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DOI:10.1016/j.jse.2015.11.059

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Predominance of the critical angle in the pathogenesis of degenerative diseases of the shoulder.

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Abstract

Hypothesis. The Critical Shoulder Angle (CSA) could be responsible for cuff tear and concentric osteoarthritis. We aimed to assess this association when excluding potential confounding factors, and to test the hypothesis that more extreme CSAs are associated with larger tear and more severe osteoarthritis.

Methods. Two-hundred patients were included: primary concentric osteoarthritis(40 patients); isolated supraspinatus tear(40 patients), cuff tear involving at least the supraspinatus and infraspinatus(40 patients); control group(80 patients). The variables CSA, age, gender, dominant arm, smoking, hypertension, Body Mass Index and the type of work were collected.

Results. The average CSA angle was 33.9±3° in the control group, 35.6±2.8° in supraspinatus tear, 40.1±3.5° in supraspinatus and infraspinatus tears, and 27.7±2.3° in concentric osteoarthritis. All the CSA angles were significantly different compared to the control group. Patients with large cuff tear had a significant greater CSA compared to isolated supraspinatus tear ($p= 0.03$). The CSA (ODDS 1.7, CI 1.37-1.96) and smoking (ODDS 3.97, CI 1.26-12.49) were the most relevant risk factors for cuff tear.

Concerning concentric osteoarthritis, the Spearman's coefficient, between CSA and grade of eccentric osteoarthritis, was 0.4 ($p= 0.01$). The two significant risk factors for concentric osteoarthritis were the CSA (ODDS 0.47, CI 0.35-0.64) and age (ODDS 1.12, CI 1.03-1.2).

Conclusion

Larger CSA are associated with increased risk of symptomatic cuff tear, larger cuff tear and severity of eccentric osteoarthritis. Smaller angles increased the risk and severity of concentric symptomatic osteoarthritis. These associations were significant also after removing some of the potential confounding variables.

Introduction

Degenerative conditions of the shoulder, including cuff tear and glenohumeral osteoarthritis, are common. Despite enormous efforts have been made in order to provide better treatments to cure these diseases, we have not reach similar success in their prevention. The reason behind this difficulty might be related to the multifactorial aetiology of these diseases, including age (1) (2), trauma and scapular morphology (3) (4).

More recently some authors showed an interest relationship between scapular morphology, cuff tear and primary osteoarthritis, with encouraging findings on the so called "Critical Shoulder Angle" (CSA) (5). The CSA is a reliable radiographic parameter that combines the measurement of the inclination of the glenoid and the lateral extension of the acromion. Moor BK *et al* found that primary glenohumeral osteoarthritis is associated with significantly smaller CSA and degenerative rotator cuff tear with significantly larger CSA, compared to asymptomatic shoulders (5). Furthermore, in another paper, has been found that the mean CSA, in combination with age and trauma, can predict the integrity of the posterosuperior rotator cuff (6).

The theory behind this association is that, in larger CSA, the resulting force vector, mostly depending on the ascending force component of the deltoid, is direct upward against the rotator cuff, determining cuff degeneration, tear and potentially eccentric arthritis. On the other hand, the resulting force vector of the deltoid muscle is more balanced on the glenoid surface when the CSA is around 33° (average angle in healthy patients) (5), with a protective effect against degenerative shoulder conditions. In case of a small CSA, the resulting force vector is unbalanced against the glenoid, favouring concentric osteoarthritis (7).

If this theory is totally or partially correct, one could assume that larger CSA angles are associated with larger cuff tear and/or higher grade of eccentric osteoarthritis, and that smaller CSA angles are associated with higher grade of primary concentric osteoarthritis. However, this correlation has never been found.

The aims of this study were to find a correlation between amount of CSA and severity of cuff tear, concentric and eccentric osteoarthritis. Moreover we want to address the contribution of the CSA as risk factor for cuff tear and concentric osteoarthritis, also when analysed excluding potential confounding factors such us age, type of work and smoking.

Material and methods

Starting from January 2013 to October 2014, 200 consecutive patients were included in the study. Patients were divided in the following groups:

- Primary symptomatic concentric osteoarthritis (40 patients).
- Isolated symptomatic full supraspinatus tear (40 patients).
- Symptomatic cuff tear involving at least the supraspinatus and infraspinatus (40 patients).
- Control group (80 patients).

Patients were included in the study if older than 18 years old, consented to the study and had a recent (within three months) true antero-posterior (AP) radiograph of the shoulder of *acceptable quality*. An acceptable quality radiograph was defined as an image with less or equal than 5 mm of overlapping between the anterior and posterior margins of the glenoid. (Figure 1).

