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Adhesive capsulitis of the shoulder: evaluation with MR arthrography

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Abstract The purpose of this study was to determine the usefulness of magnetic resonance (MR) arthrography for diagnosing adhesive capsulitis. Shoulder MR images of 28 patients with (n=14) and without (n=14) adhesive capsulitis were retrospectively analyzed. MR images were assessed for capsule and synovium thickness as well as the width of the axillary recess on oblique coronal fat-suppressed T1-weighted images and T2-weighted images, respectively. On oblique sagittal fat-suppressed T1-weighted images, the width of the rotator interval and the presence of abnormal tissue in the interval were evaluated. Significant differences were found between the two groups in capsule and synovium thickness on both sides of the recess on oblique coronal T2-weighted images (P=0.000), whereas thickness on the humeral aspect showed no significant difference on oblique coronal fat-suppressed T1-weighted images (P=0.109). On oblique coronal T2-weighted images, a cut-off value of 3-mm thickness gave the highest diagnostic accuracy for adhesive capsulitis with sensitivity, specificity, and accuracy of 79% (11/14), 100% (14/14), and 89% (25/28) at the humeral side and 93% (13/14), 86% (12/14), and 89% (25/28) at the glenoid side, respectively. There were significant differences in rotator interval width, presence of abnormal tissue in the rotator interval, and axillary recess width between the two groups (P<0.05). Thickness of capsule and synovium of the axillary recess greater than 3 mm is a practical MR criterion for diagnosing adhesive capsulitis when measured on oblique coronal T2-weighted MR arthrography images without fat suppression. The presence of abnormal tissue in the rotator interval showed high sensitivity but rather low specificity.

Keywords Shoulder · Magnetic resonance · Arthrography · Adhesive capsulitis · Frozen shoulder

Introduction

Adhesive capsulitis of the shoulder is a condition of unknown etiology that results in the development of restricted active and passive glenohumeral motion [1–3]. It has been reported that unenhanced magnetic resonance (MR) imaging is useful in diagnosing adhesive capsulitis [4, 5]. However, more recent studies [6, 7] using MR arthrography have shown controversial results in diagnosing adhesive capsulitis.

The purpose of our study was to determine the usefulness of MR arthrography for diagnosing adhesive capsulitis on each imaging sequence and to establish MR diagnostic criteria for adhesive capsulitis.

Materials and methods

Shoulder MR images of 28 patients (M:F=14:14; mean age 50 years) with (n=14) and without (n=14) adhesive capsulitis

were included in this study, which was approved by the institutional review board. We excluded patients with previous shoulder surgery, full-thickness rotator cuff tears, rheumatoid arthritis, or seronegative spondyloarthropathies. A diagnosis of adhesive capsulitis was made when the injected glenohumeral joint volume was less than 10 ml with complaining pain and when the condition fit clinical criteria for adhesive capsulitis, as evaluated by one of two experienced orthopedic surgeons. In our institution, treatment of adhesive capsulitis with a slow prolonged injection was not done. The clinical criteria included pain and stiffness for more than 15 weeks that was increasing in nature and was most severe at rest, with restriction of passive motion greater than 30° in two or more planes of movement and with normal radiographs [5, 8]. In four patients, adhesive capsulitis was proven arthroscopically.

The patient group included three men and 11 women with ages ranging from 46 to 63 years (mean age 54 years; nine right and five left shoulders). The control group consisted of 14 patients, 11 men and three women, aged 24–66 years (mean age 46 years), who had been referred for MR arthrography for evaluation of rotator cuff or labral abnormalities and who did not show evidence of adhesive capsulitis on subsequent arthroscopy. Each of these patients (10 right and four left shoulders) was injected with about 15 ml of contrast medium.

