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MR Arthrogram Features That Can Be Used to Distinguish Between True Inferior Glenohumeral Ligament Complex Tears and Iatrogenic Extravasation

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OBJECTIVE. The purpose of this study is to identify features seen at shoulder MR arthrography that distinguish between iatrogenic contrast material extravasation and inferior glenohumeral ligament (IGHL) complex tears.

MATERIALS AND METHODS. MR arthrograms (n = 1740) were screened for extravasation through the IGHL complex. Cases were defined on the basis of surgical findings or definitive lack of extravasation in a fully distended joint immediately after contrast agent injection. The location of the disruption and the morphologic features of the torn margin were assessed and compared between groups.

RESULTS. Anterior band disruption was present in eight of 16 patients with true tears and in zero of 19 patients with iatrogenic contrast material extravasation ($p < 0.001$). Isolated extravasation through the posterior half of the axillary pouch was present in 12 patients with iatrogenic extravasation, compared with none of the patients with true tears ($p < 0.001$). Thick ends were present in 10 of the true tears, whereas none of the cases of iatrogenic extravasation showed this finding ($p < 0.001$). Scarred margins were seen in eight true tears and none of the iatrogenic extravasation cases ($p < 0.001$). The presence of a torn anterior band, thick ligament, reverse-tapered caliber, and scarred appearance of the torn margin were shown to be 100.0% specific, and a torn posterior band showed 84.2% specificity for true tears. The presence of isolated involvement of the posterior portion of axillary pouch showed 63.2% sensitivity and 100.0% specificity for iatrogenic extravasation.

CONCLUSION. A torn anterior band, a thickened ligament (> 3 mm), reverse-tapered caliber, and scarred margin were 100.0% specific for a tear. Isolated disruption of the posterior axillary pouch was 100.0% specific for iatrogenic extravasation.

Keywords: arthrogram, extravasation, humeral avulsion of the glenohumeral ligament, inferior glenohumeral ligament complex

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Avulsion of the inferior glenohumeral ligament (IGHL) from its insertion on the medial humeral neck, otherwise known as the humeral avulsion of the glenohumeral ligament (HAGL) lesion, has a frequency of up to 9% in patients with glenohumeral instability [1–3]. Unfortunately, this diagnosis may be missed at both clinical examination and routine MRI interpretation. Detection is important, because arthroscopic or open surgical repair of HAGL lesions is associated with good clinical outcomes and lower recurrence rates, and failure to repair may result in recurrent anterior shoulder instability [4, 5].

The IGHL complex is composed of the anterior band, axillary pouch, and posterior band, which contributes to shoulder stability by resisting anterior and inferior translation of the humeral head. Disruption of the IGHL complex may occur at its humeral insertion, midsubstance, or glenoid insertion [6]. Mechanistically, the HAGL lesion is thought to arise secondary to hyperabduction and external rotation, usually affecting the anterior band, with one retrospective review showing that approximately 93% of such lesions involve the anterior band [7, 8].

Physical examination findings for the detection of IGHL complex lesions are nonspecific, underscoring the importance of accurate characterization at MRI. The previously described MRI findings of HAGL and IGHL complex lesions include increased signal intensity and thickening of the inferior capsule, extravasation of contrast material or a joint effusion seen tracking along the humeral neck, and a J-shaped axillary pouch. Occasionally, a bony fragment from humeral avulsion can be seen (bony HAGL) [9, 10].

Of these findings, extravasation of contrast material at shoulder MR arthrography

presents a diagnostic dilemma because of the possibility of iatrogenic contrast material leakage. The axillary recess capsule itself is a weak point that has been shown to be a frequent site of iatrogenic contrast material extravasation, which can mimic the MRI appearance of a true HAGL lesion [11]. The purpose of this study was to identify features seen at shoulder MR arthrography that can aid the clinical radiologist in distinguishing between iatrogenic contrast material extravasation and true IGHL complex tears and to determine the diagnostic performance of these imaging features.

