well visualized along its entire course.

Variants

The anterior band of the IGHL is normally thicker than the posterior band; however, the opposite may be seen. Normal slight variability in the insertion of the inferior glenohumeral ligamentous complex on the surgical neck of the humerus frequently results in a jagged appearance on axial

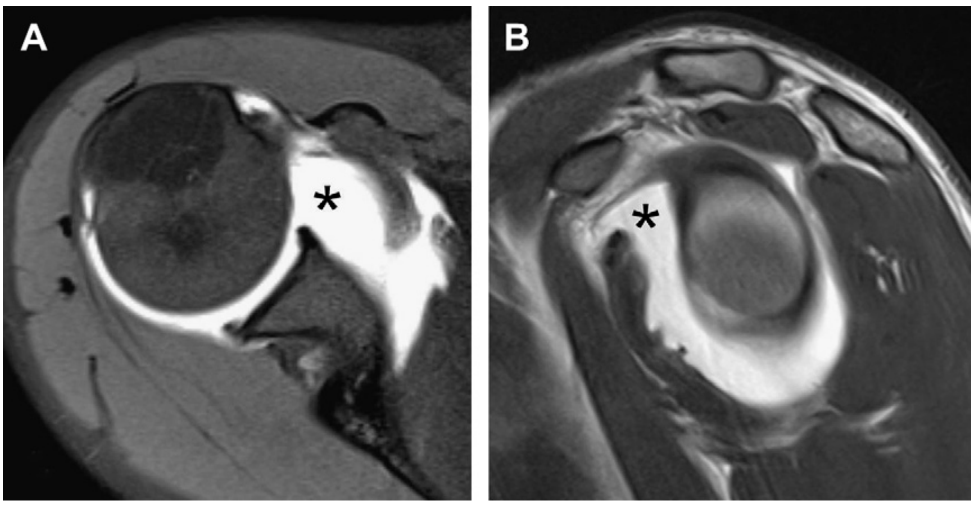

Fig. 14. Absent MGHL with large subscapularis bursa. (*A*) Axial T1-weighted (repetition time/echo time [TR/TE], 514/8.6) fat-saturated and (*B*) oblique sagittal T1-weighted (TR/TE, 420/9.4) MR arthrograms demonstrate a capacious subscapularis recess (*asterisk*) in the setting of an absent MGHL.

MR arthrographic images and should not be misinterpreted as fraying or tearing. Prominent synovial folds at the axillary recess may also be seen and can simulate debris or loose bodies.[14]

In a recent cadaveric study, Ramirez and colleagues[19] described a high origin of the anterior band of the IGHL located above the 3-o'clock position (**Fig. 15**). This high origin occurred in 4 of 10 specimens and could be mistaken for an anterior labral tear on MR arthrography. Tuoheti and colleagues[57] previously described a relationship between the long head of the biceps origin and the level of the anterior band of the IGHL origin from the anterior labrum. A variant origin of the anterior band of the IGHL from the MGHL has been previously described.[14] There have also been reports in the literature of a band of connective tissue attaching the IGHL to the SGHL termed the periarticular fiber system by Huber and Putz,[6] although there is still debate in the literature as to the nature and consistency of this structure.

A less well-known GHL of the superficial anterior capsule is the spiral GHL, named for the spiral course its fibers demonstrate when the arm is abducted and externally rotated. Originally described in classical anatomy as the fasciculus obliquus, it was revisited by Kolts and colleagues[58] in an anatomic series of 12 cadaveric specimens. The investigators reported that the ligament arises from the axillary component of the IGHL and the infraglenoid tubercle and courses laterally to fuse with the MGHL. Superiorly, the ligament blended with the superior portion of the subscapularis, inserting together with its tendon into the lesser tuberosity. In 2 other recent investigations by Merila and colleagues,[59,60] the ligament was demonstrated on MR imaging and gross dissection in 6 specimens and later confirmed to be present in 22 of 22 specimens. The investigators suggest that the spiral ligament may contribute to shoulder stability, particularly in the abducted and externally rotated position, or may affect the function of the MGHL; however, the biomechanical role of this structure is not yet fully understood.