Joint injection was performed using fluoroscopic guidance and an anterior approach. A 20-gauge spinal needle was placed in the glenohumeral joint, and 1–5 cc of iohexol (Omnipaque 300 mg/ml, Nycomed, Princeton, NJ, USA) was used to verify intraarticular injection. Gadopentetate dimeglumine 0.5 mmol/ml (Magnevist; Schering, Berlin, Germany) diluted 1:250 in normal saline was injected along with approximately 0.2 cc of 1:1,000 epinephrine (American Regent Laboratories, Shirley, NY, USA). MR imaging of the shoulder was initiated from 10 to 60 min after intraarticular injection and was performed with a 1.5-T imager (Twin Speed; GE Medical Systems, Milwaukee, WI, USA) with a phased array surface coil (Shoulder Array, Medrad, Indianola, PA, USA). Patients were positioned with neutral position of the humerus. Fat-suppressed T1-weighted (TR range/TE range, 450–800/11–16) sequences were performed in axial, coronal oblique (parallel to the long axis of the supraspinatus tendon), and sagittal oblique (perpendicular to the long axis of the supraspinatus tendon) planes. Double-echo fast spin-echo pulse sequences were used to obtain coronal oblique intermediate-weighted MR images (3,000–4,500/14–21) and T2-weighted MR images (3,000–4,500/63–112) using an echo train length of 10. MR imaging parameters for all sequences were the following: field of view, 15–16 cm; 1–2 excitations; matrix size, 256×256; section thickness, 3 mm; intersection gap, 0.3 mm.

MR images were analyzed on high-resolution monitors (1536×2048 matrix, 8-bit viewable gray scale) of a picture archiving and communication system. Each reader was blinded to the clinical information and arthroscopy results. MR images were retrospectively analyzed by consensus of two reviewers for capsule and synovium thickness on oblique coronal fat-suppressed T1-weighted images and T2-weighted images, respectively. In addition, the width of the axillary recess and rotator interval and the presence of abnormal tissue in the rotator interval were analyzed. The measurement of the capsule and synovial thickness was obtained by measuring the distance perpendicular to the adjacent humeral cortical bone at the widest portion of the humeral and glenoid aspects of the axillary recess on oblique coronal images, respectively. Sensitivity, specificity, and accuracy with cut-off values of 2.5 mm, 3 mm, and 3.5 mm, respectively, were calculated for the diagnosis of adhesive capsulitis. The width of the axillary recess was measured at the widest portion, along the perpendicular line to the adjacent cortical bone on oblique coronal T2-weighted images. The shortest rotator interval width was measured between the superior border of the subscapularis and the anterior border of the supraspinatus at the level of the tip of the coracoid process on oblique sagittal fat-suppressed T1-weighted images.

Statistical analysis of between-group differences in capsule and synovium thickness and width of the axillary recess and rotator interval was performed using the independent t-test. For all other comparisons, Fisher's exact test was used. For all statistical comparisons, significance was defined as $P < 0.05$.

Results

The mean thickness of the capsule and synovium at the axillary recess on oblique coronal fat-suppressed T1-weighted images and T2-weighted images is shown in Table 1. There were significant differences between the

Table 1 Mean thickness (mm) of capsule and synovium and width (mm) of axillary recess on oblique coronal fat-suppressed T1-weighted versus T2-weighted images

