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Superior humeral head migration might be a radiological aid in diagnosing patients with adhesive capsulitis of the shoulder

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Background: The diagnosis of adhesive capsulitis (AC) of the shoulder might be challenging, as it is a diagnosis of exclusion and mainly based on the clinical examination. The purpose of the present study was to investigate the validity and reliability of 4 commonly reported radiological parameters suggesting a superior humeral head migration on anteroposterior (a/p) shoulder radiograph in identifying patients with AC.

Methods: The a/p shoulder radiographs of 100 patients with AC and 100 control subjects were retrospectively reviewed. A disruption of the normal scapulohumeral arch (≥2 mm), the acromiohumeral interval (AHI), the inferior glenohumeral distance (IGHD), and the upward migration index (UMI) were measured.

Results: A disruption of the scapulohumeral arch was observed in 80% in the AC and 20% in the control group. The mean AHI was 9.3 ± 1.3 mm and 11.0 ± 1.7 mm ($P < .001$), the mean IGHD was 3.9 ± 3.0 mm and 0.9 ± 1.9 mm ($P < .001$), and the mean UMI was 1.37 ± 0.1 and 1.44 ± 0.1 ($P < .001$) in patients with AC and control subjects, respectively. The scapulohumeral arch's disruption demonstrated the best test characteristics with a sensitivity and specificity of 80% in detecting patients with an AC. Patients with a disruption of the scapulohumeral arch had 16 times increased odds of having an AC.

Conclusion: Measuring the superior humeral head migration might be a simple and clinically relevant tool in diagnosing an AC of the shoulder and could be reliably used by clinicians adjacent to the clinical examination without any additional cost. Especially a disruption of the scapulohumeral arch on the a/p shoulder radiograph should raise concerns of AC in the absence of a massive rotator cuff tear.

Adhesive capsulitis (AC) or "frozen shoulder" is a debilitating condition characterized by an insidious onset of shoulder pain, progressive stiffness, and significant restriction of range of motion (ROM) affecting up to 5% of the general population.[12] AC is a self-limited condition with a satisfying recovery in the majority of the cases. However, the mean duration of symptoms is 15 (range: 12 to 30) months,[29] and it is associated with a high socioeconomic burden.[3] Although the development of AC remains not fully understood, the most recognized pathology is a cytokine-mediated inflammation of the synovium with a fibroblastic proliferation,[4] resulting in adhesions formation around the rotator interval and contraction of the coracohumeral ligament and glenohumeral joint capsule.[6] Etiologically, primary (idiopathic) AC is distinguished from secondary (postoperative and posttraumatic) AC.[10,20]

The diagnosis of AC might be challenging because it is a diagnosis of exclusion, and it is mainly based on the clinical examination, with the only additional study suggested being the plain shoulder radiograph to rule out other possible causes of a limited ROM such as osteoarthritis, fracture, and chronic shoulder dislocation.[15] However, AC may clinically appear similar to other common conditions such as subacromial impingement/bursitis, rotator cuff tear (RCT), labral tear, or cervical neuropathy.[1] Hence, it is not surprising that some AC cases are misdiagnosed, and patients are often treated for subacromial impingement with poor outcomes.[14] Although several magnetic resonance imaging (MRI) findings, such as the thickening of the coracohumeral ligament and rotator cuff interval,[25] decreased volume of the axillary recess,[5] and obliteration of the subcoracoid fat triangle,[6] could support the diagnosis,[18] MRIs' cost-effectiveness in the diagnosis of AC is not yet justified.[7]

Approval for this study was received from Kantonale Ethikkommission Zürich (BASEC no. 2021-00049).

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Therefore, reliable radiological signs might be helpful, as an adjacent to the clinical examination, in supporting the diagnosis of AC.

Several studies reported that the superior humeral head migration correlates with a full-thickness RCT.[8,21,22,28] Nevertheless, a superior humeral head migration in patients with an AC has never been reported in the literature. Owing to the contraction of the coracohumeral ligament, the rotator interval, and the glenohumeral joint capsule in AC, the study hypothesis was that patients with AC would demonstrate a superior humeral migration compared to matched-control subjects without AC symptoms. Therefore, the purpose of the present study was 1) to investigate whether patients with AC would demonstrate an increased superior humeral head migration (measured on the anteroposterior [a/p] shoulder radiograph by a disruption of the normal scapulohumeral arch of ≥2 mm, the acromiohumeral interval [AHI], the upward migration index [UMI], and the inferior glenohumeral distance [IGHD]) and 2) to report the validity and reliability of each radiological parameters in identifying patients with AC.

