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FULL PAPER

MR arthrographic characterization of posterior capsular folds in shoulder joints

[1]HAYRI OGUL, MD, [2]KUTSI TUNCER, MD, [2]MEHMET KOSE, MD, [1]BERHAN PIRIMOGLU, MD and [1]MECIT KANTARCI, MD, PhD

[1]Department of Radiology, Medical Faculty, Ataturk University, Erzurum, Turkey
[2]Department of Orthopedic, Medical Faculty, Ataturk University, Erzurum, Turkey

Address correspondence to: MD Hayri Ogul
E-mail: *drhogul@gmail.com*

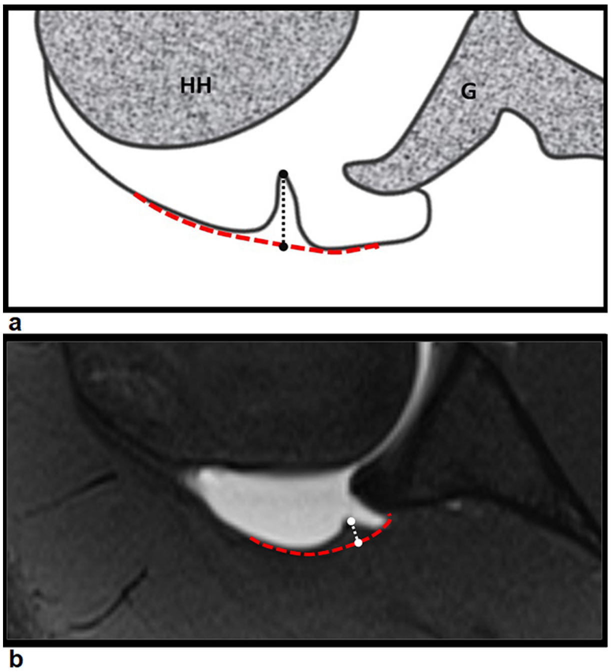
Objective: To describe the posterior synovial folds found on direct MR arthrogram to distinguish them from false posterior labrum tears seen in conventional MR using MRI and MR arthrography, we also examined vertical oblique extension, arthrographic morphology, and MRI appearance of the posterior synovial fold in the symptomatic shoulder.
Methods: This was a retrospective study of 604 consecutive shoulder MR images and MR arthrograms obtained from April 2010 to January 2018. Extension in the vertical-oblique plan of the posterior synovial fold on MR arthrography was identified according to the posterosuperior, posteroinferior, superoposterior, and inferoposterior portions. The morphologies of the posterior synovial folds on MR arthrography were divided three subtypes. Morphologic appearances of the posterior labrocapsular complex on conventional MR images were described with four subtypes.
Results: A posterior synovial fold in the shoulder joint was identified in 35 of 604 (5.8%) MR arthrography patients. 8 of 35 posterior synovial fold identified on MR arthrography were confirmed at arthroscopy. The most common MR arthrographic type of the posterior synovial fold was triangular—this was detected in 17 of 35 (48.6%) patients. The most common MRI morphology of the posterior labrocapsular complex was doubled posterior labrum. This was detected in 15 of 35 (42.9%) patients. 17 % of patients with posterior synovial folds who were diagnosed with MR arthrography had normal MRI features. The most common localization of the posterior synovial fold was posterosuperior and posteroinferior portions of the posterior labrocapsular structures. The mean of the shortest distance between the posterior synovial fold and the posterior labrum was significantly higher in the positive arthroscopic synovial fold group than in the negative arthroscopic synovial fold group ($p = 0.047$).
Conclusion: Posterior synovial folds, normal capsular anatomic variants, are seen rarely on MR arthrography, and tend to be in the posterosuperior and posteroinferior portions of the posterior capsule. Some types of the posterior synovial fold can mimic a posterior labral tear in conventional MRI.
Advances in knowledge: On a direct MR arthrographic image, a posterior capsular synovial fold may be a normal anatomic variant. A fold is more commonly occur in the posterosuperior and posteroinferior capsular portions. The results of our study may allow differentiation of normal variations from abnormalities in patients with symptomatic shoulder joint.

INTRODUCTION

Direct MR arthrography of the glenohumeral joint with intra-articular injection of diluted gadolinium chelates has described for shoulder disorders including capsulolabral pathologies, glenohumeral ligament damages, and rotator cuff ruptures.[1,2] It is also a primary imaging modality for evaluation of labroligamentous complex anatomy and variations.[3] Although synovial folds in the posterior shoulder joint capsule are rare, they can mimic a posterior labral defect on conventional MR images.[4] Thus, correct identification of labrocapsular anatomic variants such as posterior synovial fold and atypical labral morphology is very important to avoid unnecessary arthroscopic surgery. Because direct MR arthrography of the shoulder joint causes separation of intra-articular structures with capsular distention,[5] differential diagnosis of labral detachment and the posterior synovial fold can be performed more easily with MR arthrography.