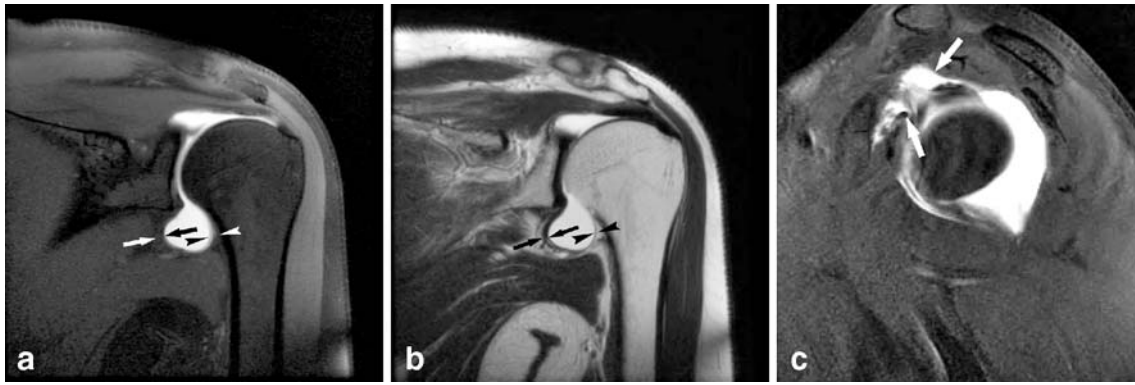| Axillary recess		Patient group	Control group	P-value
Oblique coronal fat-suppressed T1-weighted images	Humeral	4.2±1.8	3.3±0.9	$P=0.109$
	Glenoid	4.9±1.8	2.9±1.1	$P=0.002$
	Width	4.3±3.2	9.3±2.5	$P=0.000$
Oblique coronal T2-weighted images	Humeral	4.3±1.6	1.9±0.4	$P=0.000$
	Glenoid	5.2±1.5	2.3±0.8	$P=0.000$
	Width	4.4±2.8	8.6±2.5	$P=0.000$

Fig. 1 A 49-year-old female control subject. **a** Fat-suppressed T1-weighted (TR 416 ms, TE 11 ms) coronal oblique magnetic resonance (MR) arthrogram reveals the thickness of capsule and synovium, measuring 2.9 mm (*arrowheads*) and 3.3 mm (*arrows*) on humeral and glenoid aspects, respectively. **b** On T2-weighted double-echo fast spin-echo (TR 3,000 ms, TE 63 ms, echo train length 10) coronal oblique MR arthrogram capsule and synovium thickness is 1.2 mm (*arrowheads*) and 2.25 mm (*arrows*) on humeral and glenoid sides, respectively. **c** Sagittal oblique fat-suppressed T1-weighted image (TR 450 ms, TE 14 ms) reveals normal rotator interval. The rotator interval width is 14.3 mm (*arrows*)

control group (Fig. 1) and the patient group (Fig. 2) in capsule and synovium thickness on humeral and glenoid aspects of the axillary recess on oblique coronal T2-weighted images ($P=0.000$), whereas thickness on the humeral aspect showed no significant difference on oblique coronal fat-suppressed T1-weighted images ($P=0.109$).

We calculated the sensitivity, specificity, and accuracy of oblique coronal T2-weighted and fat-suppressed T1-weighted images for the diagnosis of adhesive capsulitis, using cut-off values of 2.5 mm, 3 mm, and 3.5 mm, respectively, for capsule and synovium thickness. The sensitivity, specificity, and accuracy for each cut-off value obtained on oblique coronal T2-weighted images were higher than those on fat-suppressed T1-weighted images (Table 2). On coronal oblique T2-weighted images, a cut-off value of 3-mm thickness gave the highest diagnostic accuracy for adhesive capsulitis, with a sensitivity, speci-

