Correlation of MR Arthrographic Findings and Range of Shoulder Motions in Patients With Frozen Shoulder

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OBJECTIVE. The purpose of this article is to correlate MRI arthrographic findings with range of shoulder motions in patients with frozen shoulder.

MATERIALS AND METHODS. Shoulder MRI studies of 40 patients (22 women and 18 men; mean age, 52.8 years) with frozen shoulder were retrospectively compared with MRI studies of 40 age- and sex-matched control subjects without frozen shoulder. The thickness of the coracohumeral ligament and the capsule in axillary recess were measured retrospectively. The range of shoulder motions, including external rotation (ER), internal rotation (IR), lateral abduction, and forward flexion (FF), were prospectively evaluated by one experienced orthopedic surgeon.

RESULTS. The mean (± SD) thickness of the coracohumeral ligament (4.13 ± 1.04 vs 2.51 ± 0.59 mm; $p = 0.000$) and the capsule in axillary recess (3.97 ± 1.45 vs 2.33 ± 0.87 mm; $p = 0.000$) were significantly greater in the patient group than in the control group. Multiple linear regression showed that only coracohumeral ligament thickness was significantly associated with ER ($R^2 = 0.418$; $p = 0.000$) and IR ($R^2 = 0.346$; $p = 0.001$), but not with lateral abduction and FF. Capsular thickness in axillary recess was not significantly correlated with any shoulder motion.

CONCLUSION. Coracohumeral ligament thickness on MR arthrography correlates with the range limitation of ER and IR in patients with frozen shoulder.

Keywords: adhesive capsulitis, coracohumeral ligament, frozen shoulder, MRI

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Frozen shoulder is a condition affecting the shoulder that commonly occurs in the sixth decade of life [1]. The term "frozen shoulder" was coined by Codman [2], who described a painful shoulder condition of insidious onset in 1934. He also identified severe pain with difficulty sleeping on the affected site and marked stiffness with reduction of shoulder motion in external rotation (ER) and forward flexion (FF). The term "adhesive capsulitis" has been used as a synonym for frozen shoulder since Neviaser first described it in 1945 [3]. Although this name is generally accepted, it is a bit of a misnomer, because frozen shoulder is not associated with capsular adhesion but is associated with synovitis and capsular contracture.

The pathogenesis of frozen shoulder is poorly understood, and there has been no standard definition for this common condition. Recently, shoulder specialists achieved a consensus about a standard definition and classification of frozen shoulder [4]: Frozen shoulder is a clinical condition characterized by restriction in both active and passive shoulder motion without discernible abnormality in radiographs except for the possible presence of osteopenia or calcific tendinitis. Frozen shoulder is divided into primary and secondary types. Frozen shoulder without identification of the underlying cause is included in the primary type, and frozen shoulder with an identified cause or associated condition is classified as the secondary type. Secondary frozen shoulder can be further subdivided into three categories; intrinsic, which is associated with rotator cuff disorders; extrinsic, which is associated with remote abnormalities, such as previous ipsilateral breast surgery, cervical radiculopathy, and stroke; and systemic, which is associated with systemic disorders, such as diabetes, hyperthyroidism, or hypothyroidism.

Patients with frozen shoulder progress through three overlapping phases [5]. Severe pain and shoulder stiffness develop insidiously and last for 10–36 weeks (painful freezing phase). The pain gradually subsides at 4–12 months, but nearly complete loss of passive and active shoulder motion remains (adhesive phase). The range of shoul-

der motion spontaneously improves at 12–42 months (resolution phase). Steroid injection and physiotherapy can help accelerate recovery. Manipulation under anesthesia and arthroscopic release can be tried in refractory cases. Nearly all patients recover, but the full range of movement may not be recovered.

Although frozen shoulder is clinically diagnosed, several MRI findings of frozen shoulder have been described, including capsular thickening of axillary recess, subcoracoid fat obliteration, thickening of coracohumeral ligament, and shortening of rotator cuff interval length, with discrepant findings among several different studies [6–12]. One of the possible reasons for this discrepancy is whether secondary frozen shoulder is included. Little is known regarding the link between radiologic findings and limited range of shoulder motion [6]. We therefore evaluated MRI findings in patients with primary frozen shoulder and correlated these findings with ranges of shoulder motion.

