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

Dimitris Dimitriou, MD\textsuperscript{a,*}, Peter Mazel, MD\textsuperscript{a}, Bettina Hochreiter, MD\textsuperscript{a}, Benjamin Fritz, MD\textsuperscript{b}, Samy Bouaicha, MD\textsuperscript{a}, Karl Wieser, MD\textsuperscript{a}, Florian Grubhofer, MD\textsuperscript{a}

\textsuperscript{a}Balgrist University Hospital, Orthopaedic Department, University of Zürich, Zürich, Switzerland
\textsuperscript{b}Balgrist University Hospital, Department of Radiology, University of Zürich, Zürich, Switzerland

**A R T I C L E   I N F O**

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**Level of evidence:** Level IV; Case-Control  
**Design:** Diagnostic Study

**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 (\(\geq 2\) 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 \(\pm\) 1.3 mm and 11.0 \(\pm\) 1.7 mm (\(P < .001\)), the mean IGHD was 3.9 \(\pm\) 3.0 mm and 0.9 \(\pm\) 1.9 mm (\(P < .001\)), and the mean UMI was 1.37 \(\pm\) 0.1 and 1.44 \(\pm\) 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.

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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.\textsuperscript{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,\textsuperscript{19} and it is associated with a high socioeconomic burden.\textsuperscript{7} 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,\textsuperscript{3} resulting in adhesions formation around the rotator interval and contraction of the coracohumeral ligament and glenohumeral joint capsule.\textsuperscript{4} Etiologically, primary (idiopathic) AC is distinguished from secondary (postoperative and posttraumatic) AC.\textsuperscript{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.\textsuperscript{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.\textsuperscript{1} Hence, it is not surprising that some AC cases are misdiagnosed, and patients are often treated for subacromial impingement with poor outcomes.\textsuperscript{14} Although several magnetic resonance imaging (MRI) findings, such as the thickening of the coracohumeral ligament and rotator cuff interval,\textsuperscript{15} decreased volume of the axillary recess,\textsuperscript{2} and obliteration of the subcoracoid fat triangle,\textsuperscript{5} could support the diagnosis,\textsuperscript{18} MRIs' cost-effectiveness in the diagnosis of AC is not yet justified.\textsuperscript{7}
Therefore, reliable radiological signs might be helpful, as an adja-
cent 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.5,21,22,28 Neverthe-
less, 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 gleno-
humeral 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 super-
ior humeral head migration (measured on the anteroposterior [a/p] shoulder radiograph by a disruption of the normal scap-
ulohumeral 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 under-
went a primary shoulder arthroscopy for any reason, except RCT or
AC, at the same period in our institution. The control group con-
Sisted 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 preop-
erative 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 gleno-
humeral 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 gleno-
humeral joint with 45° posterior rotation of the patient, 15° degrees
cranio-caudal 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.

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 (orange
dashed blue line), divided by the radius of the humeral head (green arrow), AC, adhesive cap-
sulitis; AHI, acromiohumeral interval; IGHD, inferior glenohumeral distance; UMI, upward migration index.

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 pa-
rameters 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
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 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).

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 ($P < .05$).

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. 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. 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, because of an imbalance between the deltoid and rotator cuff force couple. Several methods for assessing the superior humeral head migration have been investigated in patients with RCTs. Park et al. 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 16 times. To the best knowledge of the authors, 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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