Anterior Capsular Thickening: Another Significant MRI Finding for Evaluation of Adhesive Capsulitis of the Shoulder

Poster No.: P-0038
Congress: ESSR 2018
Type: Scientific Poster
Keywords: Inflammation, Imaging sequences, MR, Musculoskeletal system, Musculoskeletal soft tissue, Musculoskeletal joint
DOI: 10.1594/essr2018/P-0038

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Purpose

To evaluate the usefulness of anterior capsular abnormality on magnetic resonance imaging (MRI) for diagnosis of adhesive capsulitis of the shoulder.
Methods and Materials

This retrospective study was approved by our Institutional Review Board. Informed consent was waived due to the retrospective nature of the study.

Inclusion and exclusion criteria

Patients

Between January 2016 and December 2016, consecutive 219 shoulder MR examinations excluding MR arthrography were performed in our institution. Medical records of these patients were analyzed. The initial diagnosis of adhesive capsulitis was based on history and clinical symptoms. Clinical criteria for the diagnosis of adhesive capsulitis included restricted passive motion of greater than 30 degrees in two or more planes of movement compared to normal contralateral shoulder and gradually increasing shoulder pain that was more severe at rest for at least one month with normal radiographic findings [6, 21]. Among 46 patients who fulfilled the criteria, 17 patients were excluded for the following reasons: bilateral shoulder restricted motion, tear of rotator cuff tendon, calcific tendinitis, rheumatoid arthritis, severe osteoarthritis, labral lesion. The remaining 29 patients (12 males, 17 females; mean age, 51 years; age range, 30-73 years) with a final clinical diagnosis of adhesive capsulitis were identified and their images were evaluated retrospectively.

Control group

Control group composed of consecutive 20 patients (10 males, 10 females; mean age, 49 years; age range, 23-63 years) with normal glenohumeral joint on shoulder MRI, excluding MR arthrography. Patients in the control group had been referred for MRI at our institution between January 2016 and December 2016. They had no restricted shoulder motion or history of adhesive capsulitis. Control group patients were referred for the following reasons: evaluation of the shoulder pain (12 patients), soft-tissue masses (lipoma, 5 patients; hematoma, 1 patient), and bone lesions (2 patients).

Clinical Assessment

All patients, including control, underwent physical examination before the MRI examination by one physician (22 years of experience) in the shoulder clinic. Using a universal goniometer, range of motion (ROM), including external rotation, forward flexion, and abduction, was evaluated. The external rotation was assessed while the shoulder was maintained in 0° of abduction with 90° elbow flexion. ROM for the internal rotation was measured by noting the highest segment of spinal anatomy reached with the thumb. Forward flexion was measured as the maximum arm-trunk angle by the elevation of arm...
forward above the head. Abduction was measured as the ability to raise both arms from the side to full abduction (180°) above the head. The mean duration of symptom was 5.5 months (range, 1 - 14 months) in the adhesive capsulitis group. Mean interval between clinical assessment and MR imaging was 16 days (range, 4 ~ 48 days).

MR Image Acquisition

MRI Protocol

All patient and control group had same MRI protocol with a 3-T MRI (Intera Achieva, Philips Healthcare) unit with a dedicated shoulder coil. During imaging, patients were lying in supine position with arm externally rotated to the maximum extent possible. The following imaging parameters were used: oblique sagittal fat-suppressed proton density (PD) VISTA sequence with Spectral Attenuated Inversion Recovery (SPAIR) imaging (TR/TE, 2000/18.6; echo-train length, 140; section thickness, 1.2 mm; matrix, 268 × 267; FOV, 160 x 160 mm), oblique coronal fat-suppressed T2-weighted imaging (TR/TE, 4700/80; echo-train length, 10; section thickness, 3 mm; matrix, 356 × 255; FOV, 160 x 160 mm), oblique coronal T1-weighted imaging (TR/TE, 530/20; echo-train length, 3; section thickness, 3 mm; matrix, 358 × 258; FOV, 160 x 160 mm), oblique sagittal T2-weighted imaging (TR/TE, 3800/80; echo-train length, 16; section thickness, 3 mm; matrix, 356 × 256; FOV, 160 x 160 mm), oblique sagittal T1-weighted imaging (TR/TE, 530/20; echo-train length, 3; section thickness, 4 mm; matrix, 356 × 258; FOV, 160 x 160 mm), axial fat-suppressed PD imaging (TR/TE, 2100/30; echo-train length, 20; section thickness, 3 mm; matrix, 356 × 240; FOV, 160 x 160 mm).