Materials and Methods

Study Group

This retrospective study was approved by our institutional review board, which waived written informed consent. Between May 2005 and May 2010, 624 patients at our institution were diagnosed with frozen shoulder by a single experienced orthopedic surgeon. Patients were diagnosed with frozen shoulder if they had limitations of both active and passive shoulder motions and more severe pain at night than during the day, and if radiographs of their shoulders were normal [5, 13]. Of these, 124 patients underwent MRI with arthrography. Patients with more than a 2-week interval between physical examination and MRI (n = 23) were excluded. Usefulness of MR arthrography for diagnosis of frozen shoulder was debatable; however, clinically the purpose of MRI is not about diagnosis of frozen shoulder but about exclusion of other abnormalities, such as rotator cuff tear. We included only MRI with arthrography, which was performed more frequently than MRI without arthrography for patients with frozen shoulder in our hospital.

We included primary (idiopathic) frozen shoulder and excluded secondary frozen shoulder. Patients with associated conditions of frozen shoulder, including calcific tendinitis or tear of rotator cuff, tendinitis of biceps tendon, acromioclavicular joint osteoarthritis, prior ipsilateral breast surgery, previous cerebrovascular accident, cervical radiculopathy, chest wall tumor, clavicle fracture, prior humeral fracture, and hemodialysis, were excluded by review of medical records [4, 6, 13–17].

Although diabetes and thyroid disorders are among the most important risk factors of frozen shoulder, there are some different definitions of idiopathic frozen shoulder related to these conditions. In some studies, patients with frozen shoulder and diabetes or thyroid disorder are classified as having idiopathic frozen shoulder, but are not classified as such in other studies [4, 18–21]. Furthermore about 30% of patients with frozen shoulder have these conditions, so we included patients with diabetes or thyroid disorder in the patient group [18].

Those with rotator cuff tendon tears (n = 50), calcific tendinitis (n = 6), or posttraumatic (n = 3) or postoperative (n = 2) states were excluded. Finally, the patient group consisted of 40 patients (18 men and 22 women; mean age, 52.8 years; range, 34–68 years) and 17 right and 23 left shoulders. As a control group, we selected 40 age- and sex-matched individuals without frozen shoulder and with the same exclusion criteria.

Clinical Information

Duration of shoulder pain was assessed prospectively by one experienced orthopedic surgeon, who also evaluated range of active and passive shoulder motions, including ER, internal rotation (IR), lateral abduction, and FF. ER and IR were measured as outward and inward rotations, respectively, with the arms at the sides and the elbows flexed to 90°; lateral abduction was measured as the ability to raise both arms from the side to full abduction (180°) above the head; and FF was measured as the ability to raise both arms forward above the head [6].

MRI Examinations

Arthrography was performed by fluoroscopy-guided joint injection with an anterior approach. The procedures were performed by several radiologists by turns. To verify intraarticular injection, 1–5 mL of iohexol (300 mg I/mL; Omnipaque, Nycomed) was injected via a 20-gauge spinal needle placed in the glenohumeral joint. About 10–15 mL of gadopentetate dimeglumine (0.5 mmol/mL; Magnevist, Schering) diluted 1:200 in normal saline was injected up to 20 mL until resistance was present or contrast material was extravasated. MRI of the shoulder was initiated 10–60 minutes after intraarticular injection. MRI of the shoulder was performed with one of two 1.5-T MRI scanners (Magnetom Vision Plus, Siemens Healthcare; or Signa Excite, GE Healthcare) with a phased-array surface coil (Shoulder Array, Medrad). Patients were positioned with neutral position of the humerus. Fat-suppressed T1-weighted (TR/TE, 450–750/12–16) 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. T2-weighted MRI scans (3500–4500/96–110) using an echo-train length of 10 were obtained in axial, coronal oblique, and sagittal oblique planes. MRI parameters for all sequences were as follows: FOV, 13–16 cm; 1–2 excitations; matrix size, 320 × 224 or 512 × 238; section thickness, 3 mm for coronal plane, 3.5 mm for sagittal and axial planes; and intersection gap, 1 mm.

Evaluation of MRI Examinations

MRI examinations were analyzed on high-resolution monitors (1536 × 2048 matrix, 12-bit viewable color scale) of a PACS by two radiologists who have experience in musculoskeletal imaging for more than 15 and 2 years, respectively. They were blinded to the clinical information and arthroscopy results. MRI scans were retrospectively analyzed by two radiologists in consensus for capsular thickness and width of axillary recess on coronal

