Correlation Between MRI Findings and Clinical Impairment In Patients With Shoulder Adhesive Capsulitis: A Prospective Study

Romain GILLET (romain_gillet3@hotmail.com)  
Centre Hospitalier Universitaire de Nancy

Francois ZHU  
Centre Hospitalier Universitaire de Nancy

Pierre PADOIN  
Centre Hospitalier Universitaire de Nancy

Gabriella HOSSU  
Nancy Clinical Investigation Centre Innovative Technology

Ayrmeric RAUCH  
Centre Hospitalier Universitaire de Nancy

Pedro Augusto GONDIM TEIXIERA  
Centre Hospitalier Universitaire de Nancy

Alain BLUM  
Centre Hospitalier Universitaire de Nancy

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Abstract

Objectives:

MRI diagnostic criteria of shoulder adhesive capsulitis (AC) are widely used, but there is little information available on the association between MRI findings and clinical impairment. The aim of our study was to determine the correlation of MRI findings with the Constant-Murley Score (CMS), pain duration, and symptoms at the one-year follow-up in AC patients.

Methods:

MRI of 132 patients with a clinical diagnosis of shoulder AC were prospectively studied. A radiologist examined all patients and completed the CMS just prior to MRI. Pain duration was assessed. The signal intensity and the maximal thickness of the inferior glenohumeral (IGHL) and coracohumeral (CHL) ligaments were measured by two radiologists. Medical record analysis was performed in a sub-group of 49 patients to assess correlation approximately one year after the MRI examination.

Results:

There was a significant difference in mean pain duration score (3.8 ± 1.2 versus 3.2 ± 0.9 and 3.8 ± 1.2 versus 3.2 ± 0.9 respectively for readers 1 and 2) and in mean mobility scores (15.7 ± 8 points versus 19.6 ± 10.1 points and 15.8 ± 8.2 points versus 19.4 ± 10 points respectively for readers 1 and 2) in patients with a high IGHL signal compared to those with a low signal (P < .05). IGHL was thicker in patients with clinical improvement at one-year follow-up compared to those presenting clinical stability or worsening (P < .05).

Conclusion:

In shoulder AC patients, the degree of signal intensity at the IGHL was inversely related to shoulder pain duration and range of motion, and a thickened IGHL indicated a favorable outcome at one-year follow-up.

Introduction

Adhesive capsulitis (AC) of the shoulder is a common condition with an incidence in the general population varying considerably from 2 to 5.3% for primary and from 4.3 to 38% for secondary AC (e.g., AC preceded by a clinical or surgical event) 1. Although spontaneous resolution is the rule, years can ensue (mean 18–30 months) before joint mobility returns to normal 2. Various treatment options exist for AC (e.g., oral anti-inflammatory drugs, intraarticular corticoid injection, physiotherapy, percutaneous capsular distention, surgical release, etc.) depending on the level of clinical impairment, and on an
accurate diagnosis. Thus, disease staging and identification of inflammatory changes could have an impact on patient management.3

The diagnosis of AC is classically based on clinical presentation, medical history, and physical examination. Diagnosing this condition, however, can be challenging as AC may occur in various clinical scenarios and has multiple potential differential diagnoses (2, 4). Imaging plays an ever-growing role in the evaluation of patients with suspected AC ruling out pathologic conditions that can clinically mimic AC, and in diagnostic confirmation when clinical findings are equivocal.5–14 AC suggestive MRI findings are well recognized and primary involving the inferior glenohumeral ligament (IGHL) (hypersignal and thickening), and rotator interval (RI).7,9,10,12,15–17.

Patients with AC typically complain of a gradual and progressive onset of pain, sleep-disturbing night pain, and painful active and passive limitation at various degrees of ranges of motion (ROM), for at least 1 month.18 The Constant-Murley Score (CMS) is often used to evaluate the impact of AC in shoulder function, with potential implications in patient management.19 Although the correlation of MRI findings with clinical staging was demonstrated in 2008 by Sofka et al.,20 there is little information available on the association between MRI findings and clinical impairment, which could be important for therapeutic decision making.15,21–26 We hypothesize that IGHL and coracohumeral ligament (CHL) signal and thicknesses are associated with the degree of shoulder function impairment and AC progression over time. The aim of our study was to evaluate the correlation between MRI findings in AC patients, CMS, and symptoms at the one-year follow-up.