MR Image Analysis

Measurements of parameters were independently performed by two musculoskeletal radiologists (9 years of experience) on a picture archiving and communication system (PACS) workstation (INFINITT, Infiniti healthcare, Seoul, Korea). Two musculoskeletal radiologists who were blinded to the clinical information independently evaluated all variables on MR images. Quantitative and qualitative MRI findings for the diagnosis of adhesive capsulitis were defined as those described in the literature [3, 5, 11, 22, 23]. Prior to the measurement, training session for both readers was performed using images that were different from the analysis data. After two readers measured the parameters separately, all parameters were re-evaluated under the consensus and statistical analysis was performed with these data.

Quantitative analysis

In quantitative analysis, the following parameters were measured on MR image with magnification: anterior capsular thickness, humeral and glenoid capsular thickness in axillary recess, maximal axillary capsular thickness, coracohumeral ligament thickness,
and degree of external rotation. Anterior capsular thickness was measured on the thickest portion of the anterior portion of the glenohumeral joint capsule, below the subscapularis tendon, including the middle glenohumeral ligament and spiral glenohumeral ligament, which seemed to have relatively low signal intensity compared to the subscapularis tendon at the level of the glenohumeral joint. This measurement was performed on both oblique sagittal 3D PD VISTA SPAIR and axial fat-suppressed PD images (Fig. 1, 2) [24-26]. In the axillary recess, humeral and glenoid capsular thickness were measured on oblique coronal T2-weighted MR images of both humeral and glenoid regions after magnification at the thickest portion. The maximal axillary capsular thickness was then determined to the larger value of humeral and glenoid capsular thickness (Fig. 3). The maximal coracohumeral ligament thickness was measured on oblique sagittal T2 images (Fig. 4). The degree of external rotation on the axial MR image was measured by drawing a line from the center of the humeral head to the longitudinal axis of the scapular body with a second line from the center of the humeral head to the bicipital groove of the humeral head (Fig. 5) [6]. All measurements were recorded to two decimal places.

**Qualitative analysis**

The following findings were evaluated as present or absent: anterior capsular edema, humeral and glenoid capsular edema in axillary recess, edema and obliteration of the subcoracoid fat triangle. If there was edema on either side of the humeral or glenoid capsule of the axillary recess, the axillary capsular edema was considered present. Edema of joint capsule and subcoracoid fat triangle was evaluated on oblique coronal fat-suppressed T2-weighted MR images (Fig. 6, 7). Obliteration of the subcoracoid fat triangle was defined as low signal intensity of fat on T1-weighted images with respect to subcutaneous fat on oblique sagittal T1-weighted images. Both partial and complete obliteration were considered as signs of adhesive capsulitis [11, 12, 23] (Fig. 8).

**Statistical Analysis**

Demographic and various MR findings were compared between the adhesive capsulitis group and the control group. Fisher’s exact test or Mann-Whitney U-test was used to compare demographic data and imaging parameters between the two groups. A correlation study was also performed to evaluate the effect of external rotation degree on MRI findings.

Binary multiple logistic regression analysis was performed to determine the relative contribution of different MR imaging findings. Characteristics with a $p$-value of less than 0.05 at univariate analysis were used as independent input variables for multiple logistic regression analysis. To eliminate multicollinearity, multivariate analysis was conducted separately in quantitative and qualitative findings. To evaluate diagnostic utilities of various parameters, we performed receiver operating characteristic (ROC) analysis to determine sensitivities, specificities, and cut-off values.
Inter-class correlation coefficient (ICC) was calculated to assess the extent of agreement between the two readers in terms of measurement of four parameters in quantitative analysis. To evaluate inter-observer variability for qualitative analysis, Cohen kappa statistics were also calculated. ICC or kappa value was interpreted as follows: 0, poor agreement; 0.01-0.20, slight agreement; 0.21-0.40, fair agreement; 0.41-0.60, moderate agreement; 0.61-0.80, good agreement; and 0.81-1.00, excellent agreement.

All statistical analyses were performed using one of two computer software programs: SPSS version 20 (SPSS, Chicago, IL, USA), and MedCalc version 16.2.1 (MedCalc Software, Ostend, Belgium).
Fig. 1: Examples of quantitative measurements of capsular and coracohumeral ligament thickness on MRI. A 49-year-old man in the control group. Oblique sagittal PD VISTA SPAIR image showing measurement of the thickest portion of anterior joint capsule (dashed line). The middle glenohumeral ligament (thin arrows) leads to spiral glenohumeral ligament (thick arrows) inferiorly.

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Fig. 2: Examples of quantitative measurements of capsular and coracohumeral ligament thickness on MRI. A 58-year-old woman in the control group. Axial fat-suppressed PD image showing measurement of anterior capsular thickness (dashed line) at the level of the middle glenohumeral ligament (thin arrows) crossing superficial layer of anterior joint capsule and spiral glenohumeral ligament (thick arrows).

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Fig. 3: Examples of quantitative measurements of capsular and coracohumeral ligament thickness on MRI. A 59-year old woman with adhesive capsulitis. Oblique coronal fat-suppressed T2-weighted image showing measurement of the thickest portion of axillary joint capsule in both humeral (arrow) and glenoid (dashed arrow) attachment.