Materials and Methods

Our retrospective multiinstitution study was approved by three institutional review boards (University of California, San Diego; VA San Diego Healthcare System; and Scripps Healthcare). This study was compliant with the HIPAA, and written informed consent was waived. An electronic database search was performed for three hospital systems to identify all patients who underwent MR arthrography of the shoulder and included the words "HAGL," "humeral avulsion," or "extravasation" in the radiology report from 2010 to 2016. A third-year radiology resident screened the 1740 MR arthrograms that were identified and evaluated the coronal T1-weighted fat-suppressed MR images for potential cases with extracapsular contrast agent extending through the IGHL complex. The senior author, a fellowship-trained musculoskeletal radiologist with 7 years of experience, then reviewed the prescreened cases and excluded cases where extravasation occurred or involved sites other than the IGHL complex, such as near the needle track or through the subscapular recess. Patients with previous shoulder surgery were also excluded. The identified cases were determined to be either true IGHL complex lesions or iatrogenic cases of extravasation. True IGHL complex lesions were defined as lesions proven at the time of surgery. Cases were attributed to iatrogenic extravasation when the IGHL complex was intact at surgery and, if operative data were unavailable, when there was definitive lack of extravasation on a fully distended joint immediately after joint injection (documented on at least one fluoroscopic image). Cases that did not clearly fall into one of these two groups (true vs iatrogenic lesions) were excluded. Of note, because this was a retrospective study, standardization of arthrographic technique was not possible. Various approaches were used by the radiologists for joint access, and only a few routinely saved the final arthrographic image of a distended joint.

The MR arthrograms were independently scored by three musculoskeletal fellowship-trained radiologists (with 8, 8, and 7 years of experience). The status of the IGHL complex, including the anterior band, axillary pouch, and posterior band, was assessed using all three imaging planes. When the axillary pouch was disrupted, the status of the anterior and posterior halves was noted. For all lesions, the location of disruption along the medial-lateral dimension was noted (humeral, midsubstance, or glenoid, as determined on coronal images). In addition, the morphologic features of the disrupted margin were evaluated using the following parameters: maximum thickness of the portion floating in contrast material (grade 0 = thin, measuring < 1 mm; grade 1 = medium, measuring 1–3 mm; grade 2 = thick, measuring > 3 mm), presence of a caliber change at the torn margin (grade 0 = tapering; grade 1 = reverse-tapering or becoming larger at the free end), and regularity of the torn margin (grade 0 = single thin fascicle; grade 1 = mop-head, defined as more than a single fascicle; grade 2 = scarred). Illustrations of caliber change and regularity are shown in Figures S1 and S2, respectively, which can be viewed in the *AJR* electronic supplement to this article (available at www.ajronline.org). In cases where scores varied among images from the same patient, the higher grade was considered. The scores of the first two radiologists were used in the primary evaluation, and when there was a discrepancy between these scores, the interpretation of the third radiologist was used as a tie breaker.

Descriptive statistics were analyzed for patient demographics, days between initial injury and MRI examination, and days between MRI examination and surgery (when available). A *t* test or the Mann-Whitney *U* test was performed to determine whether there was a statistically significant association between age and IGHL complex tearing, days between injury and MRI, and days between MRI and surgery between the two groups as appropriate. A Pearson chi-square test was performed to assess whether sex; location of the tear; involvement of the anterior band, axillary pouch, or posterior band; thickness; caliber change; or regularity were significantly associated with true tears of the IGHL complex. Sensitivity and specificity of these parameters were also calculated.

Results

Of 1740 shoulder MR arthrograms performed between January 2010 and December 2016, there were 35 examinations (2.0%) with contrast material extravasation inferiorly through the IGHL complex that fulfilled inclusion criteria. Of these 35 MR arthrograms, 16 (45.7%) were true IGHL complex lesions and 19 (54.3%) were cases of iatrogenic contrast material extravasation. Twenty-six cases underwent surgical correlation, and nine cases did not but showed no evidence of extracapsular contrast agent on a fully distended joint at the end of the fluoroscopy procedure.