Material And Methods

STUDY GROUP

The institutional review board of the CHRU of Nancy, FRANCE, approved this study, and all patients gave written informed consent. All experiments were performed in accordance with relevant guidelines and regulations. From October 10, 2013, and October 16, 2017, 170 patients over 18 years of age were enrolled prospectively and consecutively. These patients had been diagnosed with AC by orthopedic surgeons or rheumatologists and underwent shoulder radiographs and MRI.

Patients with MRI contraindications, prior shoulder surgery, shoulder osteoarthritis, calcific tendinosis, shoulder bursitis, and fractures on MRI were excluded. One patient withdrew from the study; four were excluded because of missing clinical data, 33 because of rotator cuff pathology (at least one full-thickness tendon tear). Thus, the final study population consisted of 132 patients with a mean age 54.1±9.3 (22–78) years. There were 55 men and 77 women (0.63 M/F sex ratio). Two patients had bilateral AC, yielding 134 shoulder MRI studies.

SHOULDER FUNCTION ASSESSMENT
A modified CMS was applied to all patients by a senior radiologist just prior to the MRI examination. Two subjective variables for a maximum score of 35 were evaluated: daily living pain (varying from 0 – severe pain to 15 points – no pain) and daily living activity limitation (varying from 0 – maximal limitation to 20 points – no limitation). The patients answered a questionnaire assessing the degree of pain (no pain, slight, moderate or severe pain), activity level (pain during work, sports, and recreation, sleep) and arm range of motion (ROM) (arm elevation up to the waist, xiphoid process, neck, top of the head, above the head). The examiner received prior training in performing the CMS. ROM was also quantitatively assessed with a goniometer, in external and internal rotation, forward and lateral elevation, and scored in each position by the examiner (varying $0^\circ$-$30^\circ$ = 0 to $151^\circ$-$180^\circ$= 10 points for each movement). Thus, the ROM scored varied from 0 – minimal mobility to 40 – maximal mobility). The final CMS, therefore, ranged from 0, (highly impaired shoulder) to 75 points (normal shoulder) (supplementary material 1). Shoulder strength, which was part of the original CMS, was not evaluated in this study, because there was no reliable measurement device available.

Pain duration was graded from 1-5 as follows: less than 6 weeks; between 6 weeks and 3 months; between 3 and 6 months; between 6 months and 1 year and over 1 year. The presence of diurnal pain, nocturnal pain, and nocturnal pain predominance were also evaluated.

**CLINICAL FOLLOW-UP**

A clinical follow-up was available in 49 patients with a mean age of 54±8.8 (37-74) years treated by physical therapy. There were 17 men and 32 women (0.53 M/F sex ratio). Based on medical record data (pain, activities, and ROM), the symptoms at 9 to 13 months after the MRI examination were classified as improved, stable, or worsened. None of these patients had been treated by intra-articular corticosteroid injection.

**MRI EXAMINATION**

MRI examinations were performed with either a 1.5T (105 patients) or a 3.0T scanner (27 patients) (Signa HDxt, GE Healthcare, Milwaukee, WI, USA) using a dedicated eight-channel shoulder coil and similar protocols. The patients were in a supine position with the arm placed in external rotation by the side of the body.

All MRI examinations consisted of an axial and oblique sagittal fast spin-echo (FSE) T1-weighted acquisitions; axial, oblique sagittal and oblique coronal FSE T2-weighted fat-saturated images. MRI protocols are summarized in table 1.

**IMAGE ANALYSIS**

The images were retrospectively reviewed by two musculoskeletal radiologists with three (FZ) and seven years (PP) of clinical experience with MRI blinded to clinical and demographic data using a PACS station (Synapse®, v4.1.600, Fujifilm, Montigny, France). A third radiologist (P.A.G.T.) with 11 years of clinical
experience with MRI performed a training session with the two readers with 20 MRI studies of patients with AC, not included in the study population prior to the readouts.