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Fig. 4: Examples of quantitative measurements of capsular and coracohumeral ligament thickness on MRI. A 58-year old man in the control group. Oblique sagittal T2-weighted image showing measurement of the coracohumeral ligament thickness (dashed line).

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Fig. 5: Examples of quantitative measurements of capsular and coracohumeral ligament thickness on MRI. A 58-year old man in the control group. Axial fat-suppressed PD image at the level of center of humeral head showing degree of shoulder external rotation. An angle was measured between longitudinal axis of scapula (a) and a line was drawn between the center of humeral head and bicipital groove (b).

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Fig. 6: A 47-year-old woman with adhesive capsulitis. Oblique coronal fat-suppressed T2-weighted image showing axillary capsular thickening and edema. Increased thickness at the glenoid (4.71 mm) and humeral (5.69 mm) portion and T2 signal intensity of axillary joint capsule (arrows) are present.

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Fig. 7: A 47-year-old woman with adhesive capsulitis. Oblique coronal fat suppressed T2-weighted image at the coracoid process (C) level showing edema at the subcoracoid fat triangle (arrows).

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**Fig. 8:** A 47-year-old woman with adhesive capsulitis. Oblique sagittal T1-weighted image showing obliteration of the subcoracoid fat triangle (arrows).

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Results

Comparisons of MRI Findings by Univariate Analysis

There was no significant difference in sex or age between the adhesive capsulitis group and the control group. Results of comparison of MRI findings between the two groups are summarized in Table 1. All qualitative and quantitative MRI findings were significantly different between adhesive capsulitis and control groups. The mean anterior capsular thickness in the adhesive capsulitis group was higher than that of the control group (3.99 ± 1.64 mm vs. 1.66 ± 0.79 mm, \( p < 0.001 \)). Anterior capsular edema was also more frequently observed in the adhesive capsulitis group (25 vs. 4, \( p < 0.001 \)). There was no significant relationship between external rotation values measured in MR image and other MRI findings including anterior capsule thickness in the adhesive capsulitis group or the control group.

Multivariable Analysis and Diagnostic Performance

Among quantitative MR findings, humeral and glenoid capsular thickness was excluded from multivariate analysis because the maximal axillary capsular thickness was more clinically used. It is also correlated with humeral and glenoid capsular thickness. Multivariate logistic regression analysis showed that anterior capsular thickness and maximal axillary capsular thickness were useful variables that could differentiate adhesive capsulitis from control group with odd ratios of 7.97 and 17.75, respectively (\( p < 0.05 \)). Multivariate logistic regression analysis with anterior capsular edema, axillary capsular edema, and edema at the subcoracoid fat triangle in qualitative findings showed that only anterior capsular edema was significant, with odd ratio of 12.41 (\( p = 0.01 \)) (Table 1).

In ROC analysis, anterior capsular thickness showed higher diagnostic performance than maximal axillary capsular thickness to diagnose adhesive capsulitis, with AUC of 0.897 and 0.868, respectively. However, anterior capsular thickness and maximal axillary capsular thickness in ROC comparison were not significantly different (95% confidence interval: 0.787-0.970 vs. 0.682-0.914, respectively, \( p = 0.28 \)). Results of cut-off value and area under the ROC curve are shown in Table 2 and Figure 9. The cut-off value of anterior capsular thickness at 3.5 mm was clinically applicable, affording excellent diagnostic accuracy, with a sensitivity of 65.5% and a specificity of 100% (Fig. 10, 11). The cut-off value of maximal axillary capsular thickness at 4 mm was also clinically applicable, affording excellent diagnostic accuracy, with a sensitivity of 58.6% and a specificity of 100%.

In five patient (17.2%) of adhesive capsulitis group, anterior capsular thickness values were more than 3.5 mm. However, they did not meet the diagnostic criteria of maximal axillary capsular thickness (> 4 mm) and coracohumoral ligament thickness (> 3 mm).
The other qualitative parameters except anterior capsular edema were also negative in 2 (6.9%) out of these 5 patients (Fig. 12, 13, 14, 15).

**Interobserver Agreement**

Results of interobserver agreement are summarized in Table 3. Good agreement was found between anterior capsular edema (# = 0.77), edema in humeral and glenoid capsules (both # = 0.75), humeral capsule thickness in axillary recess (ICC = 0.69), and anterior capsule thickness (ICC = 0.66). Moderate agreement was found for coracohumeral ligament thickness (ICC = 0.58), glenoid capsule thickness in axillary recess (ICC = 0.47), edema at the subcoracoid fat triangle (# = 0.45), and obliteration of the subcoracoid fat triangle (# = 0.43).
Fig. 9: Receiver operating characteristic (ROC) analysis of anterior capsular thickness (AUC = 0.897) and maximal axillary capsular thickness (AUC = 0.863).