In our daily practice, we relatively often encounter suspicious posterior labral detachment on conventional MR images of some patients without clinical evidence for

Figure 1. (a) Illustration shows method of measurement of size of posterior synovial fold on axial MR arthrographic image. Size was described with maximal values of depth (black dotted line) measured vertically to imaginary line (red dotted line) of the glenohumeral joint capsule. (b) Posterior synovial fold in a 22-year-old male presenting with right shoulder habitual luxation. Axial fat set T_1 weighted SE MR arthrography shows a triangular shaped (dotted arrow) posterior synovial fold. G, glenoid bone; HH, humeral head; SE, spin echo.



posterior instability. When MR arthrography is performed, we note the presence of posterior synovial folds in a significant proportion of these patients. Thus, the aim of this study was to describe a posterior synovial fold on direct MR arthrographic images of the shoulder and to distinguish this finding from true posterior labral tears. To the best of our knowledge, MR arthrographic feature of posterior capsular fold in the shoulder joint have not been described extensively in the literature. Therefore, we also aimed to reveal the relationship between the posterior glenoid labrum and posterior synovial fold, and the detailed morphologic classification of the posterior synovial fold.

METHODS AND MATERIALS

Patients

This was a retrospective study of 614 consecutive shoulder MR images and MR arthrograms obtained from April 2010 to May 2018. This single-centre retrospective study was approved by our institutional review board, and written informed consent was obtained from all patients for the application of both MR arthrography and the injection procedures.

Injection technique

All injections were performed by two radiologists on an outpatient basis without sedation or pre-medication. The injections were done with ultrasound guidance (Applio ultrasound system; Toshiba Medical Systems, Tokyo, Japan) with a broadband 7.5- to 12-MHz linear array transducer, and were performed using a posterior approach with a 20-gauge needle.[5] Diluted contrast media (0.5 mmol l^{-1} gadopentetate dimeglumine, Magnevist; Bayer Schering Pharma, Germany) at 1:200 (0.1 ml contrast media diluted by 20 ml normal saline) was injected;12 to 20 ml was injected until the joint capsule was appropriately distended. The volume of injection was determined according to the patient's comfort level and resistance to the injection.

MR arthrography technique

MR arthrography and conventional MRI examinations were performed with a 1.5- or 3 T MR (Magnetom Avanto or Magnetom Skyra; Siemens Healthcare, Erlangen, Germany) with an 8-channel shoulder-dedicated coil. A flex coil was used for obese and very muscular patients. MR arthrograms were obtained within 15 min of the injection. The patients were placed in the supine position on the MRI table with their

Figure 2. (a) Glenolabrocapsular division: nomenclature used for localization of posterior synovial fold. Diagram shows glenolabrocapsular structure divided into eight areas. (b) Diagrams show vertically course of posterior synovial fold. According to this, it was demonstrated 10 different types for posterior synovial fold in MR arthrography. IP, inferior posterior; PI, posterior inferior; PS, posteriorsuperior; SP, superior posterior.

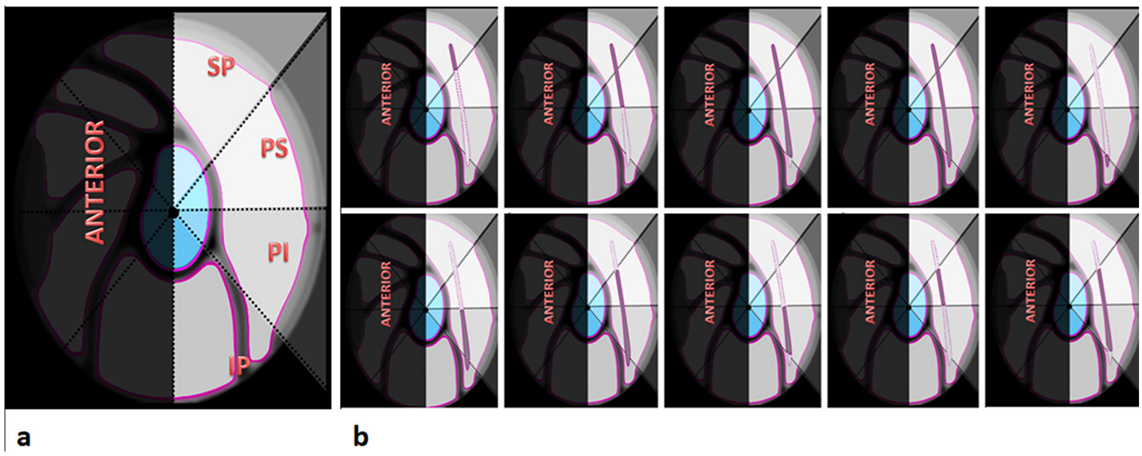


Figure 3. Diagrams reveal morphologic types of posterior synovial fold in MR arthrography. (a) Triangular shaped fold, (b) Round or flat shaped fold, (c) Cord like fold.