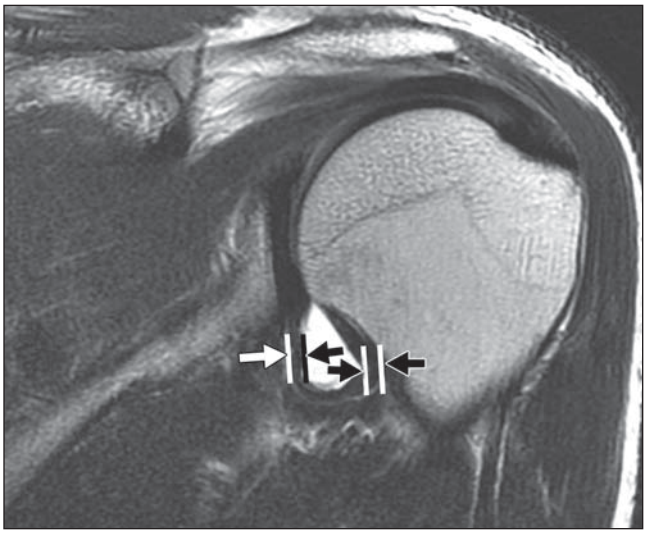
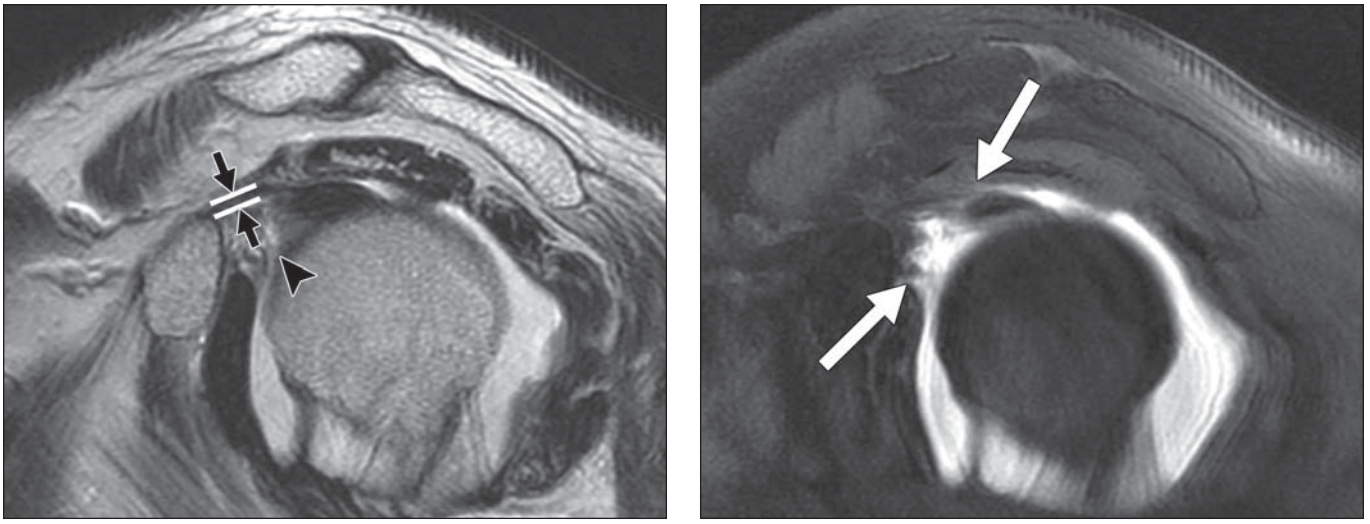


Fig. 1—34-year-old man without frozen shoulder. On coronal oblique T2-weighted MRI (TR/TE, 3500/98), thickened portion of capsule in axillary recess was measured separately for humeral and glenoid portions (*black and white arrows and lines*).



A B

Fig. 2—61-year-old man without frozen shoulder.
A, Sagittal oblique T2-weighted MRI (TR/TE, 3500/99) shows normal subcoracoid fat tissue within rotator interval (*arrowhead*). Coracohumeral ligament thickness was measured at thickest portion of it (*arrows and lines*).
B, Sagittal oblique fat-suppressed T1-weighted MR arthrogram (TR/TE, 650/14) reveals normal rotator interval (*arrows*). Shortest rotator interval width was measured between superior border of subscapularis and anterior border of supraspinatus at level of tip of coracoid process.

oblique T2-weighted images (Fig. 1) and for thickness of the coracohumeral ligament, capsular thickness, and presence of abnormal signals in the rotator interval on sagittal oblique T2-weighted images (Fig. 2A). In addition, length of the rotator cuff interval was measured on sagittal oblique fat-suppressed T1-weighted images (Fig. 2B). Coracohumeral ligament thickness was measured at the thickest portion on sagittal oblique T2-weighted images. Capsular thickness in axillary recess was determined by averaging the capsular and synovial thicknesses in the humeral and glenoid aspects of the axillary recess on coronal oblique T2-weighted images. Axillary recess width was measured at its widest portion, along the line perpendicular to the adjacent cortical bone on coronal oblique T2-weighted images. Other imaging sequences and planes were correlated if the exact margin of the capsule in axillary recess and coracohumeral ligament was not well delineated. An abnormal signal in the rotator interval was defined as partial or complete obliteration of subcoracoid fat or a synovitis-like abnormality at the superior border of the subscapularis tendon [7]. The thickest portion of the capsule was measured in the rotator interval of sagittal oblique images 1.5 cm lateral to the base of the coracoid process [7]. 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 sagittal oblique fat-suppressed T1-weighted images.