The signal intensity of the IGHL on oblique coronal T2-weighted fat-saturated images was graded from 1-4 as follows (Figure 1): normal homogenous low signal intensity; partial or foci of signal hyperintensity; global signal hyperintensity; linear hyperintensity of the peri-articular soft tissues.

The patients with IGHL scores of 1 and 2 were considered to have a low IGHL signal intensity, and those with grades 3 and 4 were considered to have high IGHL signal intensity. The thickness of the IGHL was measured at the glenoidal and humeral insertions on oblique coronal T2-weighted fat-saturated images and classified as <4 mm, between 4 and <6 mm and ≥6 mm (Figure 2). The thickest portion of the coracohumeral ligament (CHL) was measured on the sagittal T2-weighted fat-saturated images (Figure 3).

**STATISTICAL ANALYSIS**

The R Development Core Team software (version 3.0.12013, R Foundation for Statistical Computing, Vienna, Austria) was used to perform statistical analysis. Statistical significance was defined as \( P<0.05 \). Quantitative data are presented as mean ± standard deviation (range).

Linear regression analysis with the Pearson test was used to evaluate the correlation between the signs of AC studied on MRI and pain, mobility, activity scores, and pain duration. The association between MRI findings, global modified CMS score, diurnal pain, night pain, and predominance of night pain was assessed with the Fisher exact test. The association between MRI findings and clinical follow-up was assessed with the Wilcoxon test. For each MRI measurement, intraclass correlation coefficients (ICC) were calculated to assess interobserver variability. ICC values below 0.5 were considered poor, between 0.5 and 0.75 moderate, between 0.75 and 0.90 good and above 0.9 excellent.

**Results**

Table 2 shows demographic characteristics, global modified CMS, and its items in the study population. The mean CMS score was 31.3±14.2 (2-69) points, and the mean pain duration grade was 3.5±1.1 (1-5) (table 3). Night pain was frequent, and predominant in about half of the concerned patients. Table 3 shows the pain duration grade in each grade of IGHL signal intensity. IGHL signal intensity was low in 70 shoulders (52.2%) and high in 64 (47.8%) for reader 1. These figures were 72 (53.7%) and 62 (46.3%), respectively, for reader 2. Table 4 shows the MRI findings in the shoulders evaluated.

ICC was excellent in grading IGHL signal as low or high (0.96), and moderate when taking in account all the four grades (0.67). ICC values were moderate for IGHL thickness (glenoidal insertion: 0.72, humeral insertion: 0.61) and poor for CHL thickness (0.09).
Mobility scores were significantly different in patients with high IGHL signal intensity compared to those with low intensity for both readers ($P = 0.04$ and $0.02$ for readers 1 and 2). The mean mobility scores between shoulders with low and high IGHL signal intensity grades were $19.6 \pm 10.1$ (2-40) points versus $15.7 \pm 8$ (0-38) points and $19.4 \pm 10$ (0-40) points versus $15.8 \pm 8.2$ (0-38) points respectively for readers 1 and 2. The variation of mobility scores with respect to IGHL signal intensity grade is shown in Figure 4.

There was a significant difference in pain duration for both readers ($P=0.03$ and $0.04$ for readers 1 and 2) between patients with low and high IGHL signal intensity. The pain duration grades in patients with low and high IGHL signal intensity were $3.8 \pm 1.2$ (1-5) versus $3.2 \pm 0.9$ (1-5) and $3.8 \pm 1.2$ (1-5) versus $3.2 \pm 0.9$ (1-5) respectively for readers 1 and 2. As the IGHL signal intensity grade increased, there was also a decrease in mean pain duration grade for both readers (Table 3) (Figure 5). For both readers, the highest frequency of high IGHL signal intensity was found in patients with pain lasting for 3-6 months. The highest frequency of low signal IGHLs were found in patients with more than one year of pain. The presence of high IGHL signal intensity was significantly associated with nocturnal pain predominance for both readers ($P=0.003$ and $0.003$).

