Adhesive Capsulitis of the Shoulder Joint: Value of Glenohumeral Distance on Magnetic Resonance Arthrography

Kyu Hong Lee, MD, Hee Jin Park, MD,* So Yeon Lee, MD,* In Young Youn, MD,* Eugene Kim, MD,† Jai Hyung Park, MD,† and Se Jin Park, MD†*

Objective: To evaluate the usefulness of glenohumeral distance (GHD) on axial images of magnetic resonance (MR) arthrography for diagnosis of adhesive capsulitis and to compare this finding with previously reported classic MR arthrographic findings of adhesive capsulitis.

Materials and Methods: Our study was approved by the institutional ethical review board of our institute. We evaluated 41 patients (M-F, 35:6; mean age, 46 years; adhesive capsulitis, 21; no adhesive capsulitis, 20) who underwent MR arthrography. Two radiologists measured GHD, width of the axillary recess, and capsular thickness in consensus. The GHD was measured from the subchondral bone of the glenoid fossa to the subchondral bone of the humeral head at the level of the midline of the humeral head. Glenohumeral distance (anterior, middle, posterior, and mean), width of the axillary recess, and capsular thickness (anterior, posterior, and mean) were compared in the adhesive capsulitis and no adhesive capsulitis groups using the Mann-Whitney *U* test.

Results: The mean GHD of the no adhesive capsulitis group was longer than that of the adhesive capsulitis group. The length differences were statistically significant ($P < 0.05$). The mean width of the axillary recess of the no adhesive capsulitis group was significantly wider than that of the adhesive capsulitis group ($P < 0.001$). The mean capsular thickness of the no adhesive capsulitis group was significantly thinner than that in the adhesive capsulitis group ($P = 0.001$).

Conclusions: A decreased GHD on MR arthrography can be another useful feature to diagnose adhesive capsulitis in addition to previously presented radiologic features such as capsular thickening and reduced axillary recess capacity.

Key Words: MR imaging, arthrography, adhesive capsulitis, shoulder

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Adhesive capsulitis (AC), which is more commonly called frozen shoulder, is a specific disease entity characterized by pain with limited range of motion and involves inflammation and fibrosis of the shoulder joint capsule.[1] Adhesive capsulitis can be idiopathic or the result of trauma, diabetes, hypothyroidism, or surgery.[2,3] Adhesive capsulitis should be differentiated from other causes of shoulder pain, and motion limitation, such as tendinitis, rotator cuff tear, and arthritis, because treatment is determined according to the cause.[4] Therefore, correct diagnosis is important. The clinical diagnostic criteria for AC include shoulder pain and limited passive and active range of motion lasting longer than 3 months without other causes that can explain the symptoms.[2,5] Magnetic resonance arthrography of the shoulder joint with intraarticular gadolinium injection is a preferred imaging method for evaluation of the labrum, ligaments, cartilage, the articular portion of the rotator cuff, and postsurgical changes.[6–8] Although diagnosis of adhesive capsulitis remains an issue for clinicians, there are generally suggested magnetic resonance (MR) arthrographic findings of adhesive capsulitis based on the pathophysiology of this condition, such as thickened capsule of the axillary recess or coracohumeral ligament, shortened rotator cuff interval, and subcoracoid fat obliteration.[3,4,9] Lee et al[9] correlated limited shoulder motion with thickening of the coracohumeral ligament on MR arthrography. Mengiardi et al[3] reported decreased joint capacity and smaller volume of the axillary recess in patients with AC. These abnormalities can theoretically lead to glenohumeral joint space narrowing. Therefore, we hypothesize that decreased distance between the glenoid and humeral head (glenohumeral distance [GHD]) is a useful measurement in the diagnosis of AC on MR arthrography. To the best of our knowledge, no study has been performed on the correlation between GHD and AC. We evaluated the usefulness of GHD on axial MR arthrographic images for the diagnosis of AC and compared these finding with previously reported MR arthrographic findings of AC.