Materials and methods

Study design and patient selection

The present study was approved by the local ethic committee and conducted entirely at the authors' institution. The medical records and radiographs of all patients presented in our outpatient clinic with a diagnosis of AC from January 2014 to December 2019 were retrospectively reviewed. Patients with AC were randomly matched for gender and age (±5 years) with patients who underwent a primary shoulder arthroscopy for any reason, except RCT or AC, at the same period in our institution. The control group consisted of patients without shoulder stiffness (no limited active or passive ROM in clinical examination) who underwent a primary shoulder arthroscopy, as these patients had a standardized preoperative shoulder radiograph and an arthro-MRI, and an RCT could have been excluded under direct visualization during the shoulder arthroscopy.

Inclusion and exclusion criteria

The criteria for the AC diagnosis were a painful, stiff shoulder for at least four weeks, with restriction of passive external rotation to a maximum of 20°.[17] Inclusion criteria for the AC group were patients with primary or secondary AC, aged between 18 and 70 years with an adequate a/p shoulder radiograph (no overlap between the glenoid fossa and humeral head[27]) performed in our institution, and a shoulder magnetic resonance arthrogram (MRA) without any signs of RCTs. Exclusion criteria for the AC group were radiological evidence of glenohumeral arthritis, RCT on MRI, previous rotator-cuff repair in the involved shoulder, and fracture in the shoulder girdle, which could have affected the measurements. Exclusion criteria for the control group were RCT diagnosed on the arthro-MRI or arthroscopically, evidence of frozen shoulder or glenohumeral arthritis, fracture in the shoulder girdle, and unavailability of preoperative shoulder a/p radiographs.

Radiological protocol and measurements

A digital upright true a/p radiograph of the shoulder glenohumeral joint with 45° posterior rotation of the patient, 15° degrees craniocaudal angulation of the x-ray beam, neutral arm rotation, and 150-cm film/focus-distance was performed during the initial presentation at the outpatient clinic, following a standardized protocol. A reference ball of 25 mm on the radiograph was used to normalize the measurements.

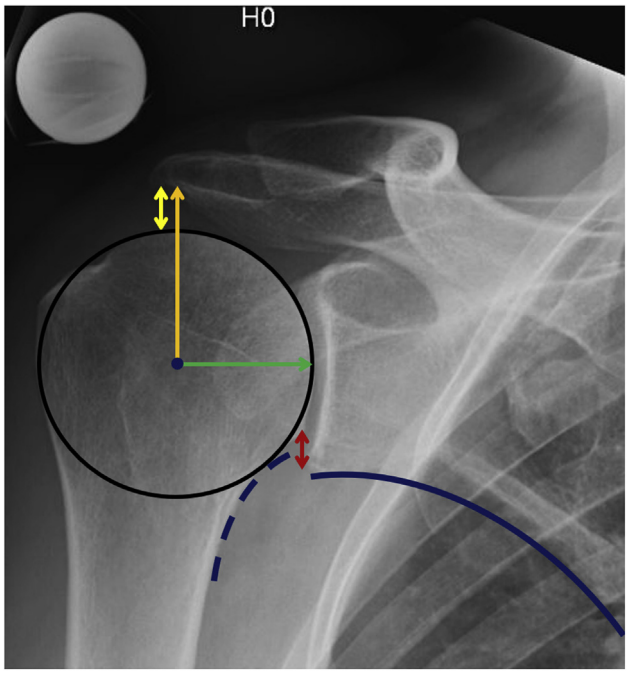

Figure 1 Anteroposterior shoulder radiograph in a patient with AC demonstrating the disruption of the glenohumeral arch (dashed blue line), the AHI (yellow double arrow), the IGHD (red double arrow) in a patient with AC. The UMI was defined as the distance between the lowest point of the acromion and the *Center* of the humeral head (orange arrow), divided by the radius of the humeral head (green arrow). *AC*, adhesive capsulitis; *AHI*, acromiohumeral interval; *IGHD*, inferior glenohumeral distance; *UMI*, upward migration index.