Demographics

Of the 35 patients who underwent MR arthrography, there were 28 men and seven women. The mean age of patients with a true IGHL complex lesion was 29.8 years, compared with 36.6 years for those with iatrogenic cases ($p = 0.16$) (Table 1). The median time elapsed between injury and MRI examination was 354 days (range, 5–2920 days) for true tears and 1095 days (range, 21–10,950 days) for iatrogenic extravasation ($p = 0.236$). The median time elapsed between MRI examination and surgery was 40 days (range, 2–336 days) for true tears and 125 days (range, 49–278 days) for iatrogenic extravasation ($p = 0.142$). Thirty-three of 35 cases (94.3%) of contrast material extravasation through the IGHL complex were visualized at its humeral attachment, and two cases (5.7%) were visualized at the midsubstance (both were cases of true pathologic IGHL complex lesions) (Fig. 1).

Anatomic Lesion Localization

With regard to anatomic location, patients with true IGHL tears were more likely to have tears of the anterior band (8/16; 50.0%), whereas none of the 19 patients with iatrogenic extravasation showed anterior band disruption ($p < 0.001$). Patients with true IGHL tears were also more likely to have tears of the posterior band compared with patients with iatrogenic extravasation (8/16 [50.0%] vs 3/19 [15.8%]; $p = 0.035$) (Fig. 2). Although axillary pouch involvement was nearly universal in both groups, none of the true IGHL complex lesions had solitary extravasation through the posterior aspect of the axillary pouch, whereas this was present in 12 of 19 (63.2%) cases of iatrogenic extravasation ($p < 0.001$) (Fig. 3).

Morphologic Evaluation

The two groups showed significant differences in morphologic features, including maximal thickness, caliber change, and regularity (Table 1). Disrupted ends that were thin were present in two of 16 (12.5%) patients in the true IGHL complex lesion group, whereas nine of 19 (47.4%) patients in the iatrogenic extravasation group showed this finding ($p = 0.015$). Thick ends were present in 10 (62.5%) patients in the true IGHL complex lesion group, whereas none of the

TABLE 1: Demographics, Specific Anatomic Inferior Glenohumeral Ligament (IGHL) Involvement, and Morphologic Features of the Torn Ligament Comparing True IGHL Tears With Those Resulting From Iatrogenic Contrast Material Extravasation

Variable	True Tear (*n* = 16)	Iatrogenic Contrast Material Extravasation (*n* = 19)	*p*
Age (y), mean ± SD	29.8 ± 15.0	36.6 ± 13.1	0.16
Sex			
Female	5 (31.3)	2 (10.5)	0.27
Male	11 (68.8)	17 (89.5)	
Time between injury and MRI (d), median (range)	354 (5–2920)	1095 (21–10,950)	0.236
Location			
Humeral	11 (68.8)	19 (100.0)	0.112
Mid	2 (12.5)	0 (0.0)	
Anterior band			
Intact	8 (50.0)	19 (100.0)	< 0.001
Torn	8 (50.0)	0 (0.0)	
Axillary pouch			
Intact	1 (6.3)	0 (0.0)	0.269
Torn	15 (93.8)	19 (100.0)	
Solitary posterior involvement	0 (0.0)	12 (63.2)	< 0.001
Posterior band			
Intact	8 (50.0)	16 (84.2)	0.030
Torn	8 (50.0)	3 (15.8)	
Thickness			
Thin	2 (12.5)	9 (47.4)	0.015
Medium or thick	14 (87.5)	10 (52.6)	
Medium	4 (25.0)	9 (47.4)	0.172
Thin or thick	12 (75.0)	10 (52.6)	
Thick	10 (62.5)	0 (0.0)	< 0.001
Thin or medium	6 (37.5)	19 (100.0)	
Caliber change			
None	5 (31.3)	14 (73.7)	0.012
Taper or reverse-tapered	11 (68.8)	5 (26.3)	
Taper	3 (18.8)	5 (26.3)	0.595
None or reverse-tapered	13 (81.3)	14 (73.7)	
Reverse-tapered	8 (50.0)	0 (0.0)	< 0.001
None or taper	8 (50.0)	19 (100.0)	
Regularity			
Single fascicle	3 (18.8)	12 (63.2)	0.008
Mop-head or scarred	13 (81.3)	7 (36.8)	
Mop-head	5 (31.3)	7 (36.8)	0.728
Single fascicle or scarred	11 (68.8)	12 (63.2)	
Scarred	8 (50.0)	0 (0.0)	< 0.001
Single fascicle or mop-head	8 (50.0)	19 (100.0)	