This definition was adopted after a pre-study phase, in which we measured the reliability of the CSA related to the quality of the radiograph. With the criteria above mentioned, the intraobserver and interobserver reliability of the CSA, measured in 30 radiographs with imperfect AP view, but within the limits of 5mm, was similar to the reliability measured in 30 controls with an AP view without overlapping (95% upper limit of agreement in perfect AP view= 2°; imperfect AP view= 3°, p= 0.5). An analysis of the outliner values suggested that a greater value of overlapping was associated with an increase of disagreement within and between observers.

Moreover, we compared the CSA measured in 20 shoulders with AP view without overlapping, to the CSA measured in the same shoulder, with imperfect quality, with 2 to 5 mm of overlapping. We select this cohort of patients by searching in our database patients who had at least two consecutive x-rays of the shoulder, performed in two different occasions (i.e. controls for clavicular fracture or proximal humeral fractures) of which one presented with an overlapping between 2 mm and 5 mm and the other without any significant overlapping. Comparing the two CSA the systematic error was + 0.6° with an upper limit of agreement of 2°. For this analysis, the same observers and statistics described below were used.

Patients with an history of shoulder fracture and inflammatory arthritis were excluded from the study.

Definition of the groups.

Symptomatic primary concentric osteoarthritis (Figure 2). The diagnosis of symptomatic primary concentric osteoarthritis was done clinically and on radiograph. An MRI was requested to confirm absence of cuff tear. An intraoperative confirmation of the integrity of the cuff tear was not available in 12 cases, since these patients were treated conservatively. The severity of the osteoarthritis was classified according to the criteria described by Samilson & Prieto (8).

Symptomatic isolated full supraspinatus tear (Figure 3). Patients were included in this group after an initial clinical diagnosis of symptomatic isolated supraspinatus full thickness tear. The diagnosis was confirmed by an MRI and during surgery. All these patients underwent arthroscopic cuff tear repair.

Symptomatic cuff tear involving supraspinatus and infraspinatus (Figure 4). The patients were symptomatic for a large supero-posterior cuff tear and the diagnosis of the dimension of the tear was made with an MRI and confirmed intraoperatively. These patients underwent arthroscopic cuff tear repair and/or LHB tenotomy or reverse shoulder replacement. In case of eccentric osteoarthritis, the severity of was classified according to the criteria described by Hamada (9). A classification of the dimension of the cuff tear in cm was not adopted because reliable data were missing in the surgical notes.

Control group (Figure 1). This group was made up of patients with no history of shoulder pain. These patients had a true AP view obtained in the emergency department in our hospital for recent trauma, excluding patients with fracture of the glenoid. During interview, they denied any problem of the shoulder in the past. We selected these patients as a control because they already had a radiograph done for the trauma, that reduced costs of the study and simplified internal review board process.

The patients were interviewed by a researcher who collected the following variables: age, gender, dominant arm, smoking habit (present or in the past, excluding occasional cigarettes), hypertension, height and weight to calculate the Body Mass Index (BMI) and the type of work that the patient declared to have done for the majority of his/her life. To assess the variable "work", a scale was designed starting from the classification of jobs described in the Dictionary of Occupational Titles, published by the USA Department of Labor (10). The details of this scale are reported on Appendix 1.

The CSA was measured using a software already in use in our department (Impax 6.5.1.501; AGFA HealthCare N.V., Mortsel, Belgium), by applying the definition described by Moore et al. (5). Two different observers measured twice the same radiographs, one week apart, in order to evaluate intraobserver and interobserver reliability. The two observers had different level of expertise; one was a shoulder and elbow specialist with 10 years of practice, one was a graduated medical student. A Bland-Altman analysis (11) of the errors measuring CSA was performed to calculate intraobserver and interobserver reliability.

Statistical analysis

In order to measure the correlation between CSA and severity of primary concentric arthritis a Spearman correlation coefficient was calculated in a cohort of patients with the diagnosis of primary osteoarthritis. The same statistic was used to measure a correlation between degree of eccentric osteoarthritis and CSA, including in the analysis patients with cuff tears. A multivariate regression analysis was performed to measure the correlation of the CSA with the severity of primary osteoarthritis and eccentric osteoarthritis, when analysed together with the other variables. The variables included in the multivariate regression analysis were: CSA, smoking, gender, dominant arm, hypertension, work, BMI and age.

To test the hypothesis that the CSA is a significant risk factor for cuff tear and concentric osteoarthritis, a logistic regression analysis, using as dependent variable the presence of a cuff tear or primary concentric osteoarthritis, was adopted.

A Student T test and a Fisher test were used to compare the average values between groups.

A sample size analyses was performed. In order to compare patients with supraspinatus tear and large tear we calculated a minimum number of 28 patients requested in each group (α= 0.05, β= 0.2, standard deviation= 4, difference expected= 3°). Twenty-nine patients were the minimum number of patients requested for an expected correlation coefficient of 0.5 (α= 0.05, β= 0.2). Considering these calculations, we planned to include 40 patients in each group, except in the control group where we decided to include 80 patients in order to have a better representation of our healthy population.

