Sonography in diagnosis of adhesive capsulitis of the shoulder: a case–control study

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Abstract

Purpose Adhesive capsulitis (AC) of the shoulder has been a diagnosis of exclusion on sonography due to lack of specific diagnostic criteria. This study prospectively assesses the efficacy of sonography using multiple static and dynamic parameters for diagnosis of AC.

Materials and methods Shoulder sonography was performed independently by two musculoskeletal radiologists on 90 subjects (60 symptomatic and 30 controls). All symptomatic subjects were subjected to an MRI. Based on clinical and MRI diagnosis, three groups were made: AC ($n = 30$), painful shoulders (PS) ($n = 30$), and control group (CL) ($n = 30$). The sonographic parameters studied were: coracohumeral ligament (CHL) thickness, increased soft tissue in rotator interval (static parameters) and restriction of abduction and external rotation on dynamic scanning. These were compared within the three groups and the accuracy of each parameter in isolation and in combination for diagnosis of AC was calculated.

Results Sonographic visualisation of CHL (96.7%) and its mean thickness (1.2 mm) were highest in the AC group ($p < 0.01$). A cut-off value of 0.7 mm was found to be accurate (sensitivity 93.1%, specificity 94.4%) for diagnosing AC. Increased soft tissue in the rotator interval was

seen in the AC group and had a high sensitivity of 86.2% and specificity of 92.8%. On dynamic scanning, restriction of external rotation was specific (sensitivity 86.2%, specificity 92.8%), whereas restriction in abduction was non-specific (specificity 6.7%). Inter-observer agreement was substantial for CHL visualisation (kappa 0.66). Overall, sonography, using multiple parameters, revealed a high sensitivity and specificity (100 and 87%, respectively) for diagnosis of AC of the shoulder.

Conclusion Sonography revealed a high accuracy for diagnosing AC of the shoulder and in differentiating it from other causes of painful shoulder. It, thus, has the potential to be adopted as a preferred imaging modality.

Keywords Shoulder sonography · Adhesive capsulitis · Frozen shoulder · Coracohumeral ligament · CHL · Rotator interval

Sommario

Scopo La capsulite adesiva (AC) della spalla è una diagnosi ecografica di esclusione, per la mancanza di criteri diagnostici specifici. Questo studio valuta prospetticamente l'efficacia dell'ecografia, utilizzando multipli parametri statici e dinamici, per la diagnosi di capsulite adesiva.

Materiale e metodi L'ecografia della spalla è stata effettuata indipendentemente da due radiologi muscoloscheletrici su 90 soggetti (60 sintomatici e 30 di controllo). Tutti i soggetti sintomatici sono stati sottoposti a risonanza magnetica (RM). Sulla base della diagnosi clinica e RM sono stati suddivisi tre gruppi: pazienti con capsulite adesiva (AC) ($n = 30$), con spalla dolorosa (PS) ($n = 30$) e gruppo di controllo (CL) ($n = 30$). I parametri ecografici studiati sono stati: lo spessore del legamento coracoomerale (CHL), l'aumento di tessuto molle nell'intervallo dei rotatori (parametri statici) e la diminuzione di

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abduzione e rotazione esterna nelle scansioni dinamiche. I risultati sono stati confrontati all'interno dei tre gruppi ed è stata calcolata l'accuratezza di ogni parametro, singolarmente e in combinazione per la diagnosi di AC.

Risultati La visualizzazione ecografica del CHL (96,7%) e il suo spessore medio (1,2 mm) erano più alti nel gruppo AC ($P < 0.01$). Il valore di cutoff di 0,7 millimetri è stato considerato accurato (sensibilità del 93,1% e specificità del 94,4%) per la diagnosi di AC. L'aumento del tessuto molle nell'intervallo dei rotatori è stato osservato nel gruppo AC e aveva elevata sensibilità (86,2%) e specificità (92,8%). Con scansioni dinamiche, la limitazione della rotazione esterna era significativa (sensibilità 86,2%, specificità 92,8%), mentre la limitazione dell'abduzione non lo era (specificità 6,7%). L'accordo inter-osservatori, nella visualizzazione del CHL è stato notevole (κ 0,66). Utilizzando più parametri, nel complesso, l'ecografia ha rivelato elevata sensibilità e specificità (100% e 87% rispettivamente) nella diagnosi di capsulite adesiva della spalla.