Note—Except where noted otherwise, data are number (%) of patients. Percentages do not always total 100.0% because of rounding.

patients in the iatrogenic extravasation group showed this finding ($p < 0.001$) (Fig. 4). In addition, a reverse-tapered margin was present in eight (50.0%) patients in the true IGHL complex lesion group, whereas none of the patients in the iatrogenic extravasation group showed this finding ($p < 0.001$). Finally, a single fascicle at the disrupted margin was present in three (18.8%) of those with a true IGHL complex lesion versus 12 of 19 (63.2%) patients with iatrogenic extravasation ($p = 0.008$) (Fig. 5), and eight (50.0%) patients with true IGHL complex lesions had a scarred margin, whereas none of the patients with iatrogenic extravasation had a scarred margin ($p < 0.001$).

Sensitivity and Specificity Analyses

Sensitivity and specificity analyses showed that the presence of a torn anterior band, thick ligament, reverse-tapered caliber, and scarred appearance of the torn margin were shown to be 100.0% specific in predicting a true IGHL complex tear, and a torn posterior band showed a specificity of 84.2% for predicting a true IGHL complex tear (Table 2). In addition, the presence of solitary involvement of the posterior portion of axillary pouch showed 63.2% sensitivity for iatrogenic extravasation, but was 100.0% specific.

Discussion

Iatrogenic contrast material extravasation during shoulder MR arthrography is not rare and may result from excessive volume of contrast material, increased injection pressure, decreased joint capacitance, or a combination of these factors. A recent retrospective review of 294 shoulder MR arthrograms showed extravasation outside the needle path at a frequency of approximately 13.6% [11]. Although extravasation most commonly involved the subscapularis muscle, in five of 40 cases (12.5%), this occurred through the axillary recess [11]. Of these five cases, one case was an arthroscopically proven HAGL lesion, and the remaining four were iatrogenic [11]. It has been previously suggested that extraarticular contrast material extravasation serves as a valid and reliable sign of HAGL and posterior HAGL lesions, in addition to the well-described J-sign [9, 12, 13]. However, to our knowledge, there are no studies in the literature that delineate MRI features that may aid in differentiating iatrogenic extravasation from pathologic IGHL extravasation.

TABLE 2: Sensitivity and Specificity of Various Parameters of the Inferior Glenohumeral Ligament (IGHL) (Location, Margin Thickness, Caliber Change, Regularity) in Determining True IGHL Tears

Parameter	Sensitivity (%)	Specificity (%)
Torn anterior band	50.0	100.0
Torn axillary pouch	93.8	0.0
Tear of the posterior axillary pouch (solitary)	0.0	36.8
Torn posterior band	50.0	84.2
Thin margin	12.5	52.6
Thick margin	62.5	100.0
Reverse-tapered margin	50.0	100.0
Single fascicle	18.8	36.8
Scarred margin	50.0	100.0

Our study is the first, to our knowledge, to delineate such MRI features, with a specific focus on location and morphologic features of IGHL disruption. In terms of the anatomic location of the IGHL extravasation events versus tears, we found that a torn anterior band was seen exclusively in patients with true IGHL tears (none of the 19 patients with iatrogenic extravasation showed anterior band disruption) and that this finding was 100.0% specific for a true IGHL tear. However, because IGHL complex tears may be localized to the axillary pouch or posterior band, there is modest sensitivity of this finding (50.0%).

We also found that an isolated disruption of the posterior aspect of the axillary pouch (i.e., intact anterior band, anterior axillary pouch, and posterior band) was 100.0% specific for iatrogenic extravasation. This finding is supported by previous anatomic data from Bigliani et al. [6], who found that the posterior portion of the axillary pouch is the thinnest portion of the IGHL (mean measurements of 1.7 mm compared with 2.3–2.8 mm for the other portions of the IGHL complex). It would be expected that iatrogenic extravasation would occur through the weakest portion of the ligament. Note that this finding only showed 63.2% sensitivity, because iatrogenic contrast material extravasation may also involve the anterior portion of the axillary pouch or the posterior band. However, this is a highly specific finding that will aid in the confident diagnosis of iatrogenic extravasation rather than a true pathologic IGHL lesion.