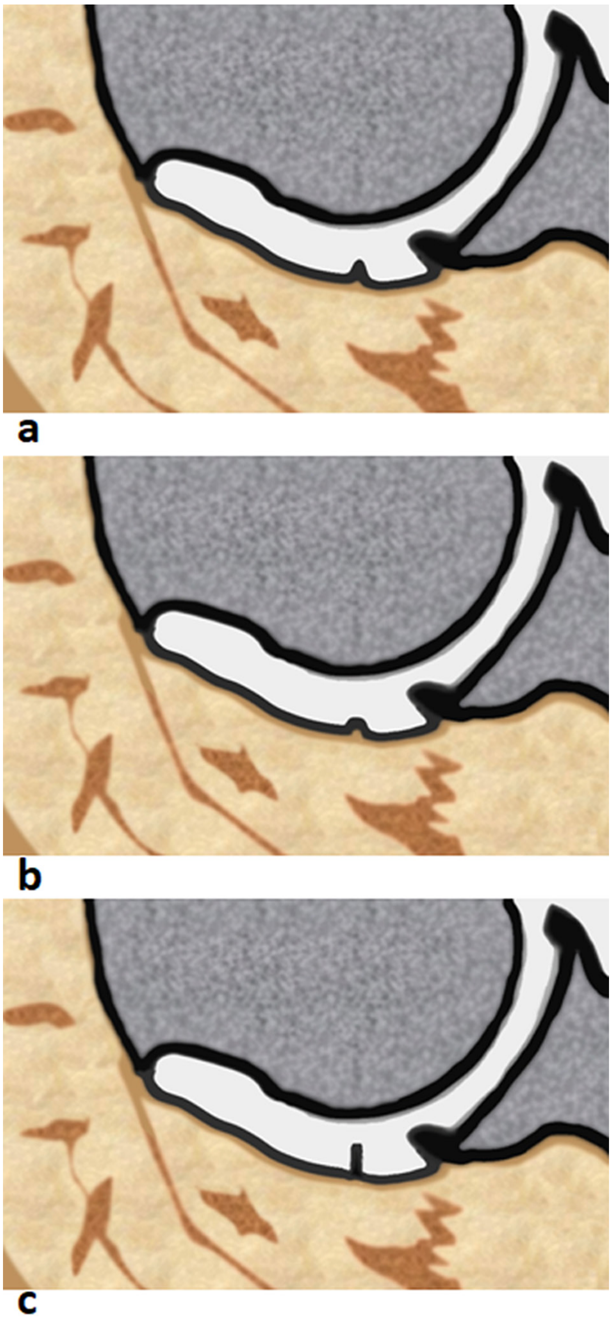
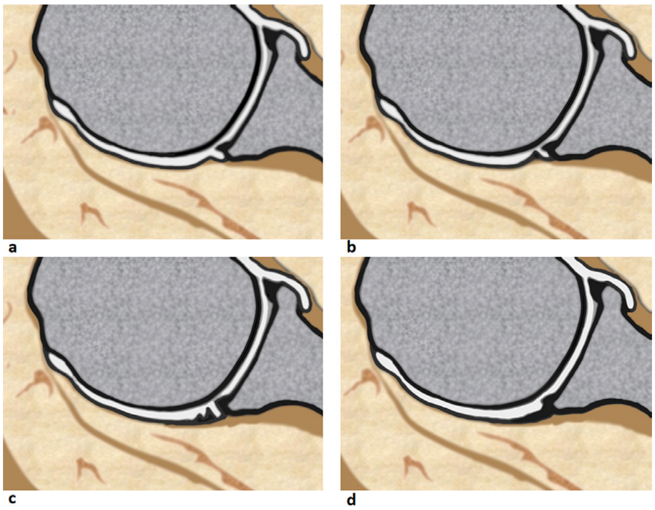


Figure 4. Diagrams of patients with posterior synovial fold reveal morphologic types of posterior labrocapsular structures in conventional MRI. (a) Normal posterior labrocapsular morphology, (b) Double posterior labrum appearance, (c) Triple posterior labrum appearance, (d) Thickened posterior labrocapsular complex.



arms slightly externally rotated at their sides. For conventional MRI, the following sequences were used: T_2 weighted fast spin echo in axial, coronal oblique, and sagittal oblique planes with frequency-selective fat saturation [repetition time/echo time (TR/TE) ms, 3700/65; echo train length, 15; section thickness, 4 mm; spacing, 0.4 mm; field of view (FOV), 16 cm; matrix 320 × 192; number of signals acquired, 3) and T_1 weighted fast spin echo in the coronal oblique plane (TR/TE, 640/20; echo train length, 8; section thickness, 3 mm; spacing, 0.4 mm; FOV, 16 cm; matrix 256 × 224; number of signals acquired, 3). Our MR arthrography protocol included fat-suppressed spin echo (SE) T_1 weighted images. These images were performed on the axial, oblique coronal, and oblique sagittal planes with surface coils placed around the shoulder joint (TR/TE, 650/15 ms; echo train length, 8; section thickness, 3 mm; spacing, 0.3 mm; FOV, 16 cm^2 ; matrix, 256 × 256; 3 signals acquired). The fat-suppressed 3D volumetric interpolated breath-hold examination (VIBE) sequence (TR/TE, 13.2/4.7 ms; flip angle, 11°; 160 × 160 mm FOV; matrix, 512 × 512; one slab of 112 slices with a slice thickness of 0.6 mm; one acquisition) was also added to the shoulder MR arthrography imaging protocol after the T_1 weighted SE fat-suppressed sequences have been acquired.