The glenoidal IGHL thickness was significantly correlated with activity limitation scores for reader 1 ($P=0.005$). Patients with IGHL measuring <4 mm, between 4 and <6 mm, and ≥6 mm presented activity limitation scores of $8.9 \pm 5$ (0-20) points, $9.7 \pm 4.5$ (0-20) points, and $11.5 \pm 3.8$ (4-20) points respectively for reader 1. For reader 2, these figures were $8.4 \pm 3.9$ (0-20) points, $10.5 \pm 4.7$ (2-20) points, and $9.9 \pm 4.6$ (0-20) points, respectively, which suggest a similar tendency for values <6 mm, but this variation was not statistically significant ($P = 0.09$). For IGHL thickness values ≥6 mm, the two readers presented a different tendency, with a lower mean score for reader 2. The IGHL thickness at the humeral insertion was significantly associated with pain duration for both readers ($P = 0.04$ and $0.02$). For reader 1, with an increasing humeral IGHL thickness, the pain duration decreased (pain duration grades of $3.6 \pm 1.1$ [1-5], $3.3 \pm 1.1$ [1-5] and $3.3 \pm 1.2$ [1-5] points for patients with IGHL thicknesses of <4 mm, between 4 and <6 mm and ≥6 mm, respectively). For reader 2, the same tendency was found for patients with IGHL thicknesses <6 mm (pain duration grades of $3.6 \pm 1.1$ [1-5] and $3.3 \pm 1.1$ [1-5] points respectively), however for patients with ligaments ≥6 mm, the pain duration was longer ($3.6 \pm 0.8$ [3-5] points).

CHL measurements are shown in table 5. This ligament could not be measured confidently in 5 patients for reader 1 and 20 patients for reader 2. There was no association between CHL thickness and clinical impairment. For both readers, there was no association between CMS modified global score, pain intensity grade, diurnal pain, and MRI findings.

Concerning clinical outcomes, 31 patients showed improvement, 11 patients stability and 7 worsening. IGHL thickness was significantly correlated with clinical outcomes, on both sides, and for both readers. Patients with clinical improvement had thicker IGHL on its glenoidal ($4.5 \pm 1.5$ [2-8.5] for reader 1 and $4.6 \pm 1.2$ [3-8] for reader 2) ($P=0.0015$ and $0.047$) and humeral ($4 \pm 1.5$ [2-8] and $4 \pm 1.3$ [2-7] respectively) ($P=0.0045$ and $0.037$) sides than those with worsening (glenoidal side: $2.7 \pm 0.6$ [2-4] and $3.4 \pm 0.7$ [3-5] for reader 1 and 2, humeral side: $2.2 \pm 0.4$ [2-3] and $2.7 \pm 0.7$ [2-4] respectively). For reader 1, patients with a
stable clinical outcome also had a thicker IGHL than those with worsening, on both sides (glenoidal side: $P=0.024$, humeral side $P=0.0045$) (glenoidal side: 4.5±1.7 [2-8] versus 2.7±0.6 [2-4], humeral side: 4.2±1.3 [3-7] versus 2.2±0.4 [2-3]). The same tendency was observed for reader 2, but these differences were not statistically significant ($P=0.171$ and 0.166). For reader 1, the presence of high IGHL signal intensity was more frequent in patients with clinical improvement (55%) compared to those with clinical worsening (14%) ($P=0.047$). The same tendency was found for reader 2, with values of 55 vs. 28%, respectively, but these differences were not statistically significant ($P=0.15$). Of note, in patients with improvement and high IGHL signal intensity, IGHL was found to be $\geq 4$ mm in 88% for reader 1 and 94% for reader 2. In none of the patients with worsening, the IGHL was thicker than 4 mm. In patients with worsening, IGHL was found to be $\leq 3$ mm in 66 to 83% for reader 1, and 83% to 100% for reader 2, and of low signal intensity in 66% and 83% for reader 1 and 2, respectively (Figure 6).