Conclusione L'ecografia ha rivelato un'elevata precisione nella diagnosi di capsulite adesiva della spalla, nonché nel differenziarla dalle altre cause di spalla dolorosa, pertanto ha le potenzialità per essere adottata come modalità di scelta tra le metodiche di imaging.

Introduction

Adhesive capsulitis (AC) commonly known as *frozen shoulder* is a common inflammatory disorder of the shoulder joint seen in 2–3% of the population, commonly affecting females in 40–70 years' age group [1, 2].

AC often presents as painful shoulder, a presentation which is far from specific and mimics several other painful shoulder disorders like rotator cuff tears, calcific tendonitis, early glenohumeral arthritis, subacromial impingement, calcific tendinitis, etc. [1, 3, 4].

Conventional arthrography, the investigation for adhesive capsulitis in yesteryears, is now obsolete. Arthroscopy is the current gold standard but it is an invasive procedure.

MRI is currently considered the reference standard for imaging in shoulder disorders and is thus an obvious modality to non-invasively identifying changes of adhesive capsulitis. Reliable signs of adhesive capsulitis on MRI which correlate well with arthroscopic findings have been reported [5–7]. MR arthrography further increases the diagnostic accuracy of MRI. Its limitations include high cost and limited availability.

High-resolution, real-time sonography has been shown to be a successful imaging modality for both rotator cuff and non-rotator cuff shoulder disorders. It is fast,

inexpensive and offers dynamic capabilities for examining the subject in multiple scanning planes and in specific arm positions or movements. However, its role in diagnosing adhesive capsulitis has not been fully evaluated.

Few studies are available wherein the authors have evaluated criteria like thickened coracohumeral ligament (CHL), presence of hypervascular soft tissue in the rotator interval, limitation of supraspinatus movement and external rotation limitation on dynamic scanning, with encouraging results [8–11]. Each criterion has been evaluated in a separate solitary study, and none of the studies has comprehensively assessed this disorder using the multiple static and dynamic parameters.

The purpose of this prospective study was to assess the efficacy of sonography using multiple static and dynamic parameters for diagnosis of adhesive capsulitis of shoulder.

Materials and methods

After obtaining approval from the institutional ethical committee and a written informed consent from all the participants, a prospective case–control study was conducted on a total of 90 subjects. Sixty patients who presented to the orthopedic out-patient department with shoulder pain were included, and 30 controls were age- and sex-matched subjects with no shoulder complaints. All patients who refused consent, had a history of major trauma, surgery to the shoulder, and patients in whom MRI was contraindicated were excluded from the study.

Study design

All cases were recruited by the study coordinator. A thorough clinical examination was done. Two musculoskeletal radiologists with more than 10 years of experience performed shoulder sonograms on all 90 subjects independently. They were blinded to the clinical diagnosis of the subject or the group to which he belonged. The study coordinator then subjected all symptomatic subjects to MRI. The MRI was reported by another set of radiologists (with more than 12 years' experience), who were blinded to the clinical and sonography findings. The final diagnosis was reached by consensus. On the basis of the final diagnosis, the subjects were divided into three groups.

1. Adhesive capsulitis (AC) group: the study group included 30 cases of any age and either gender with painful shoulder and a clinical diagnosis of adhesive capsulitis of shoulder confirmed on MRI.
2. Painful shoulder (PS) group: symptomatic shoulders with clinical and MRI diagnosis other than AC (tendon, bursal and joint pathology).

3. Control group (CL): asymptomatic shoulders in age- and sex-matched controls.

Sonographic evaluation

A high-resolution, real-time sonographic examination of the shoulder was done using an HDI 5000 ultrasound scanner (Philips) or HD 7 XE Colour Doppler Ultrasound (Philips) or Sonoline Antares (Siemens) equipped with a linear broadband 5–12 MHz transducer with the patient seated on a rotating stool. The following parameters were assessed:

Static parameters

- (a) Coracohumeral ligament (CHL): for CHL assessment, patients were scanned in a sitting position, with the shoulder in a neutral position and the forearm extended. The scanning commenced in an axial oblique plane, by positioning the transducer on the lateral border of the coracoid process, obtaining a longitudinal image of the CHL as proposed by Homsy et al. [11]. In this cross section, external and internal rotation of the shoulder was useful to identify the CHL, which folds over itself with internal rotation and stretches with external rotation. CHL evaluated in the axial oblique plane was visualised as a thin hypoechoic structure arising from the coracoid

Fig. 1 Sonogram (oblique axial view) showing **a** normal thin CHL (0.4 mm) in control patient, **b** thickened CHL (1.2 mm) in adhesive capsulitis patient

process, surrounded by a triangle of echogenic fat (Fig. 1) and reaching up to the rotator interval. It was electronically measured with the arm in external rotation.