The shoulder joints being so far from the isocentre of the scanner or extremely close to the bore of the scanner resulted in slightly reduced signal-to-noise ratio in conventional MR and MR arthrography images. However, we did not encounter diagnostic difficulties in these images. Therefore the imaging findings were considered as true anatomical features.

Image analysis

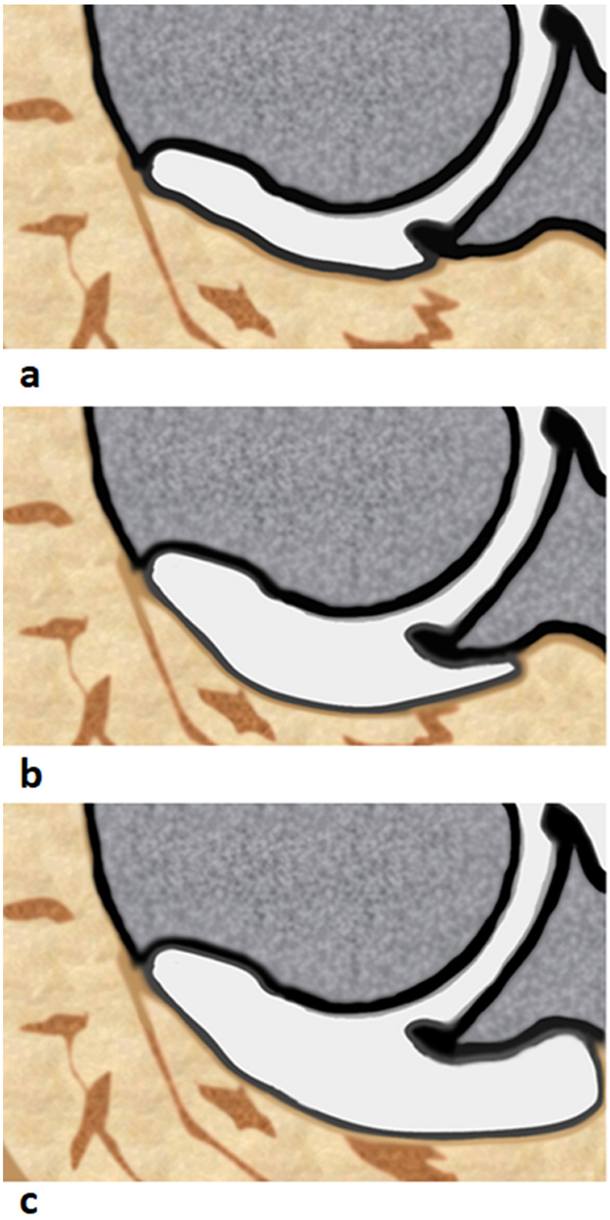
Patient selection

A total of 614 patients were referred to our hospital (Ataturk University Medical School) for MR arthrography of the shoulder joint. 10 of 614 patients were excluded. All images were examined retrospectively by the consensus of two musculoskeletal radiologists—one with 15 years of experience and the other with 5 years of experience. They recorded the imaging findings suggested posterior synovial fold. There was agreement between them for each case. Quantitative measurements were performed by the radiologist with 5 years of experience.

MR arthrographic measurement criteria for posterior synovial folds

We described an imaginary curved line in the direction of the joint capsule. The depth of the posterior synovial fold was

Figure 5. Diagrams reveal different types of posterior capsular insertion in MR arthrography. (a) Posterior labral insertion, (b) Insertion at the junction of the posterior labrum and glenoid, (c) Insertion more medial to the junction between the posterior labrum and glenoid on the cortical surface of the glenoid neck.



measured on axial MR arthrography images at the widest portion along a perpendicular line to the imaginary capsular curve (Figure 1a–b). The MR arthrographic diagnosis criteria of posterior synovial fold included: (1) a focal thickness at least 2 mm (the depth and width of the focal capsular thickness ≥2 mm) of the posterior shoulder joint capsule on axial T_1 weighted fat-suppressed MR arthrograms,[4] (2) extension in a craniocaudal oblique direction of the focal thickness of the posterior joint capsule on axial and sagittal oblique T_1 weighted fat-suppressed MR arthrograms.

MR arthrography imaging-based exclusion criteria

The exclusion criteria included cases with inadequate joint distension (three shoulders), intensive motion artifact (two shoulders), and periarticular massive contrast medium extravasation (three shoulders). We also excluded patients with inflammatory arthropathy (two shoulders) because the joint capsule thickness is difficult to assess in these subjects.