Certain morphologic features were significantly more frequent among true tears of the IGHL complex, including thick ends (> 3 mm), reverse-tapered caliber change, and a scarred irregular margin of the torn ligament. All three of these morphologic findings were 100.0% specific for a true IGHL tear, findings that have not been previously described in the literature, to our knowledge. There are two potential explanations for this finding. Ligament thickening may be an adaptive response to chronic repetitive stress. This may be seen in unstable shoulders or in subjects who perform frequent overhead throwing motions. An acute overload injury in this chronically stressed area may result in the appearance of a thicker torn margin. Alternatively, thickened morphologic features may represent imaging findings of a delayed presentation of IGHL tears. In a prior review of 23 surgically proven HAGL lesions, five HAGL lesions that were initially missed at prospective MRI interpretation appeared to have areas of IGHL thickening at retrospective review (hypothesized to represent postinjury scarring), and the time of presentation from injury to orthopedic consultation in this study ranged from 6 months to 2 years [2].

Our study found a frequency of 0.9% of true IGHL tears among all shoulder MR arthrograms reviewed, which is much smaller when compared with two prior large surgical series showing frequencies of 7.5% and 9.3% [1, 3]. However, this is likely explained by the fact that these prior studies reviewed MRI examinations performed for anterior shoulder instability, whereas we examined MR arthrograms performed for a variety of indications [1, 3]. The series by Magee [2], which, like ours, examined all shoulder MR arthrograms performed for a variety of indications, and also found a lower frequency of HAGL lesions (1.6%).

There are limitations to our study, including the inherent weakness of a retrospective design and the limited number of cases in both groups. However, we used stringent inclusion criteria, and a surgical reference standard was present for all except for nine cases attributed to iatrogenic extravasation. These cases were included to increase the cohort size. However, only those cases where there was a definitive lack of extravasation for a fully distended joint were included. A true IGHL tear would have been expected to be evident under fluoroscopy in the setting of a fully distended joint. Another limitation is the variable time frame between the date of initial injury, MRI study, and surgery. Date of initial injury was considered because several patients indicated a history of multiple injuries or instability events. In addition, a few of our patients indicated that pain was present without recollection of a discrete injury. Subgroup analysis of the imaging appearances with acute versus chronic injuries in this investigation was not performed because of the small sample size. However, we believe our overall sample is representative of patients who undergo MR arthrography in a general radiology department. Finally, some cases had a prolonged time between MRI and surgery, with five cases having more than 180 days between MRI examination and surgery (two in the iatrogenic cohort [272 and 278 days elapsed] and three in the tear cohort [185, 211, and 336 days elapsed]). At retrospective review of the two cases in the iatrogenic cohort, both had fluoroscopy images captured at the end of the arthrogram showing a definitively intact capsule. Therefore, this excludes the possibility of misclassification in these two cases. Regarding the three cases in the tear cohort, we retrospectively reviewed the progress notes in the chart for these three cases and because of the consistency of symptoms and anatomic correlation between MRI and surgery, we believe they are correctly classified as tear cases.

In summary, a torn anterior band, a thickened ligament (> 3 mm), reverse-tapered caliber, and scarred appearance of the torn margin were shown to be 100.0% specific in differentiating a true IGHL complex tear from iatrogenic extravasation on shoulder MR arthrograms. An isolated disruption of the posterior aspect of the axillary pouch showed 100.0% specificity for iatrogenic extravasation. These findings should be immediately applicable in the differentiation of iatrogenic extravasation from real IGHL complex lesions.