- (b) The rotator interval assessment: rotator interval is a triangular space in the anterosuperior rotator cuff bounded above by the anterior free edge of the supraspinatus tendon and below by the superior edge of the subscapularis tendon. The rotator interval was optimally visualised in the oblique plane with the patient's fist held by the side as proposed by Lee et al. [10] (Fig. 2a). It was scrutinised using grey-

Fig. 2 **a** Sonographic image of normal rotator interval, containing long head of biceps, CHL (single asterisk) and superior glenohumeral ligament (number sign). **b, c** Patient with adhesive capsulitis showing increased soft tissue and vascularity within the rotator interval

scale and colour Doppler sonography with particular attention given to the echogenicity and vascularity.

The presence of soft tissue hypoechoic to the long head of the biceps tendon and hyperechoic to joint fluid were considered positive for increased soft tissue within the rotator interval. The presence of colour Doppler signal within the rotator interval only, and not in surrounding structures, was considered positive for increased vascularity (Fig. 2b, c).

Dynamic parameters

- (a) Restricted abduction: for evaluation of supraspinatus tendon during abduction the transducer was placed in the oblique coronal plane with its medial margin at the anterolateral edge of the acromion. The shoulder was abducted anterolaterally (flexion and abduction) while in internal rotation (thumb down). Limitation of continuous smooth sliding movement of supraspinatus underneath the acromion and/or buckling of soft tissues lateral to the acromion edge during lateral elevation of the arm were considered indicative of restricted abduction (Fig. 3).
- (b) Restricted external rotation (of subscapularis): for evaluation of subscapularis tendon movement during

external rotation, the transducer was placed medially along the humerus relative to the biceps tendon groove to obtain a longitudinal view of the tendon, and then fixing the patient's elbow on the iliac crest (with hand supinated), external rotation was performed under continuous sonographic visualisation, as proposed by Van Holsbeeck et al. [9] (Fig. 4). The movement of subscapularis tendon on external rotation was observed in all the subjects. In the neutral position, the bursal surface of subscapularis tendon forms a V with the underlying humeral cortex, the apex of the V being the tendons' insertion at the lesser tuberosity. The apex of the V points to the 11 o'clock position on the right side and to 1 o'clock position on the left side, respectively. In a normal patient, with progressive degrees of external rotation, the apex of the V points to 10 o'clock, then 9 o'clock, and finally 7 o'clock position on the right side. Similarly on the left it goes through 2 o'clock, then 3 o'clock, and finally to 4 o'clock position (Fig. 5). Restriction of movement of subscapularis to/prior to 9 o'clock position on right (or 3 o'clock on the left) on external rotation was considered indicative of restriction.

Fig. 3 Sonogram **a, b** reveal normal abduction showing complete passage of tendon and subacromial-subdeltoid bursa beneath the acromion in a control subject. Sonogram **c, d** in adhesive capsulitis

showing incomplete passage of supraspinatus (SS) tendon beneath the acromion (A). T greater tuberosity

Fig. 4 Illustration showing probe position for dynamic assessment of external rotation

MRI examination

MRI examinations were performed on a 3.0 TESLA scanner using a dedicated extremity coil.

All MR images were reviewed by two musculoskeletal radiologists who were blinded to patient identification,

clinical history and sonographic findings. MR criteria used were adopted from previous studies [5–7], these were:

1. Thickness of joint capsule and synovium: the widest portion of low signal region equivalent to capsule and synovium between the high signal fluid in the axillary recess and low signal cortical bone of humerus was measured on oblique coronal proton density fast spin-echo images or coronal oblique STIR images, approximately perpendicular to adjacent cortical bone, similar to what was done by Emig et al. [5]. Thickening greater than 4 mm was considered to be significant, as was any enhancement on post gadolinium scans (Fig. 6).
2. Rotator interval fibrovascular scar: the rotator interval capsule is normally visualised as a region of homogeneous low signal intensity. Fibrovascular scar tissue was believed to be present if there was a discrete focus of homogeneous intermediate signal within the rotator interval, often obliterating the fat surrounding the coracohumeral and superior glenohumeral ligaments (Fig. 7). Post gadolinium enhancement of