Capsular locations in MR arthrography of the posterior synovial folds

The glenoid cavity and joint capsule were divided into eight equal portions. For this paper, the posterior labrocapsular structures were evaluated in the posterosuperior, posteroinferior, superoposterior, and inferoposterior portions (Figure 2a). Extension in the vertical-oblique plan of the posterior synovial fold on MR arthrography was identified according to these portions (Figure 2b).

Morphologic features in MR arthrography of the posterior synovial folds

The morphologies of the posterior synovial folds on MR arthrography were divided three subtypes: triangular, rounded, and cord-like (Figure 3a–c).

Morphologic features in MRI of the posterior capsulolabral complex

Morphologic appearances of the posterior labrocapsular complex on conventional MR images were described with four subtypes including normal capsulolabral morphology, doubled or bifid posterior labrum appearance, tripled posterior labrum appearance, and thickened posterior labrocapsular structure (Figure 4a–d).

Scapular insertion types of the posterior joint capsule in MR arthrography

The posterior capsular insertion classification system was modified from the anterior one proposed by Zlatkin.[6] The posterior capsular insertion was classified into three types as Type 1, posterior labral insertion; Type 2, insertion at the junction of the posterior labrum and glenoid; and Type 3, insertion more medial to the junction between the posterior labrum and glenoid on the cortical surface of the glenoid neck (Figure 5a–c).

Arthroscopy

All arthroscopies were performed by two shoulder surgeons via the anterior portal. A significant portion of the patients had labral tears and rotator cuff pathologies, and were treated arthroscopically.

Statistical analysis

Statistical analyses used SPSS software (v. 20.0; SPSS, Inc., Chicago, IL). Descriptive statistical analyses were performed for the distribution patterns of MR arthrography types of the posterior synovial folds, morphologies of posterior labrocapsular complex, posterior capsular insertions, and locations of the posterior synovial folds. Student's *t*-test was used to compare the relationship between age, depth of posterior synovial fold, and distance between the posterior synovial fold and the posterior labrum. The relationship between sex, depth of posterior

Table 1. The value of MR arthrographic findings in the diagnosis of arthroscopically proved posterior synovial fold

	Sensitivity	Specificity	PPV	NPV
Presence of the posterior synovial fold on MR arthrography	100 (8/8)	95.6 (262/274)	40 (8/20)	100 (262/262)

PPV = positive predictive value
NPV = negative predictive value

synovial fold, and distance between the posterior synovial fold and the posterior labrum were assessed with a χ^2 test. The relationship between arthrographic location of posterior synovial fold and anatomical variations between posterior synovial fold morphology and anatomical variations were assessed by the χ^2 test. The *p*-value was calculated for each comparison, and values ≤ 0.05 indicated statistical difference. The Mann-Whitney *U* test was used to compare the relationship between the distance between the posterior synovial fold and the posterior labrum and depth of posterior synovial fold in both positive and negative arthroscopic synovial fold groups.

RESULTS

A posterior synovial fold in the shoulder joint was identified in 35 of 604 (5.8%) MR arthrograms. These 35 patients with posterior synovial folds [19 (54.3%) females, 16 (45.7%) males] had a mean age of 40.02 ± 8.1 (range, 17–76) years; 18 (51.4%) had right shoulder MR arthrography examinations, and 17 (48.6%) had left shoulder MR arthrography examinations.

282 of the 604 (46.7%) patients had arthroscopic examination. All patients with posterior capsular fold who have MR arthrography also had conventional MR images. Arthroscopy was performed on 20 of the 35 (57.1%) patients with arthrographic posterior synovial fold. All arthroscopies were examined by two shoulder surgeons. All arthroscopic procedures were done on the anterior portal. A significant portion of the patients had anterior labral defect and rotator cuff pathologies, and were treated arthroscopically. The posterior synovial fold of 8 (40%) of 20 the patients was diagnosed during arthroscopy. In the rest of the patients, the posterior joint capsule was arthroscopically normal. Table 1 demonstrates the value of MR arthrographic findings in the diagnosis of arthroscopically proved posterior synovial fold.

The most common MR arthrographic type of the posterior synovial fold was triangular—this was detected in 17 of 35 (48.6%) patients (Figure 6a–f). Of the 35 patients, 10 (28.5%) had a rounded type of posterior synovial fold. A cord-like synovial fold was identified in the remaining eight patients (22.8%) (Figure 7a–f). 17% of our patients with posterior synovial folds who were diagnosed with MR arthrography had normal MRI features. The most common MRI morphology of the posterior labrocapsular complex was doubled posterior labrum. Additionally posterior capsular insertion types were summarized in Table 2 and were illustrated in Figure 5a–c.

The most common anatomical variation associated with posterior synovial fold was sublabral foramen variation detected in 6 of 35 (17.1 %) patients. The second most common anatomical variations associated with posterior synovial fold were also buford complex and posterior sublabral cleft anomaly detected in 5 of 35 (14.3 %) patients. Sublabral foramen variation was more often detected in associated with the posteroinferior and inferoposterior arthrographic location of posterior synovial fold ($p = 0.048$).

