Critical shoulder angle: Measurement reproducibility and correlation with rotator cuff tendon tears

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\section*{A B S T R A C T}

\textbf{Background:} Associations have been reported linking rotator cuff tears (RCTs) to both greater lateral extension of the acromion and greater inclination of the glenoid cavity. These two factors combined can be assessed using a recently introduced parameter, the critical shoulder angle (CSA). The primary objective of this study was to confirm the association linking a high CSA value to RCTs, and the secondary objective was to assess the reproducibility of CSA measurement using a goniometer.

\textbf{Hypothesis:} The null hypothesis was that the CSA value in a group of patients with RCTs was not significantly different from that in patients with anterior shoulder instability and a Bankart lesion, taken as the general population for this study.

\textbf{Methods:} After a power estimation, we retrospectively included 28 patients with a mean age of 55.5 years who had surgery for RCTs and 27 patients with a mean age of 27.2 years who underwent anterior labral repair. Two surgeons used a goniometer to measure the CSA in each patient. Reproducibility was assessed based on Bland-Altman plots and Pearson’s correlation coefficient.

\textbf{Results:} The mean CSA was significantly higher (\(P=0.02\)) in the RCT group (36.4\(\pm\)4.4\(^{\circ}\); range: 30–46\(^{\circ}\)) than in the labral-repair group (33.3\(\pm\)3.8\(^{\circ}\); range: 25–41\(^{\circ}\)). Intra-observer reproducibility was 96.7% and inter-observer reproducibility was 95.5%.

\textbf{Conclusion:} Our results support previously published evidence that the CSA is significantly greater in patients with RCTs. Thus, an anatomical difference seems to exist between patients with RCTs and the general population. The CSA measured on a standard radiograph using a goniometer provides a reproducible assessment of this anatomical difference.

\textbf{Level of evidence:} IV, case-control epidemiological study with a power estimation.

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1. Introduction

Rotator cuff tears (RCTs) are multifactorial lesions whose prevalence increases with age [1,2]. Until recently, the influence of acromial geometry was chiefly assessed in terms of the subacromial impingement syndrome described by Neer [3] and Armstrong [4]. New studies indicate, however, that several anatomical features of the scapula such as marked lateral extension of the acromion and upward inclination of the glenoid are associated with RCTs [3,5–11]. The critical shoulder angle (CSA) is a tool developed by Moor et al. [9,10] to assess these two anatomical factors using a single parameter. CSA values greater than 35\(^{\circ}\) were found to be associated with RCTs and lower than 30\(^{\circ}\) with gleno-humeral osteoarthritis.

The primary objective of this study was to confirm the association linking a high CSA value to RCTs. The secondary objective was to evaluate the reproducibility of CSA measurement using a goniometer. The null hypothesis was that the CSA in a group of patients with RCTs was not significantly different from that in a group of patients with anterior labral tears, taken as the general population for this study.

2. Population and methods

2.1. Inclusion criteria

The sample size required to obtain greater than 95% statistical power with the alpha risk set at 5% was estimated. Then, 89 cases were considered from the lists of consecutive
patients who had had RCT repair or anterior labral repair since 2011. Among them, 9 RCT patients and 15 labral-repair patients were excluded because of missing preoperative imaging studies (anterior-posterior double-obliquity radiograph, computed arthrography, magnetic resonance imaging, or magnetic resonance arthrography). Furthermore, a history of surgery on the same shoulder led to the exclusion of 7 RCT patients and 3 labral-repair patients.

This left 55 patients for the study, 28 in the RCT group (mean age: 55.5 years) and 27 in the labral-repair group (mean age: 27.2 years). The indication for arthroscopic labral repair was post-traumatic anterior shoulder instability.

2.2. Assessments

The CSA was measured on an anterior-posterior double-obliquity radiograph of the shoulder as the angle subtended by a line parallel to the glenoid and a line through the inferior-lateral edge of the glenoid and the inferior-lateral edge of the acromion [9] (Fig. 1).

Two observers, designated A and B hereafter, measured the CSA in each patient, using a goniometer. Inter-observer reproducibility was assessed by comparing the values obtained by these two observers and intra-observer reproducibility by having observer A repeat the measurements after a 3-week interval.

Furthermore, observer A used the scapular Y radiograph to assess the acromion in each patient according to the classification described by Bigliani et al. [12].

2.3. Statistical methods

Fisher’s exact test was chosen to compare categorical variables and the Wilcoxon–Mann–Whitney rank-sum test to compare continuous variables. Reproducibility of the measurements was evaluated using both Bland–Altman plots and Pearson’s correlation coefficient.

Univariate analyses were performed to compare the characteristics of the two groups. Then, exploratory multivariate analyses were done to look for explanatory variables. Receiver-operating characteristic (ROC) curves were plotted to determine the CSA cut-off that provided the best sensitivity and specificity.

3. Results

Intra-observer reproducibility was 96.7% and inter-observer reproducibility was 95.5%. Differences in measured values are shown on the Bland–Altman graphs in Fig. 2.

The RCT and labral-repair groups differed significantly for mean age (55.5 ± 7.07 years, range: 42–73, versus 27.2 ± 9.33 years, range: 14–50, \( P < 0.001 \)); the proportion of patients in manual or heavy labour occupations (75% versus 25%, \( P < 0.001 \)); and the proportion of Bigliani type II and III acromions, which was higher in the RCT group (\( P < 0.01 \)).