MATERIALS AND METHODS

Case Selection

This study was approved by the institutional ethical review board of our institute, which waived the requirement for informed consent due to the retrospective study nature. We retrospectively evaluated 173 patients who consecutively underwent shoulder MR arthrography from Nov 2010 to Sep 2014. Clinical indications of shoulder MR arthrography included shoulder pain and impaired mobility under various clinical suspicions such as AC, SLAP lesion, Hill-Sachs lesions, and Bankart lesions. Among those 173 patients, 21 were diagnosed with AC with or without surgical arthroscopic evaluation. Six patients (29%) underwent arthroscopy, and 15 patients were diagnosed clinically. The same surgeon who performed arthroscopy also diagnosed the clinically confirmed cases. The clinical criteria for AC included stiffness and pain for longer than 3 months that was increasing in nature and did not resolve with rest. Another sign included restriction of passive motion greater than 30 degrees in more than 2 planes.[4] The other 152 patients had a final diagnosis other than AC such as SLAP lesion, Hill-Sachs lesions, Bankart lesions, bone cysts, and fractures. Among these 152 patients, 115 were excluded due to absence of surgical arthroscopic evaluation. An additional 17 patients were also excluded to minimize age-related bias because they were younger than 30 years. Eventually, 20 patients were selected as an arthroscopically proven negative AC group (Fig. 1).

The patient group included 2 women and 19 men (mean age, 47.7 ± 10 years; range, 35–71 years), and the control group included 4 women and 16 men (mean age, 44.1 ± 9 years; range, 34–63 years).

Arthroscopic Diagnosis

The same orthopedic shoulder surgeon with 15 years of experience performed all operative procedures. The mean interval

From the Departments of *Radiology and †Orthopaedic surgery, Kangbuk Samsung Hospital, Sungkyunkwan University School of Medicine, Jongno-gu, Seoul, Republic of Korea.

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Correspondence to: Hee Jin Park, MD, Department of Radiology, Kangbuk Samsung Hospital, Sungkyunkwan University School of Medicine, 108 Pyung-dong, Jongno-gu, Seoul 110-746, Republic of Korea (e-mail: parkhiji@gmail.com).

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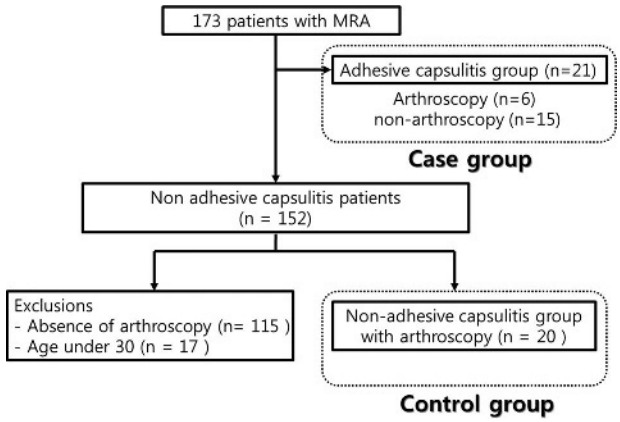

FIGURE 1. A flowchart of case selection.

between MR arthrography and surgery was 48 ± 22 days. Intraoperative findings of adhesive capsulitis were reduction of joint volume due to inflammation and fibrosis in all portions of the joint capsule, fibrotic tissue filling the rotator interval, and inflammatory change of the intraarticular portion of the biceps tendon without evidence of mechanical injury.[10]

MRA Technique and MR Parameters

Magnetic resonance arthrography (MRA) was performed by a musculoskeletal radiologist with 13 years of experience under fluoroscopy-guided joint injection with an anterior approach. Approximately 1 to 3 mL of iohexol (300 mg I/mL; Omnipaque, Nycomed) was injected using a 21-gauge spinal needle placed in the glenohumeral joint. About 10 mL of gadodiamide (0.5 mmol/mL; Omniscan) diluted 1:200 in normal saline was injected. The mean amount of injected contrast media was 18 ± 4 mL. Magnetic resonance imaging of the shoulder was initiated 20 to 40 minutes after intraarticular injection. MR examinations were performed using a 3.0 T MR scanner (Achieva, Philips, Best, Netherlands) with an 8-channel shoulder-dedicated coil with patients in a neutral upper arm position. The imaging parameters and sequences are summarized in Table 1.

Image Analysis

Two fellowship-trained musculoskeletal radiologists with 7 and 13 years of clinical experience, respectively, interpreted and measured shoulder MR arthrographic images. The radiologists were blinded to radiographic data and clinical history of the patients. They independently measured GHD, width of the axillary recess, and capsular thickness. The GHD was measured from the subchondral bone of the glenoid fossa to the subchondral bone of the humeral head at the level of the midline of the humeral head. We calculated mean GHD of 3 points using values measured at the anterior one third, midline, and posterior one third of the glenoid on axial planes of fat saturation T1-weighted images (Figs. 2A, 3A). The width of the axillary recess was measured at its widest portion, along the perpendicular line adjacent to the cortex of the humerus on the coronal T2-weighted images (Fig. 3B).[9] Capsular thickness was measured at the thickest portions of the medial and lateral aspects of the axillary capsule, based on the coronal T2-weighted images (Figs 2B, 3B).