Statistical Analysis

Duration of pain, capsular thickness and width of the axillary recess, thickness of the coracohumeral ligament, and capsular thickness and length of the rotator interval were compared in the two groups using the Wilcoxon signed rank test. The presence of abnormal signals in the rotator interval was compared in the patient and control groups using the McNemar test. Correlations among MRI measurements and range of shoulder motions in the patient group were assessed by simple and multiple linear regression analyses. We also determined the multicollinearity of independent variables and the distribution of the residuals to check for normality. The sensitivity, specificity, and accuracy of coracohumeral ligament thicknesses to diagnose frozen shoulder were calculated at cutoff values of 2.5, 3, 3.5, and 4 mm, and the sensitivity, specificity, and accuracy of axillary recess capsule thicknesses to diagnose frozen shoulder were calculated at a cutoff value of 3 mm. Because our study contained a large number of patients whose results were unverified by the reference standard (arthroscopy), we checked for evidence of verification bias by means of global sensitivity analysis [22, 23] and calculated corrected values of sensitivity and specificity using a free Web-based calculator [24]. Likelihood ratios and the diagnostic odds ratio were also calculated [25]. For all statistical comparisons, significance was defined as p less than 0.05.

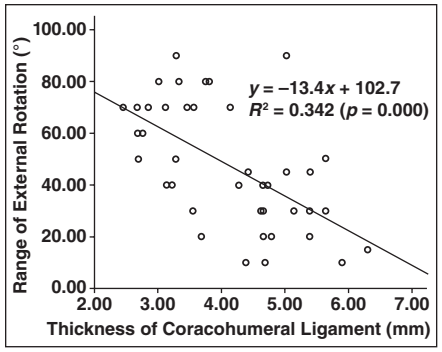
TABLE 1: Range of Shoulder Motion in Patients With Frozen Shoulder

Type of Shoulder Motion	Range of Shoulder Motion (°), Median (Interquartile Range)
External rotation	45.0 (30.0–70.0)
Internal rotation	50.0 (30.0–70.0)
Lateral abduction	90.0 (86.3–120.0)
Forward flexion	120.0 (100.0–142.5)

Note—External rotation is defined as outward rotation with the arm at the side and the elbow flexed to 90°. Internal rotation is defined as inward rotation with the arm at the side and the elbow flexed to 90°. Lateral abduction is defined as raising arm from the side to full abduction above the head. Forward flexion is defined as raising arm forward above the head.

Results

Of the 19 patients with frozen shoulder who had undergone arthroscopy, all were confirmed as having frozen shoulder. MRI showed superior labral anteroposterior lesions of the glenoid labrum in eight patients, with these lesions confirmed by arthroscopy in five patients. The median duration of shoulder pain was similar in the patient (6.5 months; interquartile range [IQR], 3.3–12.0 months) and control (4.0 months; IQR, 1.0–8.0 months) groups (p = 0.224). Six patients with frozen shoulder had a history of diabe-



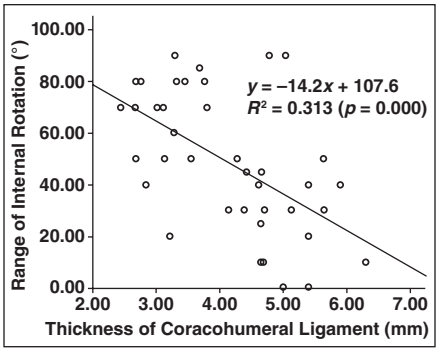


Fig. 3—Linear regression analysis.
A and **B,** Graphs show results of linear regression analysis between thickness of coracohumeral ligament and range of external rotation (**A**) and internal rotation (**B**) in patient group.

tes, compared with one patient in the control group ($p = 0.125$). None of the patients with frozen shoulder had thyroid disorder, whereas one person in the control group had hyperthyroidism.

Patients with frozen shoulder showed various limitations of ER (median, 45.0°; IQR, 30.0–70.0°), IR (50.0°; IQR, 30.0–70.0°), lateral abduction (90.0°; IQR, 86.3–120.0°), and FF (120.0°; IQR, 100.0–142.5°) (Table 1). The coracohumeral ligaments were visible completely or incompletely in all patients with and without frozen shoulder. Most cases did not need to correlate with other sequences or planes for measurements, but in several cases, correlation was useful particularly for measurement of capsular thickness in rotator interval.