ficity, and accuracy of 79% (11/14), 100% (14/14), and 89% (25/28) at the humeral side and 93% (13/14), 86% (12/14), and 89% (25/28) at the glenoid side, respectively. Although at the humeral side the highest diagnostic accuracy was obtained at the cut-off value of 2.5 mm with a sensitivity of 86%, specificity of 100%, and accuracy of 93% on coronal oblique T2-weighted images, at the glenoid side accuracy decreased because of a much lower specificity with this cut-off value. Thus, from a practical point of view, we took the cut-off value of 3 mm for both sides. The width of axillary recess was 4.3 mm±3.2 mm in the patient group and 9.3 mm±2.5 mm in the control group on fat-suppressed T1-weighted images with significant difference ($P=0.000$). On T2-weighted images, the results were similar, with 4.4 mm±2.8 mm in the patient group and 8.6 mm±2.5 mm in the control group with significant difference ($P=0.000$). Rotator interval width was 10.2 mm±3.8 mm in the patient
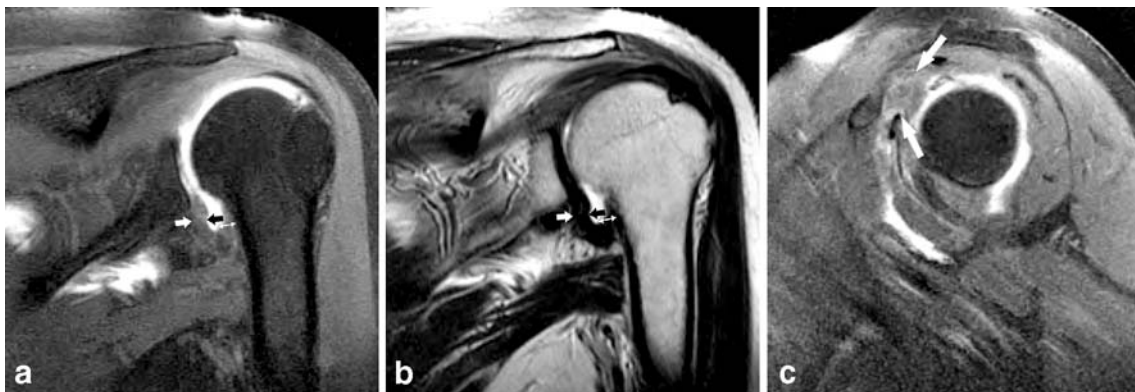

Fig. 2 A 60-year-old woman with adhesive capsulitis. **a** Fat-suppressed T1-weighted (TR 416 ms, TE 11 ms) coronal oblique magnetic resonance (MR) arthrogram reveals thickened capsule and synovium, measuring 4.0 mm (*arrow with two arrowheads*) and 5.8 mm (*arrows*) on humeral and glenoid aspects, respectively. **b** T2-weighted double-echo fast spin-echo (TR 3,000 ms, TE 63 ms, echo train length 10) coronal oblique MR arthrogram demonstrates thickened capsule and synovium, measuring 4.2 mm (*arrow with two arrowheads*) and 5.7 mm (*arrows*) on humeral and glenoid sides, respectively. **c** Sagittal oblique fat-suppressed T1-weighted image (TR 450 ms, TE 14 ms) shows abnormal signal (*arrows*) in rotator interval. The rotator interval width is 11.2 mm

Table 2 Accuracy of capsule and synovium thickness of axillary recess on oblique coronal T2-weighted images (T2WI) and fat suppressed T1-weighted images (FST1WI); numbers indicate percentage followed by fraction in parentheses

Cut-off value	Location	Sensitivity		Specificity		Accuracy	
		T2WI	FST1WI	T2WI	FST1WI	T2WI	FST1WI
2.5 mm	Humeral	86 (12/14)	86 (12/14)	100 (14/14)	29 (4/14)	93 (26/28)	57 (12/32)
	Glenoid	100 (14/14)	93 (13/14)	57 (8/14)	36 (5/14)	79 (22/28)	64 (18/28)
3 mm	Humeral	79 (11/14)	79 (11/14)	100 (14/14)	36 (5/14)	89 (25/28)	57 (16/28)
	Glenoid	93 (13/14)	86 (12/14)	86 (12/14)	57 (8/14)	89 (25/28)	71 (20/28)
3.5 mm	Humeral	64 (9/14)	57 (8/14)	100 (14/14)	50 (7/14)	82 (23/28)	54 (15/28)
	Glenoid	86 (12/14)	71 (10/14)	86 (12/14)	79 (11/14)	86 (24/28)	75 (21/28)

group (Fig. 2c), compared with 13.4 mm±2.2 mm in the control group (Fig. 1c) with a significant difference ($P=0.012$). There was more abnormal tissue in the rotator interval in the patient group [100% (14/14) in the patient group (Fig. 2c) versus 43% (6/14) in the control group, $P=0.001$]. The sensitivity, specificity, and accuracy of abnormal tissue in the rotator interval were 100% (14/14), 57% (8/14), and 79% (22/28), respectively.