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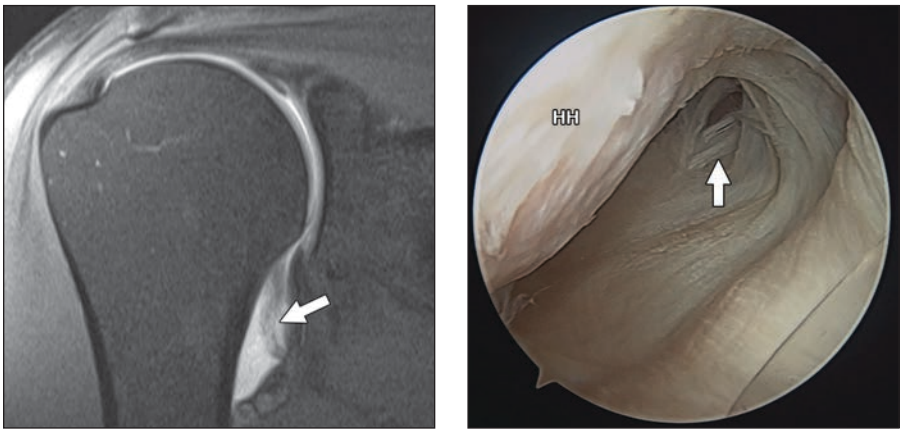


Fig. 1—46-year-old man with arthroscopically proven inferior glenohumeral ligament complex tear.
A, Coronal oblique T1-weighted fat-suppressed MR arthrogram shows disruption of axillary pouch at midportion (*arrow*). Disrupted margin measured up to 2.9 mm (medium thickness) and had mop-head configuration.
B, Inferior arthroscopic view obtained 185 days after MRI confirms torn axillary pouch (*arrow*). HH = humeral head.

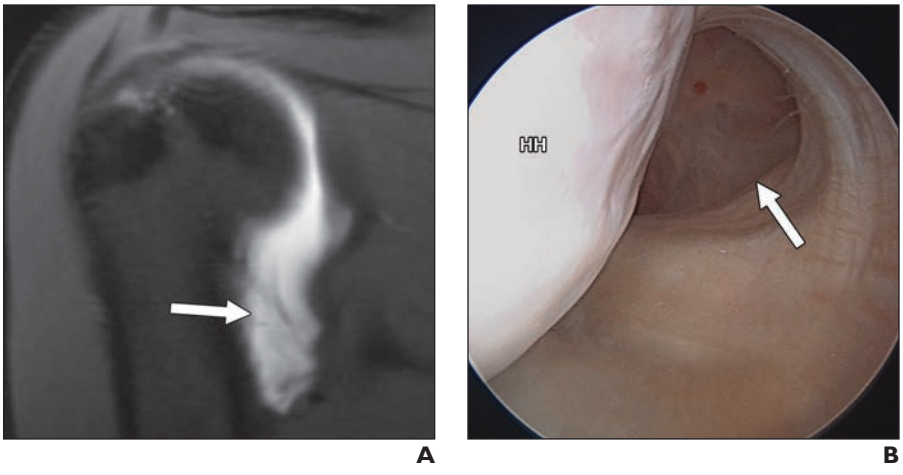


Fig. 2—Two patients with inferior glenohumeral ligament (IGHL) complex tears with posterior band involvement.
A and **B,** 19-year-old female volleyball player. Coronal oblique T1-weighted fat-suppressed MR arthrogram (**A**) shows disruption at humeral attachment with margin of medium thickness (*arrow*). Posterior inferior arthroscopic view obtained 32 days after MRI (**B**) shows torn IGHL complex involving posterior band (*arrow*). HH = humeral head.

(Fig. 2 continues on next page)