Statistical Analysis

Glenohumeral distance (anterior, middle, posterior, and mean), width of the axillary recess, and capsular thickness (anterior, posterior, and mean) were compared in the AC and non-AC groups using the Mann-Whitney *U* test. Interobserver agreement between the 2 radiologists was analyzed using intraclass correlation coefficients (ICC). The ICC values less than 0.4 indicated poor reproducibility, values of 0.4 to 0.75 indicated fair or good reproducibility, and values greater than 0.75 indicated excellent reproducibility.[11] We used Predictive Analytics Soft Ware software version 18.0 (IBM, Armonk, NY). *P* values less than 0.05 were considered to be statistically significant.

RESULTS

The mean GHD of the non-AC group was longer than that of the AC group (2.10 ± 0.63 mm and 2.11 ± 0.60 mm vs 1.52 ± 0.52 mm and 1.53 ± 0.52 mm, respectively) (Table 2). The length differences were statistically significant (*P* value = 0.004 and 0.005, respectively). The GHD at all 3 locations (anterior, middle, and posterior) showed the same result. The mean width of the axillary recess of the non-AC group was wider than that of the AC group (12.38 ± 4.22 mm and 12.30 ± 3.99 mm vs. 7.00 ± 2.63 mm and 6.99 ± 2.46 mm, respectively, Table 3), which was statistically significant ($P < 0.001$). The mean capsular thickness of the non-AC group was thinner than that of the AC group (1.41 ± 0.47 mm and 1.42 ± 0.44 mm vs 2.07 ± 0.69 mm and 2.12 ± 0.71 mm, Table 3), which was statistically significant ($P < 0.001$). However, the mean lateral capsular thickness of reader

TABLE 1. Imaging Parameters for Routine MR Sequences

Parameter	Axial PD FSE	Axial F1 FS FSE	Coro T1 FS FSE	Coro PD FSE	Coro T2 FSE	Sag T1 FSE	Sag T1 FS FSE	Sag T2 FS FSE
TR, msec	3000–3200	600–800	600–1000	3100–3200	3200–3600	750–800	750–800	3200–3300
TE, msec	30	10–30	10	30	70–110	10	10	60
Flip angle, degrees	90	90	90	90	90	90	90	90
Matrix size	340 × 231	320 × 228	340 × 252	340 × 247	356 × 252	340 × 252	340 × 256	356 × 250
Field of view, cm	16	16	16	16	16	16	16	16
Slice thickness, mm	4	4	3	3	3	4	4	4
Interslice gap, mm	1	1	1	1	1	1	1	1
Bandwidth, kHz	290	290	298	290	399	236	236	290
Echo train length	14	7	7	15	16	7	9	12
Signal average	2	2	2	2	2	2	2	2
Scan time, min:sec	02:40	02:40	02:15	01:45	02:45	02:40	02:30	02:35

Coro indicates coronal; FS, fat saturation; FSE, fast spin-echo; Sag, sagittal; PD, proton density.

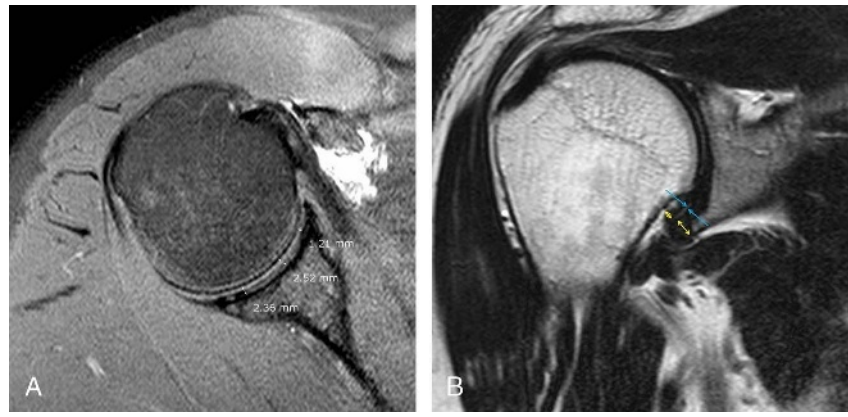

FIGURE 2. A 59-year-old man with adhesive capsulitis. A, The glenoid-humeral distances in anterior/middle/posterior portions (double arrows) are measured at the level of the center of the humeral head on axial fat saturation T1-weighted image (TR/TE, 780/25). B, The thickness of the capsule in the axillary recess (double arrows) and the width of the axillary recess (arrows) are measured on a coronal oblique T2-weighted scan (TR/TE, 3300/100). Figure 2 can be viewed online in color at www.jcat.org.