**Discussion**

Our study showed a significant correlation between high IGHL signal intensity and the pain duration in patients with AC, with a clear high signal predominance in the patients presenting pain from 3-6 months. Patients with the highest IGHL signal intensity were also shown to have the lowest score of pain duration. Linear hyperintensity of the peri-articular soft tissues might be responsible for the moderate inter-observer agreement of IGHL signal intensity grading, but when IGHL signal was evaluated as low or high, reproducibility was excellent. High IGHL signal was also associated with night pain. Thus, capsular and pericapsular ligament signal in patients with AC is indicative of an early inflammatory disease stage, associated with inflammatory type pain and limited ROM. Additionally, our results showed that patients with a thick IGHL (4 mm or higher, regardless of measurement location) were likely to have a favorable outcome at follow-up (approximately one year). Conversely, thin IGHL (3 mm or lower) was associated with clinical worsening. Those results suggest that a thickened IGHL is related to an intense capsular inflammatory reaction, which seems to be associated with impaired shoulder function and a favorable prognosis. Hence, IGHL thickness may be seen as a prognostic biomarker in patients with AC, and further studies are necessary to assess the implication of this finding in patient management.

Our results about IGHL signal intensity are in agreement with Sofka et al. $^{20}$, who stated that capsular high signal intensity in the axillary pouch was most closely associated with stage 2 disease, corresponding to pain from three to nine months. However, our findings suggest that the high signal intensity is higher early in stage 2 disease. Capsular high signal intensity has been associated with stage 1 disease (no limitation of the ROM), however a significant decrease in mobility scores was seen in patients with high IGHL signal intensity, which has not been previously reported $^{24}$.

Glenohumeral corticosteroid injections have been shown to be effective for short term pain relief and ROM improvement in the short and long term$^{29}$. A recent study showed that signs of AC, including capsular edema and rotator interval signal abnormalities, were independent predictors of a better outcome for pain relief after glenohumeral corticosteroid injections$^{30}$. These findings indicate that high IGHL signal intensity reflects inflammatory joint reaction in early disease stages, suggesting that, for such
patients, treatment with glenohumeral corticosteroid injection is more suitable than physiotherapy or that both treatments should be combined\textsuperscript{31}.

No MRI finding was correlated with CMS, in agreement with Park et al.\textsuperscript{32}, who showed a correlation of CMS with total arthrography score but not with MRI findings. Unlike Anh et al.\textsuperscript{25}, we did not find any correlation between MRI findings and pain, but we did not rate IGHL enhancement. However, prior reports indicated that contrast enhancement does not improve the performance of IGHL T2 signal assessment for the diagnosis of AC\textsuperscript{6}. Although, gadolinium injection has recently been shown to be helpful in difficult cases, contrast injection is not currently recommended for the evaluation of patients with AC\textsuperscript{33,34}. IGHL thickness >4 mm has been described as a reliable sign of AC\textsuperscript{27}, but in our study, less than 30\% of patients fulfilled this criterion.

This study has limitations. Most importantly, AC diagnosis was confirmed neither by arthroscopy nor histologically. However, clinical findings remain the basis for the diagnosis of AC, and the diagnostic performance of MRI diagnostic criteria has been previously evaluated\textsuperscript{6–8,10–12,17,35,36}. IGHL and CHL thickness could vary depending on the coronal slice selected for measurement. As the estimation of pain duration provided by patients may be imprecise, a pain score system with time intervals was used to limit this potential bias. Since the correlation between MRI findings and the range of motion each direction is still debated\textsuperscript{24,32,35}, only global motion scores were considered. There was no control group, and no systematic clinical or MRI follow-up of the patients included. The possibility of a selection bias should be considered as our institution is a tertiary referral center, and patients with severe AC might have been over-represented. However, the study population one of the largest reported so far, with various disease stages and clinical impairment levels, minimizing this issue.

In conclusion, signal intensity at the IGHL was inversely related to pain duration and ROM. Patients with IGHL high signal were more frequently in the early phases of AC (first 3-6 months), presented nocturnal pain, and were likely to show clinical improvement on follow-up. Although IGHL thicknesses presented a moderate interobserver variability and an unclear relation with shoulder function impairment at the time of the MRI examination, there was a significant relation with patient prognosis. IGHLs >4mm were associated with a favorable clinical outcome, whereas ligaments measuring <3mm were associated with clinical worsening. These findings should be considered in the MRI evaluation of patients with AC, and although further studies are still necessary, they could have therapeutic implications.

**Declarations**

**Author contributions:**

R.G.: conception of the presented idea, writing of the manuscript, direction of the project.