Fig. 5 Sonograms depicting **a, b** normal external rotation (right shoulder); subscapularis pointing to 11 o'clock position at the start of external rotation moves to 7 o'clock position at the end of maximum

external rotation. **c, d** Restriction of external rotation in adhesive capsulitis; subscapularis points to 11 o'clock position at the start and is restricted before 9 o'clock position at end of movement

Fig. 6 **a** Fat suppressed Proton Density Fast Spin Echo oblique coronal image shows thickened (7.4 mm) joint capsule and synovium (*opposed arrows*) in a subject with adhesive capsulitis, **b** control subject for comparison

fibrovascular scar was present in few of the adhesive capsulitis patients [7] (Fig. 8).

Statistical analysis

A descriptive and comparative analysis was made of the results obtained. Data was analysed by statistical software SPSS version 17.0 for Windows. One way ANOVA test was applied to compare the CHL thickness in the three groups. Comparisons of discrete measures across categories were performed using a Fisher's exact test or Chi square tests (depending on the cell size). A critical p value of 0.05 was used for all hypothesis tests. Inter-observer variability for the measurements of CHL was analysed with intraclass correlation coefficient. It is generally accepted that an arbitrary cut-off of >0.7 for the intraclass correlation coefficient implies good reliability. To find the agreement between the two reviewers on USG, kappa statistics was applied.

Fig. 7 **a** Sagittal MR image in a subject with adhesive capsulitis shows poorly defined soft tissue intensity encasing the CHL (*arrow*). **b** Normal rotator interval for comparison. Note the thin dark band of the CHL (*white arrow*) coming to sit above the biceps tendon (*white dot*), beneath the supraspinatus (*ss*). Subscapularis (*sub*) is shown

Observations and results

All parameters were compared between the three study groups: AC group, PS group and asymptomatic (CL) group.

Coracohumeral ligament

CHL was visualised in 92.2% of the 90 subjects by both the reviewers. The percentage of visualisation was highest in the AC group and lowest in the asymptomatic subjects (96.7 and 87%, respectively). CHL could not be visualised in only one subject in the AC group (Table 1).

CHL thickness

CHL was found to be thickened in all, but one, of the 30 subjects in the AC group. The thickness of CHL in the AC group was significantly higher than both the PS group and the CL group (1.2 mm in AC, 0.54 in PS and 0.4 mm in CL).

Fig. 8 Pre (a) and post (b) gadolinium sagittal oblique image shows moderate enhancement of scar tissue in the rotator interval (*opposed arrows*) in adhesive capsulitis

Table 1 Comparison of rate of visualisation of CHL in the three study groups

	R 1	R 2	Kappa	<i>p</i> value
AC group	29 (96.7%)	29 (96.7%)	0.789	0.000
PS group	28 (93.3%)	29 (98.7%)	0.651	0.000
CL group	26 (86.7%)	25 (83.3%)	0.609	0.000
Total	83 (92.2%)	83 (92.2%)	0.69	0.000

Table 2 Summary of measure of CHL thickness in the three study groups

	Range		Mean $\pm$ SD		CC
	R 1	R 2	R 1	R 2	
AC group	0.5–1.9	0.7–2.0	1.2 $\pm$ 0.35	1.18 $\pm$ 0.37	0.961
PS group	0.3–1.0	0.3–0.9	0.53 $\pm$ 0.18	0.55 $\pm$ 0.17	
CL group	0.2–0.6	0.2–0.6	0.38 $\pm$ 0.09	0.4 $\pm$ 0.09	

CC correlation coefficient

group) (Table 2) (Fig. 1). Although the mean thickness in the PS group was higher than that of the CL group, this difference was not statistically significant (Fig. 9). Intra-class correlation coefficient (CC) for inter-observer variability showed excellent agreement between the two reviewers for the measurement of CHL (Table 2).

The ROC curve made for CHL thickness showed diagnostic cut-off value of 0.7 mm at which the sensitivity and specificity were highest, i.e., 94.4 and 93.1%, respectively (Fig. 9).

Fig. 9 a A box plot of the CHL thickness in the three groups (the median is the horizontal line in the rectangles) reveals highest thickness in AC group. b ROC curve for CHL thickness

Rotator interval

Hypoechoic increased soft tissue in the rotator interval was found in about 90% subjects of the AC as against 7% in the PS group and none in the CL group (Table 3) (Fig. 2). This parameter had a high sensitivity and specificity for the diagnosis of adhesive capsulitis (Table 3).