Four radiological parameters were used to describe the superior migration of the humerus head: 1) a disruption of the normal scapulohumeral arch (Maloney line) of ≥2 mm, formed by the medial edge of the humerus and lateral border of the scapula,[13] 2) the AHI, defined as the shortest distance between the inferior cortex of the acromion and the top of the humeral head,[22] 3) the UMI defined as the distance between the lowest point of the acromion and the center of the humeral head, divided by the radius of the humeral head,[9] and the IGHD defined as the distance between the inferior glenoid and the inferior humeral head margin (Fig. 1).[26]

Repeatability analysis

Two independent blinded observers (D.D. and B.H.) evaluated all radiographs to calculate the interobserver reliability. Then each observer reassessed all the radiographs at a 4-week interval to avoid recall bias. The observers measured all four radiological parameters in 50 randomly selected patients. The intraobserver and interobserver reliabilities of the measurements were evaluated using a single-measure intraclass correlation coefficient (ICC) with a two-way random-effects model for absolute agreement.

Statistical analysis

An a priori power analysis was performed to estimate the required total sample size as a function of power 1-β: 0.95, with

Table I
Patient characteristics.

Characteristics	Adhesive capsulitis (n = 100)	Control (n = 100)	Significance (*P* value)
Age, mean ± SD (range), yr	50 ± 8 (27, 70)	48 ± 7 (26, 65)	≥.05
Male gender, %	40%	40%	≥.05
Right shoulder, %	48%	49%	≥.05
Cause of adhesive capsulitis			
Idiopathic	58%	-	
Posttraumatic	38%	-	
Postoperative	4%	-	
Operation			
Acromioclavicular resection	2%	64%	
Biceps tenotomy/tenodesis	1%	5%	
Bursectomy	-	13%	
SLAP-repair	1%	18%	

SD, standard deviation; *SLAP*, superior labrum anterior to posterior.

Table II
Summary of radiological parameter characteristics.

Parameter	Cutoff	Sensitivity (%)	Specificity	PPV (%)	NPV (%)	AUC	Odds ratio	Intraobserver reliability	Interobserver reliability
Arch disruption	Yes	80	80%	80	80	-	16.0*	0.95	0.93
AHI (mm)	≤9.2	58	92%	88	69	0.79	15.6*	0.89	0.86
IGHD (mm)	≥3.0	61	84%	80	68	0.75	8.2*	0.87	0.85
UMI	≤1.39	70	82%	79	71	0.80	6.6*	0.91	0.87

AHI, acromiohumeral interval; *AUC*, area under the curve; *IGHD*, inferior glenohumeral distance; *NPV*, negative predictive value; *PPV*, positive predictive value; *UMI*, upward migration index.
*Statistically significant difference ($P < .05$).

medium effect size, and a = 0.05 using free statistical power analysis software (G*Power version 3.1; Franz Faul, Universität Kiel, Germany). According to our preliminary analysis, a size effect d = 0.4 was necessary to achieve a 90% power for AHI, UMI, and IGHD. Descriptive statistics used standard deviation and range to describe all the continuous variables, whereas frequencies and percentages were used to present the discrete variables. A receiver operating characteristic (ROC) curve analysis was performed to define the optimal cutoff value of the AHI, UMI, and IGHD in detecting an AC. The Youden index[16] was used to determine the ideal cutoff value with the highest sensitivity and specificity. Based on the calculated cutoff value, the negative predictive value, positive predictive value, accuracy, and odds ratio of each radiographic parameter were also calculated.

Results

Power analysis, intraobserver, and interobserver reliability

A total of 100 patients in each group were necessary to achieve a statistical power of 90%. The intraobserver ICC and interobserver ICC were excellent (ICC > 85%) for all measurements (Table II).

Patient characteristics

A total of 100 patients with an AC (male: 60, female: 40) and a mean age of 50 ± 8 (range: 27 to 70) years met the inclusion criteria. Most of the patients (58%) suffered from an idiopathic, 38% from posttraumatic, and 4% from postoperative AC (Table I). The average time from beginning of the symptoms to shoulder radiograph was 6 ± 4 (range: 4 to 14) months. From the total number of 365 patients, who underwent a primary shoulder arthroscopy for any reason, except RCT or AC in our clinic, 100 patients matched-controlled to age and gender were identified (Table I). The majority of the control group (64%) underwent arthroscopic resection of the acromioclavicular joint, superior labrum anterior to posterior repair (18%), bursectomy (13%), and biceps tenotomy ± tenodesis (5%).