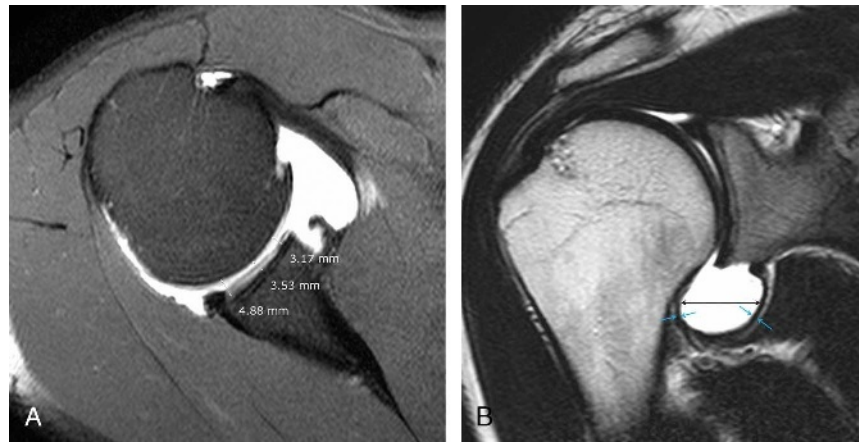

FIGURE 3. A 35-year-old man without adhesive capsulitis but with a Hill-Sachs lesion and bony Bankart lesion. A, The glenoid-humeral distances in anterior/middle/posterior portions (double arrows) are measured at the level of the center of the humeral head on axial fat saturation T1-weighted image (TR/TE, 780/25). B, The thickness of the capsule in the axillary recess (arrows) and the width of the axillary recess (double arrow) are measured on a coronal oblique T2-weighted scan (TR/TE, 3300/100). Figure 3 can be viewed online in color at www.jcat.org.

1 did not show a significant difference ($P = 0.064$) between 2 groups. The ICCs of each measurement between 2 radiologists were from 0.974 to 0.993, indicating excellent interobserver agreement (Table 4).

DISCUSSION

Some researchers have reported an AC prevalence rate as high as 2% among the general population.[12] This affliction typically affects shoulders of women older than 40 years, which is why it is also called the "fifties shoulder" in Korea.[13] The diagnosis of AC has remained mainly clinical and includes symptoms, such as shoulder pain, limited shoulder motion, and no other demonstrable abnormalities explaining the symptoms. Careful clinical examination is sufficiently sensitive and specific for diagnosis of AC with established history and typical physical signs.[12] However, clinical findings might be confusing at early stages of disease. There are several commonly encountered problems that should be differentiated from AC, such as calcific tendinitis, rotator cuff injury, or impingement syndrome in clinical practice. Thus, it is not surprising

TABLE 2. Mean Glenohumeral Distance According to Location (mm)

Diagnosis	Anterior	Middle	Posterior	Mean Distance
No adhesive capsulitis	2.31(±1.03)/2.28(±1.03)	2.29(±0.86)/2.31(±0.77)	1.71(±0.41)/1.74(±0.40)	2.10(±0.63)/2.11(±0.60)
Adhesive capsulitis	1.62(±0.77)/1.60(±0.75)	1.64(±0.63)/1.65(±0.62)	1.30(±0.46)/1.35(±0.44)	1.52(±0.52)/1.53(±0.52)
P	0.012/0.012	0.006/0.003	0.005/0.008	0.004/0.005

Reader 1/reader 2.

Data in parentheses are standard deviations.

TABLE 3. Mean Axillary Recess Width and Capsule Thickness According to Location (mm)

Diagnosis	Axillary Recess	Medial Capsule	Lateral Capsule	Mean Capsular Thickness
No adhesive capsulitis	12.38(±4.22)/12.30(±3.99)	1.36(±0.56)/1.37(±0.49)	1.46(±0.52)/1.47(±0.53)	1.41(±0.47)/1.42(±0.44)
Adhesive capsulitis	7.00(±2.63)/6.99(±2.46)	2.18(±0.74)/2.20(±0.74)	1.95(±0.82)/2.03(±0.80)	2.07(±0.69)/2.12(±0.71)
P	<0.001/< 0.001	0.001/< 0.001	0.064/0.028	0.001/0.001

Reader 1/reader 2.
Data in parentheses are standard deviations.