Increased vascularity within the rotator interval was observed in 10% of subjects in the AC group and only 3.3% in the PS group and in none of the subjects in CL group (Table 3). This parameter, thus, was not significantly different between the groups.

Dynamic parameters

Restricted abduction It was noted that dynamic restriction of abduction was present in all subjects of the AC group and 28 of the 30 subjects in the PS group (Table 3). Thus, restricted abduction was sensitive but not specific for AC (Fig. 3).

Restricted external rotation In 96.7% subjects in the AC group, external rotation was blocked prior to attaining the 9 o'clock position on right side (or 3 o'clock on left as the case may be), most subjects failing to progress beyond the 10 o'clock position (Fig. 5). In the PS group, 10% subjects showed restriction (Table 4), and two of these patients had subscapularis tendinitis. None in the CL group demonstrated restriction (Table 4). Thus, restricted external rotation was both highly sensitive and specific parameter for diagnosis of AC (Table 3).

Diagnostic accuracy of sonography Combining all parameters, ultrasound showed a sensitivity of 100% and specificity of 87% for the diagnosis of adhesive capsulitis, taking MRI as reference standard (Table 4). Both static and

dynamic parameters in isolation also revealed a high sensitivity and specificity for AC diagnosis. There was almost perfect agreement between the two modalities (Table 4).

Discussion

Adhesive capsulitis is classified into two categories: (1) primary, which is insidious and idiopathic, or (2) secondary, which is generally secondary to trauma, tear, osteoarthritis, calcific tendinitis, SASD bursitis, etc. [3, 4]. Those with primary adhesive capsulitis generally have a very gradual onset and progression of symptoms, with no known precipitating event that can be identified.

Although the exact etiology of AC is controversial, this disease is thought to be a cytokine-mediated synovial inflammation with subsequent capsular fibrosis. The initial stages of AC have a predominance of pain, with gradually increasing joint stiffness brought on by ongoing synovial inflammation and capsular fibrosis. In the later stages, as the inflammatory phase subsides, capsular fibrosis is at its peak [12].

The rotator cuff interval, known to be important in the motion of the glenohumeral joint, has been implicated in the pathogenesis of adhesive capsulitis in recent studies. Thickening and contraction of the rotator interval act as a tight check-rein that prevents external rotation of the arm [13]. The contents of the rotator interval include the coracohumeral (CHL) and superior glenohumeral ligaments, both of which are encased in capsuloseynovial membrane and thus are subject to the same pathological process as the rest of the glenohumeral joint. Neer et al. [14] suggested that a tightened CHL restricts external rotation in patients with frozen shoulder. Contraction of the CHL and thickening of the joint capsule in the rotator cuff interval were found.

Table 3 Comparison of the various sonographic parameters (except CHL) in the three study groups and the diagnostic accuracy of each for adhesive capsulitis

	AC group	PS group	CL group	<i>p</i> value	Sen.	Sp.	PPV	NPV
Static parameters								
Rotator interval soft tissue	25 (86.2%)	02 (6.7%)	0	0.00	86.2	92.8	86.7	86.7
Vascularity: rotator interval	03 (10%)	01 (3.4%)	0	0.61	10.0	96.7	75	51.8
Dynamic parameters								
Abduction restriction	30 (100%)	28 (93.3%)	0	0.492	100%	6.7%	51.7%	100%
External rotation restriction	29 (96.7%)	3 (10%)	0	0.000	96.7%	90%	90.6%	96.4%

Sen sensitivity, Sp specificity

Significant at *p* value <0.05

Table 4 Diagnostic accuracy of sonography for diagnosis of adhesive capsulitis

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Kappa
Overall ultrasound diagnosis	100	86.70	88.20	100	0.864
Static parameters	96.70	93.30	93.50	96.60	0.859
Dynamic parameters	96.70	93.30	93.50	96.60	0.9

Sonography was found to be simple and reproducible and imaged both the rotator interval and CHL well. Slight difficulty was encountered in imaging the obese patients.

The *CHL* was assessed in the oblique axial plane for its thickness, as proposed by Homsí et al. [11], the only study on *CHL* thickness in adhesive capsulitis. These authors, however, advocated two planes: oblique axial and sagittal plane view. The sagittal view was attempted but was found to be difficult to attain and gave poor *CHL* visualisation. Hence, it was abandoned and only the oblique axial plane was adopted for *CHL* assessment in our study.