The mean thickness of the coracohumeral ligament was significantly greater in the patient (4.13 ± 1.04 mm) than in the control (2.50 ± 0.59 mm) group ($p = 0.000$), as was the mean thickness (3.97 ± 1.45 vs 2.33 ± 0.87 mm; $p = 0.000$) and mean width (6.72 ± 3.71 vs 9.83 ± 3.10 mm; $p = 0.000$) of the axillary recess (Table 2). However, there were no significant between-group differences in capsular thickness and width of the rotator interval. Twenty-five patients with frozen shoulder had abnormal signals in rotator interval with partial ($n = 18$) or complete ($n = 7$) subcoracoid fat obliteration. In comparison, 12 patients without frozen shoulder had partial ($n = 9$) or complete ($n = 3$) subcoracoid fat obliteration, a difference that was statistically significant ($p = 0.007$).

Therefore, we evaluated the association between range of shoulder motions and MRI parameters, including the mean thickness of the coracohumeral ligament and axillary recess and subcoracoid fat obliteration in the patient group. Simple linear regression revealed statistically significant correlations between coracohumeral ligament thickness and range of shoulder motions, including ER ($R^2 = 0.342$; $p = 0.000$), IR ($R^2 = 0.313$; $p = 0.000$), and lateral abduction ($R^2 = 0.154$; $p = 0.012$) (Fig. 3), but not between the capsular thickness of axillary recess and range of shoulder motions, including ER ($R^2 = 0.062$; $p = 0.122$), IR ($R^2 = 0.037$; $p = 0.235$), lateral abduction ($R^2 = 0.038$; $p = 0.226$), and FF ($R^2 = 0.016$; $p = 441$). Simple linear regression showed statistically significant correlations between the width of axillary recess and range of ER ($R^2 = 0.205$; $p = 0.003$), IR ($R^2 = 0.119$; $p = 0.029$), and FF ($R^2 = 0.123$; $p = 0.026$). In contrast, we found no statistically significant correlation between coracohumeral ligament thickness and FF ($R^2 = 0.082$; $p = 0.074$) or axillary recess width and lateral abduction ($R^2 = 0.096$; $p = 0.052$). There was no statistically significant correlation between range of any shoulder motion and abnormal signals in the rotator interval.

From these findings, we selected coracohumeral ligament thickness and width of axillary recess as independent variables for multiple linear regression analysis. Despite the absence of significant correlation between capsular thickness of axillary recess and range of shoulder motions, we included this MRI parameter in multiple regression analysis because it has been shown to be one of the most reliable MRI findings for diagnosis of frozen shoulder [7, 9–11]. Finally, multiple linear regression showed that only coracohumeral ligament thickness was significantly associated with ER ($R^2 = 0.418$; $p = 0.000$) and IR ($R^2 = 0.346$; $p = 0.001$). In contrast, we found no significant correlations between coracohumeral ligament thickness,

TABLE 2: Comparison of Patient and Control Groups

MRI Measurement	Patient Group	Control Group	*p*
Coracohumeral ligament thickness (mm)	4.13 ± 1.04	2.50 ± 0.59	0.000[a]
Axillary recess capsular thickness (mm)	3.97 ± 1.45	2.33 ± 0.87	0.000[a]
Axillary recess width (mm)	6.72 ± 3.71	9.83 ± 3.10	0.000[a]
Rotator interval abnormal signal, % (no./total)	63 (25/40)	30 (12/40)	0.007[b]
Rotator interval width (mm)	16.14 ± 3.53	15.73 ± 3.38	0.582[a]
Rotator interval capsular thickness (mm)	4.41 ± 4.22	3.25 ± 3.08	0.180[a]

Note—Except where noted otherwise, data are mean ± SD.
[a]Wilcoxon signed rank test.
[b]McNemar test.

TABLE 3: Accuracy of the Thickness of Coracohumeral Ligament on Sagittal Oblique T2-Weighted Image for Diagnosis of Adhesive Capsulitis

Cutoff Level (mm)	Sensitivity	Specificity	Accuracy
2.5	98 (39/40)	43 (17/40)	70 (56/80)
3.0	85 (34/40)	83 (33/40)	84 (67/80)
3.5	65 (26/40)	95 (38/40)	80 (64/80)
4.0	53 (21/40)	100 (40/40)	76 (61/80)

Note—Data are % (no./total).