F.Z: measurement of data.

P.P.: measurement of data.
A.R.: interpretation of the results, conceptual ideas.

G.H.: analytical methods and calculations.

P.A.G.T.: conception of the presented idea, verification of analytical methods, writing of the manuscript.

A.B.: supervision of the project.

Additional Information:

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References

1. Kelley, M. J. et al. Shoulder Pain and Mobility Deficits: Adhesive Capsulitis: Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability, and Health From the Orthopaedic Section of the American Physical Therapy Association. J Orthop Sports Phys Ther 43, A1–A31 (2013).

2. Brue, S. et al. Idiopathic adhesive capsulitis of the shoulder: a review. Knee Surg Sports Traumatol Arthrosc 15, 1048–1054 (2007).

3. D’Orsi, G. M., Via, A. G., Frizziero, A. & Oliva, F. Treatment of adhesive capsulitis: a review. 9.

4. Sano, H., Hatori, M., Mineta, M., Hosaka, M. & Itoi, E. Tumors masked as frozen shoulders: a retrospective analysis. J Shoulder Elbow Surg 19, 262–266 (2010).

5. Zappia, M. et al. Multi-modal imaging of adhesive capsulitis of the shoulder. Insights into Imaging 7, 365–371 (2016).

6. Teixeira, P. A. G. et al. Adhesive Capsulitis of the Shoulder: Value of Inferior Glenohumeral Ligament Signal Changes on T2-Weighted Fat-Saturated Images. American Journal of Roentgenology 198, W589–W596 (2012).

7. Suh, C. H. et al. Systematic review and meta-analysis of magnetic resonance imaging features for diagnosis of adhesive capsulitis of the shoulder. European Radiology 29, 566–577 (2019).

8. Song, K. D., Kwon, J. W., Yoon, Y. C. & Choi, S.-H. Indirect MR Arthrographic Findings of Adhesive Capsulitis. American Journal of Roentgenology 197, W1105–W1109 (2011).

9. Mengiardi, B., Pfirrmann, C. W. A., Gerber, C., Hodler, J. & Zanetti, M. Frozen Shoulder: MR Arthrographic Findings. Radiology 233, 486–492 (2004).

10. Lefevre-Colau, M.-M. et al. Magnetic resonance imaging of shoulders with idiopathic adhesive capsulitis: reliability of measures. European Radiology 15, 2415–2422 (2005).

11. Harris, G., Bou-Haidar, P. & Harris, C. Adhesive capsulitis: Review of imaging and treatment: Adhesive capsulitis: review of imaging and treatment. Journal of Medical Imaging and Radiation Oncology 57, 633–643 (2013).
12. Jung, J.-Y. *et al.* Adhesive capsulitis of the shoulder: evaluation with MR arthrography. *European Radiology* **16**, 791–796 (2006).

13. Chi, A. S., Kim, J., Long, S. S., Morrison, W. B. & Zoga, A. C. Non-contrast MRI diagnosis of adhesive capsulitis of the shoulder. *Clinical Imaging* **44**, 46–50 (2017).

14. Ahn, K.-S., Kang, C. H., Kim, Y. & Jeong, W.-K. Diagnosis of adhesive capsulitis: comparison of contrast-enhanced MRI with noncontrast-enhanced MRI. *Clinical Imaging* **39**, 1061–1067 (2015).

15. Lee, K. H. *et al.* Adhesive Capsulitis of the Shoulder Joint: Value of Glenohumeral Distance on Magnetic Resonance Arthrography. *Journal of Computer Assisted Tomography* **41**, 116–120 (2017).

16. Kim, K. C., Rhee, K. J. & Shin, H. D. Adhesive capsulitis of the shoulder: Dimensions of the rotator interval measured with magnetic resonance arthrography. *Journal of Shoulder and Elbow Surgery* **18**, 437–442 (2009).

17. Connell, D., Padmanabhan, R. & Buchbinder, R. Adhesive capsulitis: role of MR imaging in differential diagnosis. *European Radiology* **12**, 2100–2106 (2002).