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Fig. 10: A 46-year-old man with adhesive capsulitis. Axial fat-suppressed PD image also showing marked thickening of anterior joint capsule (arrows).

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**Fig. 11:** A 46-year-old man with adhesive capsulitis. Fig. 4a. Oblique sagittal PD VISTA SPAIR image showing thickening (6.94mm) of anterior joint capsule (arrows).

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Fig. 12: A 50-year-old man with adhesive capsulitis. Oblique coronal fat-suppressed T2-weighted image showing no significant thickening (3.7 mm) of the axillary joint capsule (arrows). There is no significant axillary capsular edema.

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**Fig. 13:** A 50-year-old man with adhesive capsulitis. Oblique sagittal T2-weighted image showing no significant thickening (2.9 mm) of the coracohumeral ligament (arrows).

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Fig. 14: A 50-year-old man with adhesive capsulitis. Axial fat-suppressed PD image also showing thickening and edema of anterior joint capsule (arrows).

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Fig. 15: A 50-year-old man with adhesive capsulitis. Oblique sagittal PD VISTA SPAIR image showing prominent thickening (6.94 mm) of the anterior joint capsule (arrows).

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Table 1: Demographic and MRI findings between adhesive capsulitis group and control group

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Adhesive capsulitis (n=29)</th>
<th>Control (n=20)</th>
<th>Univariate p-value</th>
<th>Odd ratio</th>
<th>Multivariate p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex M : F</td>
<td>12 : 17</td>
<td>10 : 10</td>
<td>0.551</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>51.21 ± 9.18</td>
<td>49.15 ± 11.34</td>
<td>0.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantitative analysis³</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior capsular thickness (mm)</td>
<td>3.99 ± 1.64</td>
<td>1.66 ± 0.79</td>
<td>&lt; 0.001</td>
<td>7.97</td>
<td>0.02</td>
</tr>
<tr>
<td>Maximal axillary capsular thickness (mm)</td>
<td>4.61 ± 1.53</td>
<td>2.55 ± 1.03</td>
<td>&lt; 0.001</td>
<td>17.75</td>
<td>0.02</td>
</tr>
<tr>
<td>Humeral capsular thickness (mm)</td>
<td>3.41 ± 1.71</td>
<td>2.23 ± 0.69</td>
<td>0.015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glenoid capsular thickness (mm)</td>
<td>4.03 ± 1.74</td>
<td>2.47 ± 0.99</td>
<td>0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coracohumeral ligament thickness (mm)</td>
<td>3.13 ± 1.16</td>
<td>2.25 ± 1.04</td>
<td>0.008</td>
<td>6.75</td>
<td>0.06</td>
</tr>
<tr>
<td>Degree of external rotation</td>
<td>137.41 ± 9.70</td>
<td>149.67 ± 10.06</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qualitative analysis³</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior capsular edema</td>
<td>25 (86.2%)</td>
<td>4 (20.0%)</td>
<td>&lt; 0.001</td>
<td>12.41</td>
<td>0.01</td>
</tr>
<tr>
<td>Axillary capsular edema</td>
<td>24 (82.8%)</td>
<td>2 (10%)</td>
<td>&lt; 0.001</td>
<td>3.55</td>
<td>0.29</td>
</tr>
<tr>
<td>Humeral capsular edema</td>
<td>21 (72.4%)</td>
<td>4 (21.1%)</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glenoid capsular edema</td>
<td>19 (65.5%)</td>
<td>1 (5.3%)</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edema at subcoracoïd fat triangle</td>
<td>27 (93.1%)</td>
<td>5 (26.3%)</td>
<td>&lt; 0.001</td>
<td>4.33</td>
<td>0.26</td>
</tr>
<tr>
<td>Obliteration of the subcoracoïd fat triangle</td>
<td>28 (96.6%)</td>
<td>8 (40.0%)</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note — MRI = Magnetic Resonance Imaging. ³Data are presented as mean ± SD. ⁵Data are presented as number.
**Table 2:** TABLE 2. Diagnostic Performance of Parameters by ROC Curve Analysis

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**Table 3: TABLE 3. Interobserver Agreement**

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Conclusion

In conclusion, anterior capsular abnormality such as thickness and increased signal intensity (edema) can be used for diagnosis of adhesive capsulitis of shoulder. Among various MR findings of adhesive capsulitis, anterior capsular thickness and edema as well as maximal axillary capsular thickness had strong diagnostic value in adhesive capsulitis. In addition to known abnormal MRI findings at the rotator interval including the subcoracoid fat triangle and axillary recess, evaluation of the anterior capsule of shoulder joint could be used for early diagnosis of adhesive capsulitis.


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