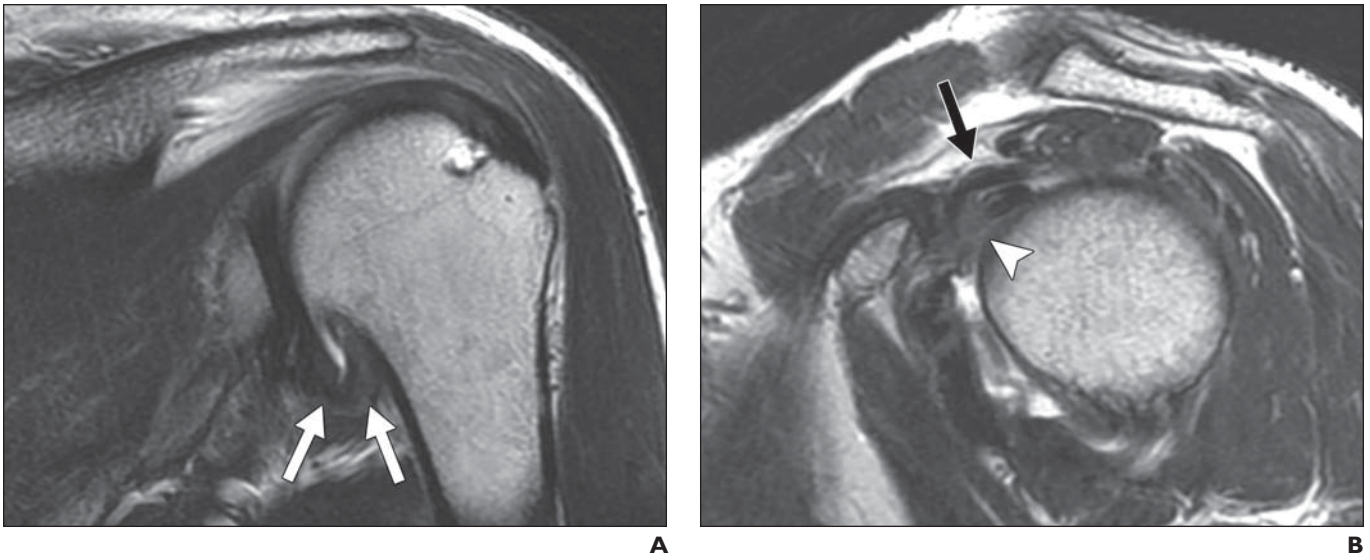


Fig. 4—58-year-old man with frozen shoulder.
A, Coronal oblique T2-weighted MRI (TR/TE, 3500/106) shows capsular thickening in axillary recess (*arrows*) with decreased width of axillary recess.
B, Sagittal oblique T2-weighted MRI (TR/TE, 3500/106) shows diffuse thickening of coracohumeral ligament (*arrow*) and obliteration of subcoracoid fat (*arrowhead*). Active range of shoulder motions of this patient had been limited as follows: external rotation, 30°; internal rotation, 30°; lateral abduction, 60°; and forward flexion, 120°. Subsequent arthroscopy revealed superior labral anteroposterior lesion at glenoid and hypertrophic and fibrotic synovium consistent with frozen shoulder.

axillary recess thickness, and axillary recess width with lateral abduction (R^2 = 0.194; p = 0.048) or FF (R^2 = 0.157; p = 0.102). The variance inflation factors were 1.177–1.704, indicating no multicollinearity between independent variables. Standardized residual plots revealed no apparent skewing, with the residuals apparently distributed normally.

A 3-mm cutoff value of coracohumeral ligament thickness gave the highest accuracy for diagnosis of frozen shoulder. The uncorrected sensitivity, specificity, and accuracy of MRI using a coracohumeral ligament cutoff of 3 mm were 85% (34/40), 83% (33/40), and 84% (67/80), respectively (Table 3). Global sensitivity analysis showed significant verification bias in the uncorrected estimates. Bias-corrected estimates of sensitivity and specificity were calculated from the data in Table 4. The bias-corrected estimate of sensitivity is 0.603 (95% CI, 0.427–0.779). The bias-corrected estimate of specificity is 0.892 (95% CI, 0.668–1.0). On the basis of these bias-corrected values, the likelihood ratio of a positive test is 5.6, the likelihood ratio of a negative test is 0.45, and the diagnostic odds ratio is 12.5. Using a 3-mm thickness of the capsule in axillary recess, we found that the sensitivity, specificity, and accuracy were 83% (33/40), 80% (32/40), and 81% (65/80), respectively. When abnormal thickening was defined as more than 3 mm for both coracohumeral ligament and capsule in axillary recess, 39 of 40 patients with frozen shoulder had abnormal MRI findings, including 28 with both coracohumeral ligament and axillary recess thickening (Fig. 4), six with only coracohumeral ligament thickening (Fig. 5), and five with only axillary recess capsular thickening.