18. Binder, A. I., Bulgen, D. Y., Hazleman, B. L. & Roberts, S. Frozen shoulder: a long-term prospective study. *Annals of the Rheumatic Diseases* **43**, 361–364 (1984).

19. Constant, C. R. & Murley, A. H. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res* 160–164 (1987).

20. Sofka, C. M., Ciavarra, G. A., Hannafin, J. A., Cordasco, F. A. & Potter, H. G. Magnetic Resonance Imaging of Adhesive Capsulitis: Correlation with Clinical Staging. *HSS Journal* **4**, 164–169 (2008).

21. Yoon, M. A. *et al.* The Association between the Magnetic Resonance Imaging Findings of Adhesive Capsulitis and Shoulder Muscle Fat Quantification Using a Multi-Echo Dixon Method. *Korean Journal of Radiology* **19**, 63 (2018).

22. Yoon, J. P. *et al.* Correlations of magnetic resonance imaging findings with clinical symptom severity and prognosis of frozen shoulder. *Knee Surgery, Sports Traumatology, Arthroscopy* **25**, 3242–3250 (2017).

23. Park, Y. H., Park, Y. S., Chang, H. J. & Kim, Y. Correlations between MRI findings and outcome of capsular distension in adhesive capsulitis of the shoulder. *Journal of Physical Therapy Science* **28**, 2798–2802 (2016).

24. Park, S., Lee, D.-H., Yoon, S.-H., Lee, H. Y. & Kwack, K.-S. Evaluation of Adhesive Capsulitis of the Shoulder With Fat-Suppressed T2-Weighted MRI: Association Between Clinical Features and MRI Findings. *American Journal of Roentgenology* **207**, 135–141 (2016).

25. Lee, S.-Y., Park, J. & Song, S.-W. Correlation of MR Arthrographic Findings and Range of Shoulder Motions in Patients With Frozen Shoulder. *American Journal of Roentgenology* **198**, 173–179 (2012).

26. Ahn, K.-S., Kang, C. H., Oh, Y.-W. & Jeong, W.-K. Correlation between magnetic resonance imaging and clinical impairment in patients with adhesive capsulitis. *Skeletal Radiology* **41**, 1301–1308 (2012).
27. Emig, E. W., Schweitzer, M. E., Karasick, D. & Lubowitz, J. Adhesive capsulitis of the shoulder: MR diagnosis. *American Journal of Roentgenology* **164**, 1457–1459 (1995).

28. Koo, T. K. & Li, M. Y. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine* **15**, 155–163 (2016).

29. Wang, W. *et al.* Effectiveness of corticosteroid injections in adhesive capsulitis of shoulder: A meta-analysis. *Medicine* **96**, e7529 (2017).

30. Sun, Y., Lu, S., Zhang, P., Wang, Z. & Chen, J. Steroid Injection Versus Physiotherapy for Patients With Adhesive Capsulitis of the Shoulder: A PRISMA Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Medicine* **95**, e3469 (2016).

31. Park, G.-Y., Park, J. H., Kwon, D. R., Kwon, D. G. & Park, J. Do the Findings of Magnetic Resonance Imaging, Arthrography, and Ultrasonography Reflect Clinical Impairment in Patients With Idiopathic Adhesive Capsulitis of the Shoulder? *Archives of Physical Medicine and Rehabilitation* **98**, 1995–2001 (2017).

32. Small, K. M. *et al.* ACR Appropriateness Criteria® Shoulder Pain-Atraumatic. *Journal of the American College of Radiology* **15**, S388–S402 (2018).

33. Pessis, E. *et al.* Usefulness of intravenous contrast-enhanced MRI for diagnosis of adhesive capsulitis. *European radiology* (2020) doi:10.1007/s00330-020-07003-4.

34. Gokalp, G., Algin, O., Yildirim, N. & Yazici, Z. Adhesive capsulitis: Contrast-enhanced shoulder MRI findings: Adhesive capsulitis: MRI. *Journal of Medical Imaging and Radiation Oncology* **55**, 119–125 (2011).

35. Jung, J. H., Kim, D. H., Yi, J., Kim, D.-H. & Cho, C.-H. Determination of magnetic resonance imaging criteria for diagnosis of adhesive capsulitis. *Rheumatol Int* **39**, 453–460 (2019).