![Fig. 1. Measurement of the critical shoulder angle (CSA). CSA measurement on an anterior-posterior double-obliquity radiograph of the shoulder. The CSA is subtended by a line parallel to the glenoid and a line through the inferior-lateral edge of the glenoid and the inferior-lateral edge of the acromion.](image1.png)

![Fig. 2. Inter-observer (A) and intra-observer (B) measurement differences assessed using Bland–Altman plots.](image2.png)
The mean CSA was significantly different \( (P=0.02) \) between the two groups: \( 36.4° \pm 4.4° (30°–46°) \) in the RCT group and \( 33.3° \pm 3.8° (25°–41°) \) in the labral-repair group. Fig. 3 reports the CSA values in each group. The CSA did not vary significantly with sex, side involved, or dominant side. The area under the ROC curve was 69\% (Fig. 4). A CSA cut-off of 35° had 53\% sensitivity and 74\% specificity. Among patients whose CSA was greater than 35°, 68\% had a RCT.

4. Discussion

Several studies showed good reproducibility of CSA measurements performed on picture archiving and communication systems (PACS) \([9,10,13]\). Using a goniometer, we also demonstrated good intra-observer and inter-observer reproducibilities of 96.7\% and 95.5\%, respectively.

One study found no association between RCTs and scapular anatomy \([14]\), whereas in others RCTs were associated with greater lateral extension of the acromion \([5,6,9,10]\) and with glenoid cavity version \([7]\) and inclination \([7,8,11]\). The mean CSA in our study was significantly higher in the RCT group (36.4°) than in the control group. This high value is consistent with reports by Moor et al. (38°) \([9,10]\), Spieg et al. (37.3°) \([13]\), and Daggett et al. (37.9°) \([11]\) and corroborates our hypothesis that a high CSA is associated with RCTs.

Among patients whose CSA was greater than 35°, the proportion with RCTs was 84\% according to Moor et al. \([9]\), 79\% according to Spieg et al. \([13]\), and only 68\% in our study. The mean CSA in our control group (33.3°) is consistent with the value found in healthy controls in these studies (33.1° and 32.7°) \([9,10,13]\) and greater than the values reported in controls with osteoarthritis (27.7°, 28.1°, and 28.7°) \([9–11,13]\). Those findings are probably ascribable to our use as controls of patients free of osteoarthritis who were similar to the general population.

Greater obliquity of the glenoid cavity is associated with an increase in the shear component of the forces generated by the deltoid muscle \([8]\) and, therefore, with greater humeral head elevation \([15]\). Marked lateral acromion extension increases the vertical component of the deltoid forces \([9,10]\). These vertical forces may increase humeral head elevation, thereby promoting the development of both damage to the deep rotator cuff surface and of subacromial impingement \([9,16]\). Fig. 5 illustrates this hypothesis.

A strong point of our study is the sample size estimation, which ensured sufficient statistical power. Furthermore, only measurement tools available to orthopaedic surgeons in their everyday practice were used, and the measurement method was simple, in contrast to the techniques needed for assessments of glenoid inclination \([17]\).

Several factors may have introduced bias. The main weakness of the study lies in the characteristics of the control group. Thus the two populations had significant differences for age, occupation, and acromion type according to Bigliani et al. \([12]\).

4.1. Influence of age

The incidence of RCTs increases with age \([1,2]\), and RCTs are exceedingly rare before 30 years of age \([2,18,19]\). Our control group was similar to a general population of individuals who may or may not develop shoulder osteoarthritis or tendinopathies.

4.2. Influence of manual occupations

The high proportion of manual workers in our RCT group may have biased the interpretation of the influence of the CSA. Several studies demonstrated an association between clinical rotator cuff symptoms and the level of physical activity \([20,21]\). Only limited evidence exists, however, to support a link between physical activity and RCTs \([22]\). Yamamoto et al. \([2]\) reported a non-significant trend toward a higher prevalence of RCTs among manual workers in the general population. Another study, however, failed to find any link between manual work and RCTs \([23]\).

The smaller proportion of manual workers in our control group is unlikely to have had a substantial influence, given that RCTs are extremely uncommon before 30 years of age \([2,18,19]\).

Fig. 3. Critical shoulder angle (CSA) values in the group with rotator cuff tears (RCTs) and in the group of controls. The left-hand panel shows the results in the RCT group and the right-hand panel those in the labral-repair group. CSA values are in degrees. The solid horizontal line indicates the median, the blue and red boxes the first and third quartiles, and the dashed lines the maximal and minimal values.

Fig. 4. ROC curve. Area under the ROC curve, with the 95% confidence interval. The best CSA cut-off was 34.6°.
4.3. Influence of acromion type according to Bigliani

Types II and III were more common in the RCT group. The impact and aetiology of acromion geometry according to Bigliani remain controversial [12,15,24–29]. We are not aware of published evidence that the lateral acromion changes with age. We assumed that the CSA is an anatomical characteristic that remains unchanged once growth is complete [24].

The retrospective study design may have introduced selection bias. Nevertheless, we obtained uniform populations in both the RCT and the labral-repair groups.

In sum, our study provides confirmation that a significant anatomical difference exists between shoulders with RCTs and those in a control group similar to the general population. This difference can be assessed reproducibly on standard radiographs by using a goniometer to measure the CSA.

Given the large number of factors that contribute to rotator cuff degeneration, the exact mechanism remains to be determined. Specific anatomical characteristics probably exert biomechanical effects that play a key role in the pathogenesis of RCTs.

Disclosure of interest

P. Clavert is a consultant for Mitek and Tornier.
L. Cherchi, J.F. Giornohac, J. Godet and J.-F. Kempf declare that they have no competing interest.

References