Discussion

The coracohumeral ligament acts a biceps pulley, preventing subluxation of the long head of the biceps tendon and resisting inferior subluxation of the shoulder [5, 26–28]. The loss of active and passive ER is the hallmark of frozen shoulder [29]. In patients with frozen shoulder, the coracohumeral ligament tightens, restricting ER [26–28]. Histologically, the coracohumeral ligament is similar to the joint capsule without any ligament features [26–28, 30]. The coracohumeral ligament originates from the lateral aspect of the base of the coracoid process and is inserted into the supraspinatus tendon, rotator interval, and subscapularis tendon [26]. This ligament can split or form a complex with the superior glenohumeral ligament. The rate of coracohumeral ligament visualization has been found to vary, from 60% to 100% on MR arthrography and from about 63% to 88% on ultrasound [7, 8, 31, 32].

Several recent studies have assessed the importance of the coracohumeral ligament in the diagnosis of frozen shoulder [7, 8]. Mengiardi et al. [7] found that patients with frozen shoulder had a significantly thicker coracohumeral ligament (mean, 4.1 mm; range, 2.5–6.0 mm) than did control subjects (mean, 2.7 mm; range, 0.0–4.0 mm) on MR arthrography. Similar to the present results, that study reported that a cutoff value of 4 mm resulted in high sensitivity (95%) and specificity (59%) for diagnosis of frozen shoulder. In addition, the average thickness

TABLE 4: Verification of Frozen Shoulder by Arthroscopy in Patient and Control Groups

	Patient Group (n = 40)		Control Group (n = 40)	
MRI Finding	Arthroscopy Performed	Arthroscopy Not Performed	Arthroscopy Performed	Arthroscopy Not Performed
Coracohumeral ligament > 3 mm	25	9	1	6
Coracohumeral ligament ≤ 3 mm	4	2	2	31
Total	29	11	3	37

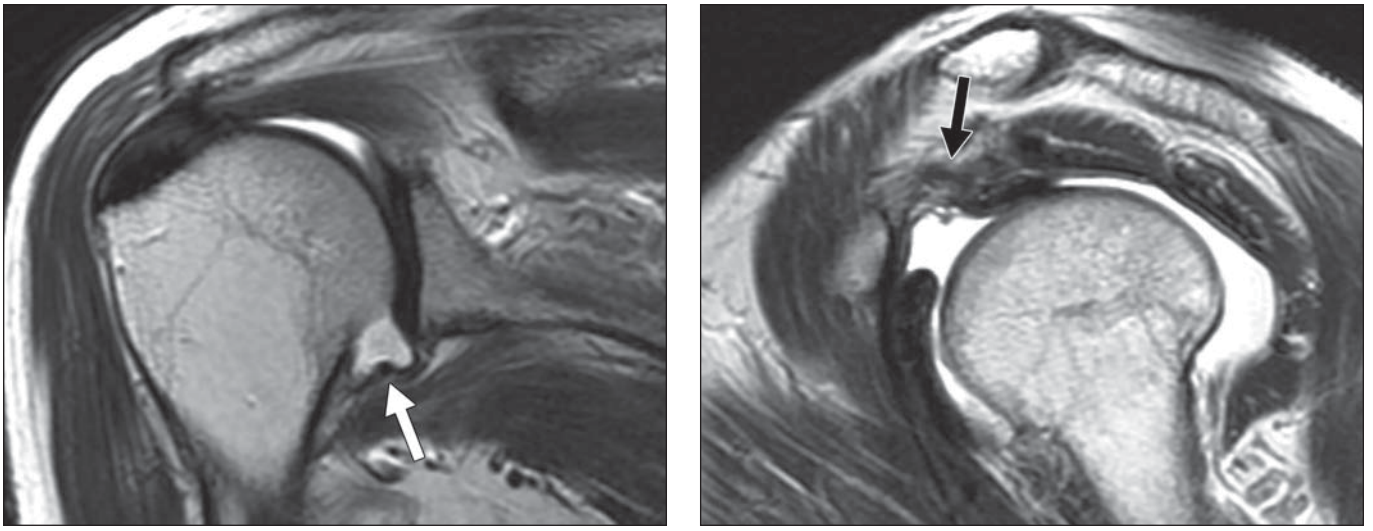


Fig. 5—60-year-old woman with frozen shoulder.
A, Coronal oblique T2-weighted MRI (TR/TE, 3500/102) shows normal axillary recess (*arrow*) without capsular thickening or decreased volume of axillary recess.
B, Sagittal oblique T2-weighted MRI (TR/TE, 3500/102) shows nodular thickening of coracohumeral ligament (*arrow*). Active range of shoulder motions of this patient had been limited as follows: external rotation, 15°; internal rotation, 10°; lateral abduction, 80°; and forward flexion, 80°.

of the coracohumeral ligament on ultrasound was found to be significantly greater in patients with frozen shoulder (3.0 ± 0.85 mm) than in those with asymptomatic (1.34 ± 0.32 mm) and painful shoulders (1.39 ± 0.54 mm) on ultrasound, suggesting that differences in mean coracohumeral ligament thickness as assessed by MRI and ultrasound may have been due to differences in arm position.