In the present study, the *CHL* was visualised in majority of patients with ease after an initial learning curve. The visualisation was highest in the AC group followed by the painful shoulder group and was lowest in the asymptomatic group. Inter-observer agreement between the two reviewers was good for the visualisation of *CHL*.

Our findings are in concurrence with those of Homsí et al. [11] who studied 498 shoulders and found a highest visualisation rate in the AC group (88.2%) followed by PS group (63%) and the asymptomatic group (76%). However, their study had only one observer and no inter-observer agreement was calculated. Higher visualisation rate of *CHL* in the AC group can be explained on account of its greater thickness and conspicuity in this group of patients (Table 5).

The *CHL* in our study was found to be significantly thicker in the AC group as compared to the PS and asymptomatic group. Although the thickness was greater in the PS group than in the asymptomatic group, the difference was not statistically significant. This suggests that thickening is quite specific for adhesive capsulitis.

The mean thickness of *CHL* in present study in all groups was lower than those reported by Homsí et al. [11] (3 mm for the AC group, 1.39 mm for the PS group and 1.34 mm for the CL group).

Two possible reasons for this discrepancy are: firstly, in our study the *CHL* thickness was measured with arm in external rotation, which causes the *CHL* to stretch, and this might explain the smaller average values obtained in comparison to those found by Homsí et al. [11], who performed the measurements with shoulder in neutral position with forearm extended. Secondly, there was demographic difference in the subjects of the two studies. Homsí et al. [11] conducted their study in Brazil, no Indian studies are available to compare with our study.

We found a cut-off value of 0.7 mm for *CHL* can be used for diagnosis of adhesive capsulitis, with a high sensitivity and specificity. No other study has calculated any cut-offs.

The *rotator interval* was evaluated using an oblique view as proposed by Lee et al. [10], only study on rotator interval assessment. Presence of increased soft tissue in the rotator interval was found to be a sensitive and specific parameter for diagnosis of adhesive capsulitis and was present in about 84% subjects AC in both studies.

However, increased vascularity in rotator interval was found in only 2 out of 30 subjects of adhesive capsulitis in our study as against 26 out of 30 subjects in the study by Lee et al. [10]. The possible reason being the stage of AC when imaged. The duration of symptoms of all the 26 subjects in the study by Lee et al. [10] was <12 months, while it was higher (>15 months) in the present study, this could account for this difference of observations, as vascularity decreases in later stages of AC.

The inter-observer agreement for confidence scoring for the presence/absence of soft tissue was moderate (kappa 0.589) in our study. No such confidence scoring or inter-observer agreement was evaluated in the study by Lee et al. [10] or any other researchers.

In our study restriction of *abduction* was seen to be a sensitive but not a specific parameter for AC as it was seen in large number of other pathologies also. However, Ryu

Table 5 Comparison of our results with previous studies

Parameter	Our study	Literature
<i>CHL</i> thickness	Increased ($p < 0.05$) Mean 1.2 mm	Increased ($p < 0.05$) Mean 3 mm [9]
Soft tissue in rotator interval	Sen 86.2%, sp 92.8%	Sen 97%, sp 100% [8]
Abduction restriction	Sen 100%, sp 6.7%	Sen 91%, sp 100% [6]
Restriction of external rotation	Sen 96.7%, sp 90%	Reported as sensitive [7]

Sen sensitivity, Sp specificity

et al. [8] reported a high sensitivity and specificity of restriction of abduction (91 and 100%, respectively) (Table 5).

The wide difference in specificity in the two studies can be explained by difference in the study groups taken in both the studies. A painful shoulder group (having pathologies other than AC) was also included in our study besides normal controls, thus giving the true specificity. No such control group was taken in the study by Ryu et al. [8], who only compared AC group with normal controls and hence the specificity was artifactually high in their study.

This is explained by the fact that restricted abduction is known to occur in many other pathologies such as rotator cuff tears, impingement syndromes, tendinitis, subacromial bursitis, etc.

In the present study, *restriction of external rotation* was seen to be both a sensitive and a specific dynamic parameter for diagnosing AC on sonography. The only author to report this finding, Van Holsbeeck et al. [9] also proposed restriction in external rotation based on degree of exposition of subscapularis tendon as a specific sign of adhesive capsulitis (Table 5). The possible explanation was this is the thickened tightened CHL restricting external rotation as proposed by Neer et al. [14].