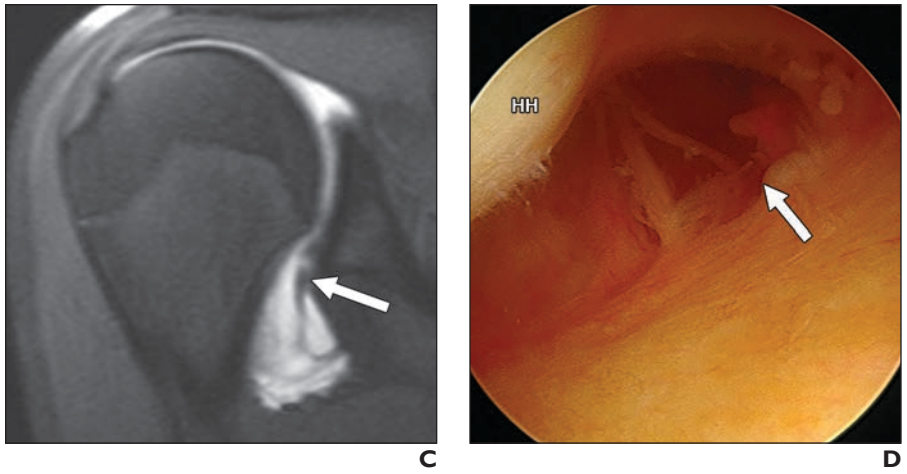


Fig. 2 (continued)—Two patients with inferior glenohumeral ligament (IGHL) complex tears with posterior band involvement.
C and **D,** 15-year-old female volleyball player. Coronal oblique T1-weighted fat-suppressed MR arthrogram (**C**) shows margin of medium thickness with reverse taper that was disrupted at humeral attachment but flopped toward glenoid (*arrow*). Posterior inferior arthroscopic view obtained 211 days after MRI (**D**) shows torn IGHL complex involving posterior band (*arrow*).

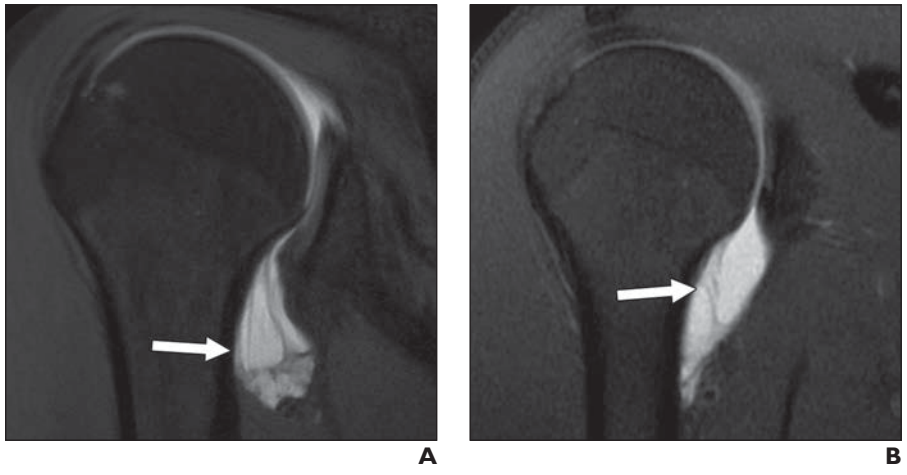


Fig. 3—Two patients with iatrogenic contrast material extravasation through posterior axillary pouch.
A and **B,** 26-year-old man with history of dislocation (**A**) and 29-year-old man with volleyball-related injury (**B**). Coronal oblique T1-weighted fat-suppressed MR arthrograms show disrupted margins near humerus that were rated as thin and mop-head in configuration (*arrows*). Arthroscopic images (not shown) showed intact inferior glenohumeral ligament complexes in both cases.

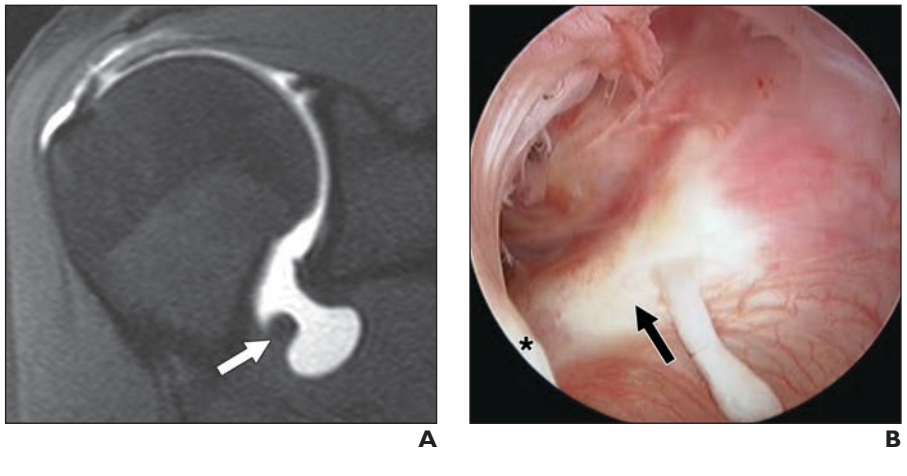
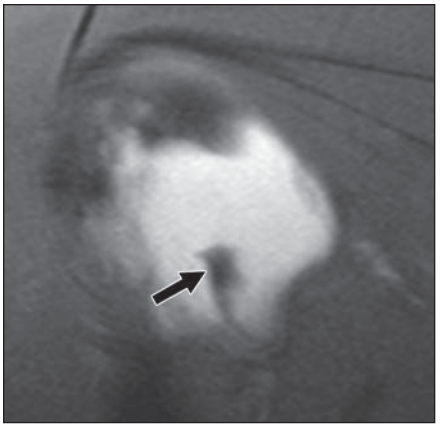