Similar to the present study, Kerimoglu et al. [6] and Mengiardi et al. [7] found a significant difference between patient and control groups with regard to the presence of subcoracoid fat obliteration. However, the accuracy for the diagnosis of frozen shoulder using the complete loss of subcoracoid fat is a bit different among them. Sensitivity and specificity were 32% (7/22) and 100% (22/22), respectively, in the study by Mengiardi et al. [7] and 21% (6/29) and 100% (3/3), respectively, in the present study. Kerimoglu et al. [6] found the sensitivity was 36% (7/17). The differences among literature may have been the result of our inclusion of only those patients with primary frozen shoulder and our exclusion of patients with systemic disease and rotator cuff tendon tears. In contrast, the earlier studies included patients with secondary frozen shoulder associated with amyloidosis and rotator cuff tendon tears.

There are few studies about the correlation between MRI findings of frozen shoulder and range limitation of shoulder motions [6]. Kerimoglu et al. [6] found that subcoracoid fat obliteration of patients receiving long-term hemodialysis strongly correlated with ER range limitations (r_s, 0.81–0.96; $p < 0.001$), whereas coracohumeral ligament thickness was not associated with ranges of shoulder motions. Whether secondary frozen shoulder was included or not is one of the most important causes of these conflicting results. The range limitations in shoulder motion may be due to other shoulder abnormalities. For example, all directional motions, including abduction, ER, and IR, may be restricted in patients with tears in the rotator cuff tendon [31, 33]. Subcoracoid and subacromial impingement can restrict the ranges of IR, FF, and lateral abduction [34]. In addition, we examined ER and IR with flexion of the elbow joint, whereas the earlier study assessed IR with extension of the elbow joint. Finally, in the earlier study, four of 17 coracohumeral ligaments were not included in the comparison of patient and control groups because of the inability to distinguish coracohumeral ligament from abnormal signals in the rotator interval. Exclusion of these patients may have affected their results. In contrast, our evaluation was more thorough because of our ability to correlate coracohumeral ligament thickness with other sequences and planes and to optimally adjust the MRI contrast using the PACS monitor, thus permitting all coracohumeral ligaments to be delineated and measured.

As in previous studies, we observed significant differences between our patient and control groups in the width and capsular thickness of axillary recess [7, 9–11]. However, these parameters were not significantly associated with ranges of shoulder motion in our patient group, suggesting that the inferior capsule is not important in limiting the range of shoulder motion, particularly in ER [33, 35]. Only the release of the anterior capsule was found to result in good recovery of shoulder motion in patients with frozen shoulder [33]. Moreover, arthroscopic investigations failed to show adhesion in the axillary recess in patients with frozen shoulder [7, 27, 28].

It is unclear whether rotator interval width differs significantly between patients with and without frozen shoulder [7, 10–12]. In addition, the reported ranges of rotator interval width have been found to vary considerably, variations that may be due to differences in the injected volume of intraarticular contrast medium and individual variations in subcoracoid space [9, 35, 36]. In contrast to our findings, other studies have reported significant between-group differences in the synovial thickness of the rotator interval [7]. Most patients in that study, however, had tears in the rotator cuff tendon, which can affect synovial thickening in the rotator interval [9]. In addition, delineation of the exact margin of the capsule in the rotator interval was frequently difficult because it is a complex structure composed of abnormal signals in subcoracoid fat and synovitis-like abnormalities in the superior subscapularis recess and superior glenohumeral ligament.

This study has several limitations. First, we could correlate only the active range of shoulder motion because the medical records of some patients lacked information on the passive range of shoulder motions. Limitation of active shoulder motions may be due to pain; therefore, the relationship between MRI finding and internal rotation could be overestimated. The majority of individuals in both groups were not confirmed arthroscopically as having or not having frozen shoulder.

In conclusion, we found that limitations of ER and IR in patients with frozen shoulder were associated with the thickness of the coracohumeral ligament on MR arthrography. The presence of a thickened coracohumeral ligament, although not diagnostic of a frozen shoulder, increases the odds of frozen shoulder by a factor of 5.6. In addition, the odds of a frozen shoulder among subjects with coracohumeral ligament thickening are about 12.5 times higher than the odds of a frozen shoulder among subjects with no coracohumeral ligament thickening.

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