SUMMARY

MR imaging and MR arthrography remain the primary imaging modalities for evaluation of patients with suspected internal derangement of

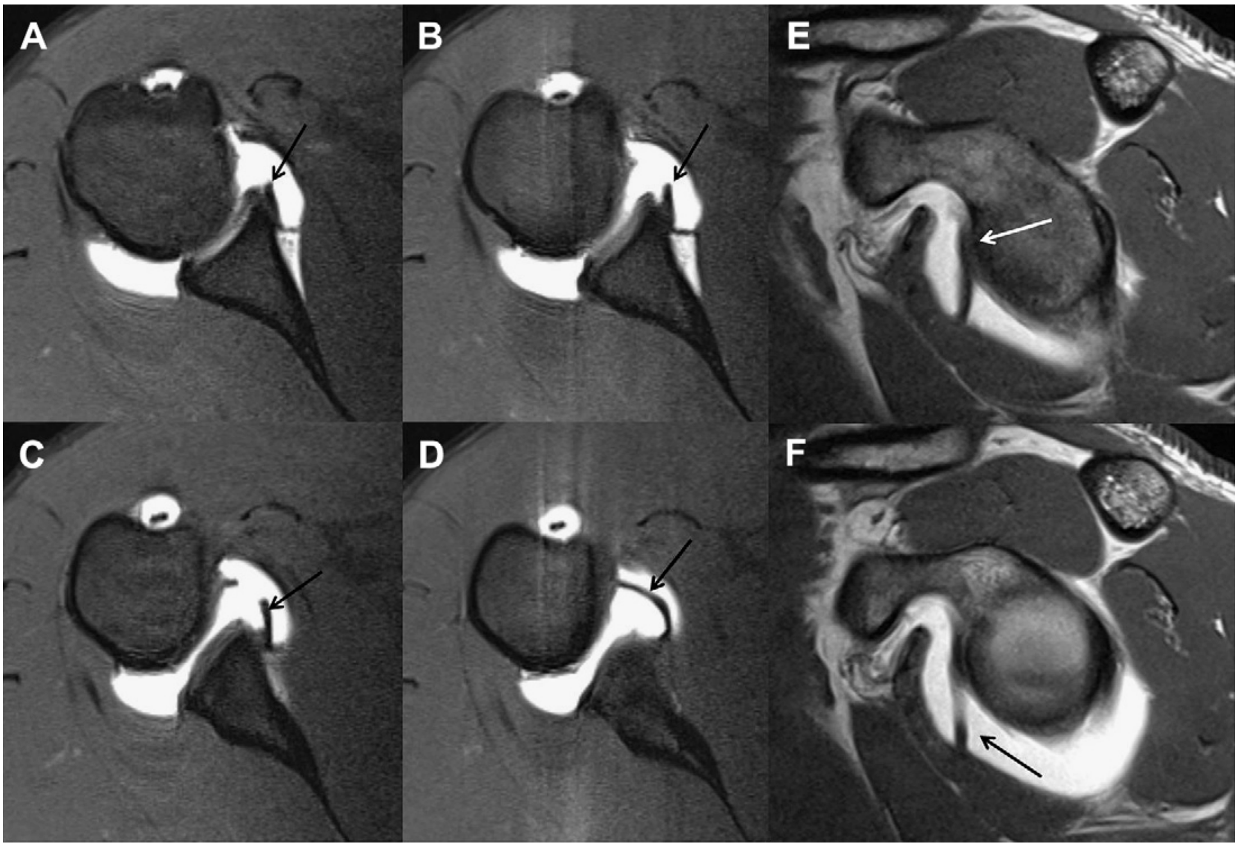

Fig. 15. High origin of the IGHL. (*A–D*) Consecutive axial fat-suppressed T1-weighted (repetition time/echo time [TR/TE], 514/8.6) MR arthrographic images demonstrate a high origin of the anterior band of the IGHL (*arrow*) from the anterior superior quadrant. (*E*, *F*) Oblique sagittal T1-weighted (TR/TE, 574/9.4) images from the same patient demonstrate the origin of the IGHL above the level of the anterior equator (*arrow* again denotes anterior band GHL). A high origin of the anterior band of the IGHL should not be mistaken for a displaced anterior labral fragment.

the shoulder. Accurate interpretation of these studies requires an understanding of the complex anatomy of the shoulder joint as well as the potential anatomic variants and imaging pitfalls that are routinely encountered. Although many of the variants and pitfalls have been extensively described in the radiologic and surgical literature, this body of knowledge continues to evolve.

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