There was no significant difference in the relationship between sex, the mean depth of posterior synovial fold, and the mean distance between posterior synovial fold and posterior labrum ($p = 0.367$). The mean of the shortest distance between the posterior synovial fold and the posterior labrum was 4.13 ± 1.4 mm (range, 2.2–6.6 mm) in the positive arthroscopic synovial fold group. It was 3.27 ± 0.9 mm (range, 1.8–4.1 mm) in the negative arthroscopic synovial fold group. The mean of the shortest distance between the posterior synovial fold and the posterior labrum was significantly higher in the positive arthroscopic synovial fold group than in the negative arthroscopic synovial fold group ($p = 0.047$).

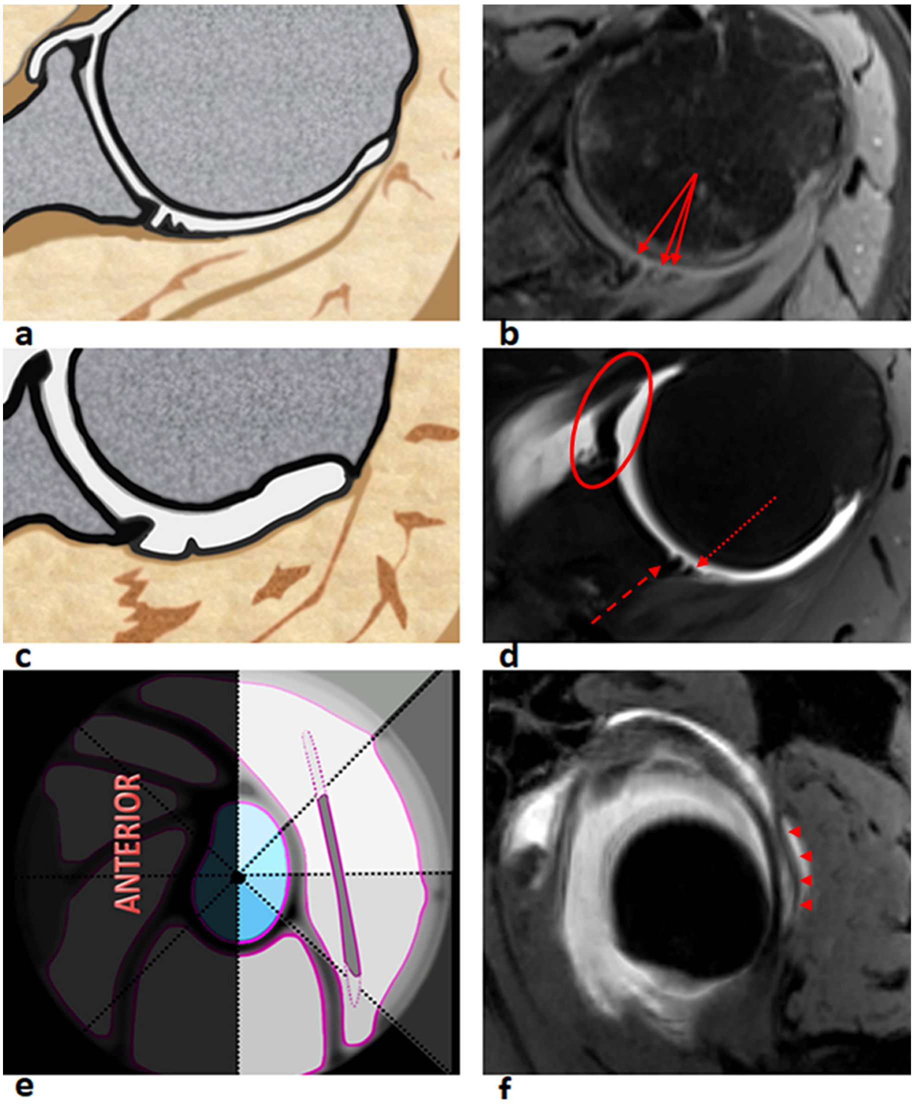
The mean depth of the posterior synovial fold was also 3.3 ± 1.2 mm (range, 2.1–4.1 mm) in the positive arthroscopic synovial fold group. It was 2.55 ± 0.9 mm (range, 2–3.4 mm) in the negative arthroscopic synovial fold group. There was no significant difference in the relationship between the mean depth of the posterior synovial fold, the positive and arthroscopic synovial fold groups ($p = 0.061$).

The most common localization was posterosuperior, superoposterior, posteroinferior and inferoposterior portions of the posterior labrocapsular structures in the positive arthroscopic synovial fold group. In the negative arthroscopic synovial fold group, the most common localization was also posterosuperior and posteroinferior portions of the posterior labrocapsular structures.