### Tables

**Table 1. MRI acquisition protocols.**
Table 2. Summary of patients' ages and clinical impairment items.

| Parameter              | Minimum | Maximum | Mean  | Standard Deviation |
|------------------------|---------|---------|-------|--------------------|
| Patient Age            |         |         |       |                    |
| All patients (n=132)   | 22      | 78      | 54.1  | 9.3                |
| Men (n=55)             | 22      | 70      | 53.5  | 8.8                |
| Women (n=77)           | 22      | 78      | 54.4  | 10.8               |
| Modified Constant-Murray score | 2 | 69 | 31.3 | 14.2 |
| Pain Intensity Score   | 0       | 15      | 4     | 3.8                |
| Activity Score         | 0       | 20      | 9.8   | 4.5                |
| Mobility Score         | 0       | 40      | 17.7  | 9.3                |
| Pain Duration Grade    | 1       | 5       | 3.5   | 1.1                |

Table 3. Summary of patients' pain characteristics
*: 22 data were missing, because patients were not able to determine it.

Diurnal pain, night pain and predominance of night pain are given for the 134 shoulders.

**Table 4. Pain duration grade according to inferior glenohumeral ligament signal intensity grade.**

| Parameter                        | Effective       |
|----------------------------------|-----------------|
| Pain Duration Grade             | N=112*          |
| 1                                | 4.5% (n=5)      |
| 2                                | 13.4% (n=15)    |
| 3                                | 32.1% (n=36)    |
| 4                                | 24.1% (n=27)    |
| 5                                | 25.9% (n=29)    |
| Diurnal Pain                     | 94.7% (n=127)   |
| Night Pain                       | 87.3% (n=117)   |
| Predominance of Night Pain       | 46.2% (n=62)    |

**Table 5. Summary of patients’ MRI measurements.**

| IGHL Signal Intensity | Reader 1 (n=34) | Reader 2 (n=34) | Pain Duration Grade Reader 1 | Reader 2 |
|-----------------------|-----------------|-----------------|-----------------------------|---------|
| 1                     | 1 (n=34)        | 1 (n=34)        | 3.9±1.1                     | 3.8±1.2 |
| 2                     | 2 (n=24)        | 2 (n=25)        | 3.6±1.3                     | 3.7±1.1 |
| 3                     | 3 (n=21)        | 3 (n=34)        | 3.3±0.9                     | 3.2±0.9 |
| 4                     | 4 (n=33)        | 4 (n=19)        | 3.1±1                       | 3.1±1   |

IGHL: inferior glenohumeral ligament

Results of pain duration score are presented on mean ± standard deviation. Range of all sub-groups of pain duration grade was 1-5.

**Table 5. Summary of patients’ MRI measurements.**
| Parameter                     | Minimum | Maximum | Mean | Standard Deviation |
|-------------------------------|---------|---------|------|--------------------|
|                               | R1      | R2      | R1   | R2     | R1   | R2   |
| IGHL thickness (glenoidal side) | 2       | 2       | 10   | 8      | 4.3  | 4.5  | 1.3  | 1.2   |
| IGHL thickness (humeral side)  | 2       | 2       | 8    | 7      | 3.8  | 3.7  | 1.3  | 1.2   |
| CHL thickness                 | 1.5     | 1       | 5    | 4      | 2.5  | 2.2  | 0.6  | 0.6   |

Values are given in millimeters.

IGHL: inferior glenohumeral ligament, CHL: coracohumeral ligament

R1: Reader 1, R2: Reader 2

**Figures**
Figure 4

Mean mobility score is shown according to inferior glenohumeral ligament intensity grade for reader 1 and reader 2, accompanied by a linear tendency (dotted line) curve for each reader. Note for reader 2 the v-shaped tendency, not found for reader 1. IGHL: inferior glenohumeral ligament.
Figure 6

Box plot representing inferior glenohumeral ligament thickness (y axis) according to clinical outcomes for reader 1 on the glenoidal (a) and humeral side (b), and for reader 2 on the glenoidal (c) and humeral side (d).

Supplementary Files

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- suplementalinfoSR.docx