Discussion

Adhesive capsulitis is caused by the combination of inflammation and a fibrotic reaction in the capsule and synovium that subsequently leads to formation of adhesions [8–10]. Because treatment depends on the primary diagnosis, adhesive capsulitis should be differentiated from other causes of a stiff and painful shoulder, such as calcific or noncalcific tendinitis, rotator cuff tear, bicipital tenosynovitis, and glenohumeral arthritis, all of which can mimic adhesive capsulitis [2].

MR arthrography has gained increasing popularity as a diagnostic tool in assessing intraarticular derangements such as rotator cuff or glenoid labral abnormalities [11, 12]. On the other hand, the usefulness of MR arthrography for diagnosing adhesive capsulitis has not been fully established. Conventional arthrography has been used as the most useful diagnostic tool for adhesive capsulitis because the intraarticular injection of the contrast medium allows a clear visualization of the decreased joint capacity and obliteration of the axillary recess, which are the main findings necessary to diagnose adhesive capsulitis [13, 14]. In Lee et al.'s study using MR arthrography [7], the width of the axillary recess was significantly reduced in the patient group with adhesive capsulitis, similar to our results. Such decrease in the axillary recess width probably reflects the decrease in the volume of the axillary recess, a known criterion for diagnosing adhesive capsulitis through conventional arthrography. Recently, Mengiardi et al. [15] confirmed a significant decrease in volume in the patient group by measuring both the width and the height of the axillary recess from MR arthrography and indirectly calculating the volume.

According to Emig et al. [4], joint capsule and synovium thickness greater than 4 mm was a useful MR criterion for diagnosing adhesive capsulitis, showing a sensitivity of 70% and a specificity of 95% on nonarthrographic oblique coronal T2-weighted images. Using MR arthrography, however, we found that capsule and synovium thickness greater than 3 mm showed reasonable diagnostic accuracy at humeral and glenoid aspects of the axillary recess on coronal oblique T2-weighted images.

Our results are consistent with a previous report by Manton et al. [6] using oblique coronal fat-suppressed T1-weighted MR arthrography images to measure the capsule and synovium thickness on the humeral side of the axillary recess, which showed no significant differences between patient and control groups. Using oblique coronal T2-weighted images, however, we observed a significant difference between the two groups in capsule and synovium thickness on the humeral and glenoid aspects of the axillary recess. The overestimation of thickness on fat-suppressed T1-weighted images in control subjects resulted in an almost comparable sensitivity but caused a dramatic loss of specificity and, thus, of accuracy. In the study by Manton et al. [6] using coronal oblique fat-suppressed T1-weighted MR arthrography images, the mean thickness of the capsule and synovium in patients with adhesive capsulitis was 4.1 mm±1.0 mm, which was similar to our results of 4.3 mm±1.6 mm using coronal oblique T2-weighted images. However, their mean thickness of capsule and synovium in controls ($n=19$) was 5.1 mm±2.0 mm, in comparison to our results of 1.9 mm± 0.4 mm. Such discrepancy in control groups could be related to the fact that in contrast to the findings on our T2-weighted images without fat suppression, on fat-suppressed T1-weighted images of Manton et al.'s study, the capsule, synovium, and adjacent fat tissues all appear as low signal and are included as one in calculating the capsule and synovial thickness. In their study [6], the capsule and synovium thickness was 5.1 mm in the control group, whereas it was 3.3 mm in our control group on coronal oblique fat-suppressed T1-weighted images. Their trend was for a higher capsular and synovial thickness in the control group compared with the patient group. As least part of this difference might be explained by the fact that

6/19 of their controls had a full-thickness tear of the rotator cuff, whereas we excluded such patients as controls. The capsular and synovial thickness was 4.1 mm in their patient group and 4.2 mm in our patient group on coronal oblique fat-suppressed T1-weighted images. In their patient group, only one patient out of nine had a full-thickness tear, which could not make a difference.