DISCUSSION

Our study showed that the prevalence of posterior synovial folds in the shoulder joint during MR arthrographic studies was 5.8%. The most common location of the posterior synovial fold was posterosuperior and posteroinferior quadrants (20%) of the posterior shoulder joint capsule. In addition, the posterior synovial fold was frequently associated with other labrocapsuloligamentous anomalies (62.9%) such as the sublabral foramen, posterior sublabral cleft, superior sublabral recess, Buford complex, and glenohumeral ligament hypoplasia. For the posterior synovial fold of the shoulder joint, capsular morphologic changes on MRI or MR arthrography have been described in only one study.[4] Unlike our study, this study had a small patient population. Moreover, the study did not provide detailed comments about the location, size and morphologic types of posterior capsular fold, and accompanying capsulolabral-ligamentous abnormalities.

Figure 6. Posterior synovial fold in a 76-year-old male presenting with clinical left shoulder pain. First diagram (a) and axial proton density weighted MRI (b) show a triple labrum appearance (arrows) in posterior labrocapsular area. Second diagram (c) and axial fat set T_1 weighted SE MR arthrography (d) show a triangular shaped (dotted arrow) posterior synovial fold. The synovial fold is demonstrated in adjacent area to the posterior labrum in MR arthrography. Arthrographic image also reveals a Buford complex anomaly (solid circle) and posterior sublabral cleft variation (dashed arrow). Last diagram (e) and coronal oblique fat set T_1 weighted VIBE MR arthrography (f) show a vertical-oblique coursed posterior synovial fold (arrwoheads) in PS and PI portions of the glenolabrocapsular complex.

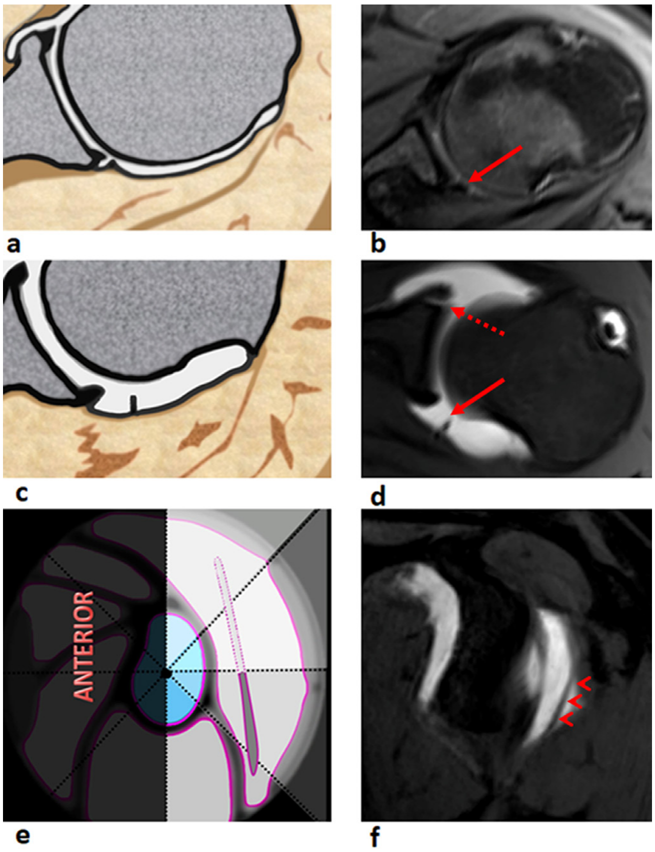


Anatomically, the glenohumeral joint capsule begins at the glenoid border close to the labrum and inserts into the humeral anatomic neck. Histologically, the capsule consists of three layers including outer, middle, and inner. The inside is covered with a synovial membrane, and the anterior joint capsule is reinforced by glenohumeral ligaments. It is thinner from the posterior glenohumeral joint capsule.[7] Biomechanically, the labral–capsular–ligamentous complex helps stabilize the glenohumeral joint. The two main functions of the glenohumeral ligaments are to avoid superoinferior translation and anterior instability.[8]

Histopathological studies of the posterior joint capsule could elucidate the true nature of the posterior synovial fold.[4] However, we believe that the visualization of what we are calling the posterior synovial fold is either a normal structure like the anterior glenohumeral ligaments or a normal variant like the synovial plica in the knee which can sometimes be inflamed and symptomatic.

Most of our patients who underwent arthroscopy had rotator cuff tears or anterior shoulder instability. However, only 4 of the 20 scoped patients were symptomatic for posterior synovial plica syndrome or posterior labrum pathology. Other than this, we had only a few patients suspected of posterior labral tears based on the MR images. MR arthrography of these patients showed that the posterior labrum was normal. However, these subjects had a capsular fold that was close to the posterior labrum. Arthroscopy revealed posterior capsular fold in two of these four patients.

Figure 7. Posterior synovial fold in a 33-year-old female presenting with clinical anterior instability of the left shoulder. First diagram (a) and axial proton density weighted MRI (b) show double labrum appearance (arrow) in posterior labrocapsular area. Second diagram (c) and axial fat set T_1 weighted SE MR arthrograhy (d) show a cord like (arrow) posterior synovial fold. Arthrographic image also reveals a perthes lesion (dashed arrow) in the anteroinferior labrum and hill-sachs deformity in the posterolataral of the humeral head. Third diagram (e) and coronal oblique fat set T_1 weighted VIBE MR arthrography (f) show a vertical-oblique coursed posterior synovial fold (arrowheads) in PI and IP portions of the glenolabrocapsular complex.