Radiologic evaluation

A disruption of the scapulohumeral arch was observed in 80% of the AC patients and 20% of the controls. Patients with a scapulohumeral arch disruption in shoulder a/p radiograph had 16 increased odds of having an AC compared to patients without arch disruption (odds ratio: 16, 95% CI: 8 to 32, $P < .001$). The mean AHI was 9.3 ± 1.3 (range: 7.1 to 12.1) mm and 10.7 ± 1.7 (range: 8.0 to 18.0) mm in patients with AC and control subjects, respectively ($P < .001$). The mean IGHD was 3.9 ± 3.0 (range: 0 to 12.4) mm and 0.9 ± 1.9 (range: 0 to 7.8) mm in patients with AC and control subjects, respectively ($P < .001$). The mean UMI was 1.37 ± 0.1 (range: 1.2 to 1.5) and 1.44 ± 0.1 (range: 1.3 to 1.7) in patients with AC and control subjects, respectively (Table II) ($P < .001$).

ROC curve analyses and characteristics of the AHI, IGHD, and UMI

The ROC curve analysis demonstrated that all radiological parameters had an area under the curve of more than 75% (Table II). However, the scapulohumeral arch's disruption demonstrated the best test characteristics with a sensitivity of 80% and a specificity of 80% in detecting patients with an AC.

Discussion

The most important finding of the present study was that 80% of patients with the diagnosis of an AC demonstrated signs of superior humeral head migration on true ap shoulder radiographs. Despite other radiographic parameters, the disruption of the scapulohumeral arch was the radiographic finding with the highest

sensitivity and specificity (both 80%) increasing the odds for having an AC by 16 times. To the best knowledge of the authors, the present study is the only available one in the literature investigating the validity and reliability of the superior humeral head migration as a radiological aid in diagnosing patients with AC of the shoulder.

The findings of the present study might be of clinical relevance, especially as the diagnosis of an AC might be challenging as it is mainly based on the clinical examination, but symptoms might appear similar to other common conditions such as subacromial impingement/bursitis, RCT, labral tear, or cervical neuropathy.[1] As advanced imaging studies are usually not routinely available at the primary clinical visit, plain radiographs of the shoulder are still considered as primary imaging studies to rule out other possible causes of a limited ROM such as osteoarthritis, fracture, and chronic shoulder dislocation.[15] Therefore, reliable radiological signs might be helpful, as an adjacent to the clinical examination, in supporting the diagnosis of AC.

Superior humeral head migration is commonly observed in association with full-thickness RCTs[8];[28] because of an imbalance between the deltoid and rotator cuff force couple.[24] Several methods for assessing the superior humeral head migration have been investigated in patients with RCTs. Park et al[25] investigated the AHI, IGHD, and UMI in the preoperative a/p shoulder radiograph in patients who underwent a complete or partial arthroscopic rotator cuff repair for a massive RCT (involving $\geq$ 2 tendons). In patients with a complete repair, the mean AHI, IGHD, and UMI were 7.8 $\pm$ 1.5 mm, 6.5 $\pm$ 1.8 mm, and 1.32 $\pm$ 0.08, respectively.

It is commonly agreed and proven by several biomechanical studies that the glenohumeral joint capsule is the primary static stabilizer of the shoulder.[2,23] Based on our clinical impression and supported by the aforementioned biomechanical observations, we hypothesized that patients with AC would demonstrate a superior humeral head migration because of the increased thickness and tightening of the inferior glenohumeral capsule.[11,14,19] The results of the present study confirmed our hypothesis as all radiographic parameters suggesting a proximal migration of the humerus were significantly different between patients with AC and controls.

The present study should be interpreted in light of its potential limitations. The main drawback was the retrospective design. However, owing to the standardized clinical and radiological follow-up protocol, valid patient data were available for the current analysis. Furthermore, all the patients included in the present study suffered from a severe AC, defined as an external rotation of less than 20°. Therefore, the results of the present study might not reflect the radiographic findings in patients with mild AC.

Conclusions

Measuring the superior humeral head migration might be a simple and clinically relevant tool in diagnosing an AC of the shoulder and could be reliably used by clinicians adjacent to the clinical examination without any additional cost. Especially a disruption of the scapulohumeral arch on the a/p shoulder radiograph should raise concerns of AC in the absence of a massive RCT.

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