Unlike the study by Manton et al. [6], Lee et al. [7] found meaningful difference in the capsule and synovium thickness between the patient and the control groups even by using oblique coronal fat-suppressed T1-weighted MR arthrography. However, as discussed above, on fat-suppressed images the thickness of the capsule and synovium is not precisely delineated and has a much lower diagnostic accuracy than on T2-weighted images. The overestimation of thickness on fat-suppressed T1-weighted images in control subjects results in an almost comparable sensitivity but causes a dramatic loss of specificity and, therefore, of accuracy. Thus, the capsule and synovium thickness in the axillary recess as measured on fat-suppressed-T1 weighted images is clearly overestimated in control subjects, and it would be highly recommended to use T2-weighted evaluation without fat suppression.

Most recently, Mengiardi et al. [15] measured the capsular thickness on intermediate-weighted MR images without fat suppression and found no significant difference between the control and the patient groups, in contrast to our results. This discrepancy could be partially related to the fact that patients with full-thickness rotator cuff tears were included in both control and patient groups in the study by Mengiardi et al. [15], whereas we excluded patients with full-thickness rotator cuff tears in both groups. Loss of intraarticular pressure secondary to complete-thickness tears of rotator cuffs may allow the capsular thickness to be overestimated. The loss of intraarticular pressure also seems a good explanation for the difference in the width of the axillary recess between our control group (8.5 mm) and that of Mengiardi et al. (6.0 mm). Another possible cause of loss of intraarticular pressure is rupture of the subscapular recess due to excessive shoulder motion. Another possible reason for this discrepancy could be related to the measurement method. We measured the thickness of the capsule and synovium on an extended line perpendicular to the humerus and cortical bone, as did Emig et al. [4], but Mengiardi et al. [15] calculated the thickness on a line parallel to the transverse plane of the images as depicted on their figures. Although the width of the axillary recess and the rotator interval showed significant differences in our study, there was a substantial overlap in the two groups, and the cut-off value could not be obtained.

In contrast to our results, Emig et al. [4] reported no significant differences between the two groups in the rotator interval width on nonarthrographic MR images. This debate regarding the rotator interval currently applies to MR arthrography as well, and Lee et al. [7] claimed that no meaningful difference exists in the rotator interval width between two groups. Connell et al. [5] and Mengiardi et al. [15] demonstrated that there was a significant difference of abnormal signal within the rotator interval between two groups, as in our results. Our results regarding rotator interval width and abnormal tissue in the rotator interval are supported by previous arthroscopic report by Ozaki [16]. Such opposing results may be partly related to the influence of the injected volume on the abnormal inflammatory tissue in the rotator interval space. In addition, the subcoracoid space and coracoid process itself are known to have great variations depending on the individual and his or her carriage [17]. We assumed that that was why the presence of the abnormal tissue in the rotator interval showed rather low specificity in our study.

This study had several limitations. The study population was small. Although the control group consisted of individuals arthroscopically confirmed not to have adhesive capsulitis, the majority of the patient group was not confirmed by arthroscopy.

The usefulness of each imaging sequence could only be determined in the assessment of capsule and synovium thickness in the axillary recess. Because T2-weighted images were obtained only in the oblique coronal plane, the role of T2-weighted images could not be determined in the measurement of the rotator interval width nor in the assessment of synovitis in this interval. The age and gender of the patients and controls were not well matched. Because the measurements and interpretations of the images were not performed independently by two different reviewers or repeatedly by each reviewer, inter- or intraobserver variances could not be obtained. Bias could have also been introduced during comparison of the individual imaging sequences because each individual sequence was interpreted with the other imaging sequences available. This bias would likely lead to decreased discrepancy between interpretations of the different imaging sequences. Thus, the differences between imaging sequences observed here are likely valid.

In conclusion, in absence of a full-thickness rotator cuff tear, thickness of capsule and synovium greater than 3 mm at the level of the axillary recess is a practical MR criterion for diagnosing adhesive capsulitis on oblique coronal T2-weighted MR arthrography images without fat suppression. Discordant results of some other authors are at least partly explained by the fact that they included full-thickness tears in their control groups. There were significant differences between the two groups in the width of the axillary recess and rotator interval, as well as the presence of abnormal tissue in the interval. The presence of abnormal tissue in the rotator interval showed high sensitivity but rather low specificity.

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