None of the cases of adhesive capsulitis cases diagnosed on MRI were missed on ultrasound, thus there were no false negatives. However, there were four false positive cases on ultrasound, where sonograms suggested adhesive capsulitis but the MRI diagnosis was not consistent. Two of these patients had subscapularis tendinitis causing limitation of external rotation and leading to a false positive diagnosis of adhesive capsulitis on sonography.

Sonography had a high diagnostic accuracy for the diagnosis of adhesive capsulitis using a combination of parameters. The sensitivity, specificity, positive and negative predictive value of ultrasound for diagnosing AC shoulder was 100%, 87%, 88.2% and 100% respectively, taking MRI as gold standard.

The current study has a few limitations. No correlation with the gold standard arthroscopy was done and also the sample size was small and the findings need to be corroborated in a larger study group.

However, despite these limitations, sonography was found to be a robust modality for diagnosing adhesive capsulitis of the shoulder and differentiating it from other causes of shoulder pain. Thus, it merits to be adopted as a preferred modality for these cases.

Compliance with ethical standards

Conflict of interest All author declare that they have no conflict of interest.

Ethical standard All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Written informed consent was obtained from patients for publication of this report and images.

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References

1. Ewald A (2011) Adhesive capsulitis: a review. *Am Fam Physician* 83(4):417–422
2. Brue S, Valentin A, Forssblad M, Werner S, Mikkelsen C, Cerulli G (2007) Idiopathic adhesive capsulitis of the shoulder: a review. *Knee Surg Sports Traumatol Arthrosc* 15:1048–1054
3. Draghi F, Scudeller L, Draghi AG, Bortolotto C (2015) Prevalence of subacromial-subdeltoid bursitis in shoulder pain: an ultrasonographic study. *J Ultrasound* 18(2):151–158. doi:10.1007/s40477-015-0167-0
4. Della Valle V, Bassi EM, Calliada F (2015) Migration of calcium deposits into subacromial-subdeltoid bursa and into humeral head as a rare complication of calcifying tendinitis: sonography and imaging. *J Ultrasound* 18(3):259–263. doi:10.1007/s40477-015-0163-4
5. Emig E, Schweitzer M, Karasick D, Lubowitz J (1995) Adhesive capsulitis of the shoulder: MR diagnosis. *AJR* 164:1457–1459
6. Connell D, Padmanabhan R, Buchbinder R (2002) Adhesive capsulitis: role of MR imaging in differential diagnosis. *Eur Radiol* 12:2100–2106
7. Carrillon Y, Noel E, Fantino O, Perrin-Fayolle O, Tran-Minh VA (1999) Magnetic resonance imaging findings in idiopathic adhesive capsulitis of the shoulder. *Rev Rhum Engl Ed* 66:201–206
8. Ryu KN, Lee SW, Rhee YG, Lim JH (1993) Adhesive capsulitis of the shoulder joint: usefulness of dynamic sonography. *J Ultrasound Med* 12:445–449
9. Van Holsbeeck M, Vanderschueren J, Wohlend J Shoulder (1997) Sonography in adhesive capsulitis. In: 83rd annual meeting of the Radiological Society of North America, Chicago, USA
10. Lee JC, Sykes C, Saifuddin A, Connell D (2005) Adhesive capsulitis: sonographic changes in the rotator cuff interval with arthroscopic correlation. *Skelet Radiol* 34:522–527
11. Homsi C, Rodrigues MB, Silva JJ et al (2006) Ultrasound in adhesive capsulitis of the shoulder: is assessment of the coracohumeral ligament a valuable diagnostic tool? *Skelet Radiol* 35:673–678
12. Rodeo SA, Hannafin JA, Tom J et al (1977) Immunolocalization of cytokines and their receptors in adhesive capsulitis of the shoulder. *J Orthop Res* 15:427–436
13. Lee MH, Ahn JM, Muhle C et al (2003) Adhesive capsulitis of the shoulder: diagnosis using magnetic resonance arthrography, with arthroscopic findings as the standard. *J Comput Assist Tomogr* 27:901
14. Neer CS 2nd, Satterlee CC, Dalsey RM et al (1992) The anatomy and potential effects of contracture of the coracohumeral ligament. *Clin Orthop* 280:182–185