TABLE 4. The Intraclass Correlation Coefficients for Distance Measurements Between Readers

Location	Anterior Glenohumeral Distance Anterior	Middle Glenohumeral Distance	Posterior Glenohumeral Distance	Mean Glenohumeral Distance	Axillary Recess Width	Medial Capsular Thickness	Lateral Capsular Thickness	Mean Capsular Thickness
Value	0.985	0.993	0.974	0.993	0.981	0.981	0.984	0.992
95% Confidence interval	(0.972–0.992)	(0.987–0.996)	(0.951–0.987)	(0.986–0.996)	(0.965–0.990)	(0.964–0.990)	(0.969–0.992)	(0.983–0.996)

that some cases are misdiagnosed and thus result in a poor outcome.[14] Imaging studies, such as magnetic resonance imaging or MRA, can provide critical information in vague clinical settings.

The pathophysiology of AC is not yet fully understood. However, there are several commonly presenting mechanisms that might explain the clinical aspects. Neviaser[15] described AC as a condition due to chronic inflammatory changes of the capsule, resulting in capsular thickening, adhesion of the shoulder joint, and contracture. Previous histological study has also presented AC as a condition of inflammatory changes including fibrotic thickening and synovial proliferation.[16] This fibrotic change might restrain the flexibility of the rotator cuff muscles and lead to possible pain. In real surgical practice, arthroscopic capsular release is a well-established surgical procedure for intractable AC, resulting in reduction of pain and increased shoulder joint mobility. Tendons are freed from all intraarticular adhesions in this procedure.[10]

There have been several suggested radiologic findings to describe AC. Emig et al[17] suggested a useful MR criterion for diagnosis of AC based on capsular thickening greater than 4 mm at the axillary recess without abnormality in the rotator cuff interval. Jung et al[4] found fibrotic tissues in the rotator interval with decreased interval width and axillary recess and an axillary recess capsule thicker than 3 mm. Lee et al[9] also reported a significantly decreased volume of the axillary recess of the affected shoulder joint. In our study, we found that AC resulted in decreased dimension of the axillary recess and thicker capsule of the axillary recess (Table 3). However, we found the cutoff value to be different from those in previous studies. Our result of mean capsular thickness of AC was about 2 mm (while the mean thickness of the non-AC was 1.4 mm), and AC/non-AC ratio of capsule thickness was about 1.5. This ratio is located within the range of previous studies, 1.3 to 2.26.[4,9] We therefore suggest that capsular thickness greater than 4 or 3 mm is not a criterion standard for the radiologic diagnosis of AC.

We found GHD to be another useful method to evaluate AC on MR arthrography. The mean GHD of the AC group was less than 75% of that of the non-AC group, which was statistically significant ($P < 0.05$, Table 2). This evaluation was reproducible and showed excellent interobserver agreement (Table 4). The exact pathophysiology of GHD narrowing is not known; however, it is might be due to a series of extensions of chronic inflammatory changes with tendon or cartilaginous thickening or a result of decreased joint capacity.

There are several limitations in this study. First, we studied a relatively small number of AC patients with MR arthrography compared with the entire number of AC patients in clinic. Clinicians hesitate to perform MR arthrography because of its high cost and unpleasant intraarticular contrast injection. Also, MR arthrography was not always needed to diagnosis AC because it is largely a clinical diagnosis. However, 21 patients are not too small of a number to draw statistical conclusions compared to previous radiological reports. Second, we used an arthroscopically confirmed non-AC group as the reference group, almost all of which had pathologies. This could be a bias. Third, there is a possibility of limited accuracy of measurements. According to our MR parameters, the picture of the shoulder was drawn with a slice thickness of 3 to 4 mm and an interslice gap of 1 mm. These are relatively large values in comparison with measured values. Fourth, our study did not contain the research on whether adding of the GHD to the diagnostic criteria of AC can improve diagnostic performances or not.

In conclusion, a decreased GHD on arthrography can be another useful feature to diagnose AC in addition to previously presented radiologic features, such as capsular thickening and reduced axillary recess capacity.

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