Fig. 4—Two patients with inferior glenohumeral ligament (IGHL) complex tears.
A–D, 26-year-old male hockey player (**A** and **B**) and 17-year-old male football player (**C** and **D**). Coronal oblique T1-weighted fat-suppressed MR arthrograms (**A** and **C**) show humeral avulsions of IGHL complex with thick, reverse-tapered, and scarred margin (*arrows*). Inferior arthroscopic views obtained 124 (**B**) and 2 (**D**) days after MRI examinations both confirm true tears with thick margins (*arrows*). Asterisks denote humeral heads.

(Fig. 4 continues on next page)



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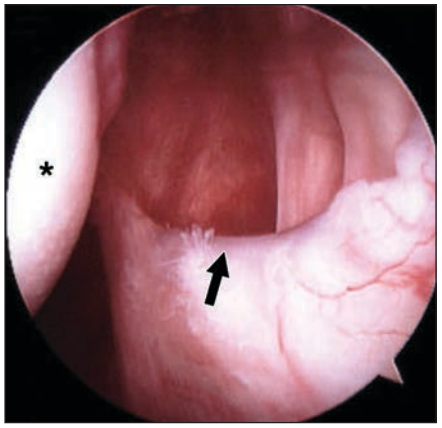
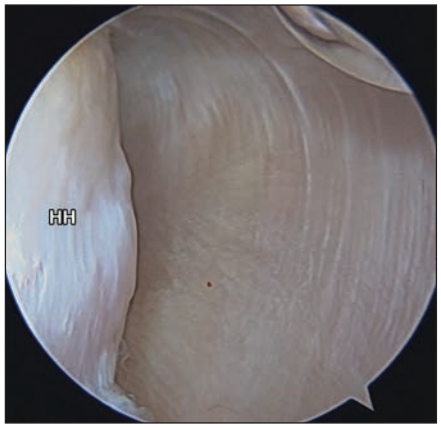


D

Fig. 4 (continued)—Two patients with inferior glenohumeral ligament (IGHL) complex tears. **A–D,** 26-year-old male hockey player (**A** and **B**) and 17-year-old male football player (**C** and **D**). Coronal oblique T1-weighted fat-suppressed MR arthrograms (**A** and **C**) show humeral avulsions of IGHL complex with thick, reverse-tapered, and scarred margin (*arrows*). Inferior arthroscopic views obtained 124 (**B**) and 2 (**D**) days after MRI examinations both confirm true tears with thick margins (*arrows*). Asterisks denote humeral heads.

A

B



C

Fig. 5—Two patients with surgically proven iatrogenic contrast material extravasation.
A–C, 25-year-old male pitcher with history of subluxation (**A**) and 38-year-old man with history of subluxation but no specific injury (**B** and **C**). Coronal oblique T1-weighted fat-suppressed MR arthrograms (**A** and **B**) show disrupted margins that were characterized as medium thickness, tapering, and showing single fascicle (*arrows*). Inferior arthroscopic view obtained 49 days after MRI examination (**C**) shows intact inferior glenohumeral ligament complex. HH = humeral head.

FOR YOUR INFORMATION

A data supplement for this article can be viewed in the online version of the article at: www.ajronline.org.