The actual prevalence of the posterior synovial fold in the shoulder is unknown. However, an MRI and MR arthrography study performed by Novak et al[4] showed that that frequency of anomalies in shoulder MR arthrography and MRI was 2.7 and 1.5%, respectively. Although they retrospectively investigated a limited number of MR arthrography patients, fewer posterior synovial folds were observed on shoulder MR images than on shoulder MR arthrography. We studied a larger MR arthrographic patient population, and our results had a few differences than those of Novak et al.[4] We performed MRI at the same period for each patient who underwent MR arthrography; 17% of our patients with posterior synovial folds who were diagnosed with MR arthrography had normal MRI features. Interestingly, 48.6% of these patients had doubled and tripled posterior labrocapsular morphology in MR images. This labrocapsular structure mimicked a posterior labral tear in conventional MR images. Thus, it is important to avoid misdiagnosis and to be aware of this labral morphology in MRI.[9]

Table 2. Shows posterior capsular insertion types

Posterior capsular insertion types		
Type 1	Type 2	Type 3
15	16	4

The posterior synovial fold of the shoulder joint capsule extends from the inferoposterior capsular portion to the superoposterior capsular portion in a vertical oblique direction. It has the closest course to the labrum on the posterosuperior and posteroinferior portions of the shoulder joint capsule. Thus, the posterior capsular fold can be mistaken for a posterior labral seperation on conventional MR images.[9] On the other hand, the distance between the posterior labrum and the posterior synovial fold rarely increases. Only one of our patients (2.9%) had a synovial fold in isolated inferoposterior portions of the posterior joint capsule in MR arthrography. In this patient, the distance between the posterior labrum and the posterior fold was 8.6 mm. This was longest reported.

In previous studies, morphological variations of the anterior and posterior labrums in MR images and MR arthrographies have been described.[10,11] These imaging studies revealed that a cleaved or notched morphology of the posterior glenoid labrum was extremely rare. Neumann et al[11] advocated that these labrocapsular morphologic types should raise the suspicion of a labral defect when encountered posteriorly. In this context, we note the presence of cleaved and notched posterior labrocapsular morphologies in 48.6% of the patients with posterior synovial folds in conventional MR images. We think that two type labrocapsular morphological variants in conventional MR images may represent posterior capsular folds in MR arthrographies.

Three types of the anterior glenohumeral capsular insertion variations have been described in the literature.[6] According to these studies, a large anterior capsular pouch could be associated with recurrent anterior glenohumeral joint instability.[6,12] Little association has been seen between posterior labrocapsular insertion type and posterior instability. However, Neumann et al, found no Type 2 or 3 insertion patterns at the posterior part of the shoulder joint capsule.[11] Surprisingly, 57% of our patients were Type 2 and 3 posterior capsular insertion in MR arthrography. Thus, we think that a posterior synovial fold could strengthen posterior stability in these patients. However, further biomechanical studies are clearly needed to confirm this theory. There are several potential limitations in our study. Our main limitation was the retrospective nature of this study. We used shoulder arthroscopy as a gold-standard for posterior synovial folds. However, posterior capsular fold in only 40% of our patients were arthroscopically confirmed. This result was less than expected. There may be a few reasons for this. Because the patients have lounge chair position during arthroscopic procedure, the arm is in the internal rotation. Therefore, the patients have a stretched posterior joint capsule. Because of the stretched capsule, posterior capsular fold may not be seen arthroscopically. All of our MR athrography patients had moderate external rotation of the arm during arthrographic procedure. Secondly, because shoulder joint capsules of the patients are markedly stretched with saline solution during arthroscopic procedure, posterior capsular fold may not be seen.

Although arthroscopy is accepted as gold-standard for the shoulder capsule pathologies, the posterior synovial folds may be missed in arthroscopy due to especially internal rotation and excessive capsular distention. Future works are needed about this topic. Moreover, our surgeons performed arthroscopic procedure for different shoulder pathologies such as the Bankart lesion, rotator cuff tear or superior labral anteroposterior tear. They could not entirely focused the presence of the posterior capsular folds. This situation can explain the cause of the low true positivity in our arthroscopic examinations. On the other hand, the lack of pathologic and biomechanic correlations was one obvious weakness of our study. Another potential limitation was the absence of interobserver correlation. Finally, symptomatic patients with variable abnormalities of the shoulder joint were enrolled. Therefore, we could not determine if there was a relationship between the patient's symptoms and the posterior synovial fold on MR arthrography.

In conclusion, posterior synovial folds later confirmed to be normal capsular anatomic variants were rare on MR arthrography with 5.8%. They tended to be in the posterosuperior and posteroinferior portions of the posterior joint capsule and had different morphological types. Knowledge of this rare anatomic variation in the posterior joint capsule is very important for the examination of MR images and MR arthrography of shoulder joint because some types of the posterior synovial fold can mimic a posterior labral tear in conventional MRI.

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