Results

CSA Reliability.

The measurement of the CSA was reproducible both for the expert observer as for the less expert observer. The average error between the two measurements made by the two observers, in two separate occasions, was 0° with an 95% upper limit of agreement of 2°. The average error between the first measurement of the CSA made by the expert observer and the first measurement made by the less expert observer was 0° with an upper limit of agreement of 3°.

Demographic data and CSA

The demographic data are summarized on Table 1.

The average CSA angle was 33.9°± 3° in the control group, 35.6° ± 2.8° in the patients with an isolate supraspinatus tear, 40.1° in patients with supraspinatus and infraspinatus cuff tear, and 27.7°±2.3° in patients with concentric osteoarthritis. All the CSA angles were significantly different compared to the CSA in the control group (Figure 5). Moreover patients with large cuff tear had a significant greater CSA compared to patients with an isolated supraspinatus tear (p= 0.03)

Risk factors for cuff tear and correlation between CSA and eccentric osteoarthritis

In the logistic regression analysis the CSA, type of work, smoking and age, were variables significantly related to the occurrence of a cuff tear. The CSA seemed to be the most relevant risk factors for cuff tear. The data are reported on Table II.

Spearman's coefficient of rank correlation (rho) between CSA and grade of eccentric osteoarthritis was 0.4 (p= 0.01) (Figure 6A). The multiple regression analysis confirmed the association between CSA and severity of eccentric osteoarthritis. Among all the independent variables included in the multiple regression analysis, a significant association was found between grade of eccentric osteoarthritis and CSA ($r = 0.15$, $p<0.001$), age of the patient ($r = 0.04$, $p = 0.001$), and BMI ($r = 0.1$, $p=0.008$).

Risk factors for concentric osteoarthritis and correlation between CSA and concentric osteoarthritis

The only two significant risk factors for primary concentric osteoarthritis were the CSA (ODDS 0.47, 95% CI 0.35-0.64) and age (ODDS 1.12, CI 1.03-1.2).

Spearman's coefficient of rank correlation (rho) between CSA and grade of concentric osteoarthritis was -0.36 ($p=0.04$) (Figure 6B). Using multivariable analysis, a significant association was found between grade of primary concentric osteoarthritis, CSA ($r= -0.08$, $p= 0.001$) and age ($r= 0.02$, $p= 0.001$).

Discussion

The CSA has been suggested to be responsible for the occurrence of cuff tear and concentric osteoarthritis (7) when the angle is significantly different from the corresponding angle in the control group. The aims of this study were to investigate furthermore the CSA by assessing its contribution to the development of cuff tear and primary osteoarthritis when excluding confounding factors, and to test the hypothesis that more extreme CSAs are associated with larger tear and more severe osteoarthritis.

The CSA in our control group was approximately 34° with a very small standard deviation, a value similar to the one reported by Moore *et al.* (5). This data reinforces the theory that an angle of approximatively 33° to 34° can be protective against degenerative atraumatic diseases of the shoulder. In a pre-study phase we have analysed the potential error that could occur using an imperfect AP view, when measuring the CSA. Using an imperfect AP view we measured a potential overestimation of the CSA of approximately 0.6°. This data could justify the little difference between the average CSA that we measured in controls compare to the CSA angle reported by Moore et al. (5).

The data reported in our study showed for the first time that an angle larger than 34° increases the risk of developing a cuff tear also when analysed in a multivariable setting. Moreover, this study showed that larger is the CSA angles larger is the cuff tear and more severe the eccentric osteoarthritis. Interestingly the variable with the more statistically significant ODDS ratio for the occurrence of a cuff tear was the critical angle ($p<0.001$) that seemed to be more relevant than the smoking, age and work variables. Among these variables, however, smoking was the one that had the higher ODDS ratio. The influence of the smoking habit in the occurrence of cuff tear has been already investigated by Gumina *et al*. (12). They found that the severity of the tears increases with the average number of cigarettes smoked in a day and the total number of cigarettes smoked in life.

Our study also found that age and type of work were independent factors that can increase the risk of symptomatic cuff tear, confirming the degenerative aetiology of cuff tear. If age has been confirmed by several authors to be a relevant risk factors for cuff tear (1) (2), interestingly no detailed information are available in literature on the occurrence of rotator cuff tears in working populations, in terms of duration and magnitude of exposure to work-related risk. In a revision of the literature focused in this topic, authors did not found any articles that reported associations between work-related factors and the occurrence of rotator cuff tear. In a study aimed to find prevalence and risk factors of rotator cuff tear in the general population, the type of work (classified in light, intermediate and heavy) was found to be a potentially related factor for the occurrence of cuff tear but this association was not confirmed in a multivariate analysis (15). Using a dedicated scale, we have confirmed the association between work and cuff tear also in a multivariate analysis.

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Differently to what has been reported in previous studies (13) (14) we could not find a statistically relevant association between hypertension, BMI and cuff tear. Several causes could be responsible for that, including the inclusion in the multivariate analysis of the CSA, as a new strong independent variable, that could have limit the influence of the other variables. Another reason could be that we trusted the data reported by patients, at the moment of the inclusion in the study, to calculate the BMI. We cannot exclude incorrect weight and height reported by patients. Moreover, the average age of our control group (70 years) was higher that the control group of the study of Gumina *et al*. (14) (62 years), that could had increased the incidence of hypertension in our controls, hiding a significant association between hypertension and cuff tear.

Other than to analyse the risk factors for symptomatic cuff tear, this study aimed to find the variables potentially associated with the progression from a “simple” cuff tear to a larger cuff tear and eccentric osteoarthritis. Although it is conceivable that the same variables that can determine a cuff tear can be responsible for the progression to an eccentric osteoarthritis, the impact of the single variables in determining larger tear and eventually osteoarthritis is not known beforehand. We found that type of work and smoking habit did not seem to affect the progression in osteoarthritis. On the contrary, CSA, age of the patients and BMI seemed to be the variables related to the severity of eccentric osteoarthritis.

This study confirmed also that smaller CSA are associated with concentric osteoarthritis. Furthermore, we found for the first time, that smaller the angle is, more severe seems to be the osteoarthritis.

The analysis of risk factors for symptomatic concentric osteoarthritis showed that CSA and age were independent significant risk factors. These data confirmed the effect of age showed previously (16).

Regarding the reliability of CSA, we found that the measurement of the angle is easy and reliable, results that confirms the data reported by Moore B.K. *et al* (7). Moreover, our study reported that the reliability of the measurement of the CSA is independent from the level of expertise of the observers, which confirms that the landmarks used to draw the CSA are easily identified also by less experience observers.

The data reported in this study strongly supports the correlation between amount of CSA and degenerative conditions of the shoulder. Considering other variables, the CSA seemed to be one of the most “critical”.

Although this association is very interesting, it must be considered with great caution. This study does not prove unanimously that changes in CSA cause a more sever osteoarthritis. The association we found could be justified by the fact that in severe osteoarthritis, the humeral head deforms the glenoid, by determining a larger or smaller CSA. In this case a change in CSA would be the effect and not the cause of the osteoarthritis. Although this is a possible bias, a severe glenoid erosion was rarely observed in the patients included in this study. This issue will be clarified in long-term prospective studies.

This study has other limitations. Our control group was made of subjects that denied any shoulder problems in the past. However this statement does not exclude that they could have asymptomatic cuff tear of osteoarthritis. The osteoarthritis was excluded with radiographs, but we did not prescribe MRI to confirm cuff integrity. Another limitation is that the data were collected retrospectively and that a new scale was used to assess the work variable. The psychometric features of this scale were not tested.

Conclusion

With these limitations, this study confirms the average CSA angle in control subjects, and the reliability of the measurement of the CSA. The reliability was not affect by the level of expertise of the observer. Larger angles are associated with increased risk of symptomatic cuff tear, larger cuff tear and severity of eccentric osteoarthritis. Smaller angles increased the risk and severity of concentric symptomatic osteoarthritis. These associations were significant also after removing potential confounding variables.

Figure 1

AP radiograph showing a 75 woman, included in the control group, affected by a proximal humeral fracture. The critical angle was measured between a line connecting the inferior margin to the superior margin of the glenoid fossa and a second line connecting the inferior margin of the glenoid to the later margin of the acromion. In this case the critical angle was 34°.

Figure 2

AP view radiograph shows a 45-year-old right-dominant man with concentric osteoarthritis. A critical shoulder angle of 26.2° was measured.

Figure 3

The figure shows a post-op AP view x-ray of a 55-year-old woman with an isolated supraspinatus tear. The Critical Shoulder Angle was 35.9°.

Figure 4

The figure shows a pre-op AP view x-ray of a 65-year-old woman with a large cuff tear, involving the supraspinatus and infraspinatus. The critical shoulder angle was 39.4°. A narrowing of the acromiohumeral distance was also evident.

Figure 5

The figure shows the average critical shoulder angle in the different subgroups of patients included in the study

Figure 6A & B:

Figures show the Spearman's coefficient of rank correlation between CSA and severity of eccentric osteoarthritis (A) and concentric osteoarthritis (B). The severity of eccentric osteoarthritis was classified into 5 subgroups according to Hamada classification. The severity of concentric osteoarthritis was classified in three subgroups according to Samilson & Prieto classification.

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