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Quantitative study of the architecture of the human subacromial space and its relationship with rotator cuff tears

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Summary

Rotator cuff tears usually cause a grinding facet in the undersurface of the acromion, called facies articularis acromialis, which is observable in dried scapulas. Some authors have related the pathogenesis of rotator cuff tears to an intrinsic degeneration of the cuff, while others have indicated that this pathology would be due to subacromial impingement. Some of the latter suggest that rotator cuff tears are associated with a narrowing of the subacromial space, mainly related to variations in the anatomy of the acromion. In order to obtain more information about the pathogenesis of rotator cuff tears we studied several anatomical parameters related to the architecture of the subacromial space in 112 human scapulas, divided into a healthy group and a pathological group depending on the lack or presence of a facies articularis acromialis in the undersurface of the acromion. The results obtained have not allowed us to identify significant differences in the different parameters studied in the two groups, not even in those related to the anatomy of the acromion. Our results, however, do allow us to suggest that rotator cuff tears seem to be more related to a primary degeneration of the cuff itself rather than to the anatomical characteristics of the subacromial space.

Key words: Rotator cuff tears – Subacromial space – Acromion

Introduction

Full-thickness rotator cuff tears involve a direct contact between the acromion and the greater tubercle of the humerus. This contact usually leads to the appearance of a grinding facet in the undersurface of the anterior third of the acromion called facies articularis acromialis (Herrmann et al., 1990; Prescher, 2000; Takase and Yamamoto, 2005; Jih-Yang et al., 2006).

At present, there is no general agreement about the pathogenesis of rotator cuff tears. Some authors suggest that rotator cuff tears would be related to subacromial impingement, generally due to a narrowing of the subacromial space (Neer, 1972). Since Bigliani et al. (1986) classified three acromion types according to their morphology - type I or flat acromion, type II or curved acromion and type III or hooked acromion - many authors have associated subacromial impingement and rotator cuff tears with a type III acromion (Bigliani et al., 1986; Morrison and Bigliani, 1987; Gohlke et al., 1993; Farley et al., 1994; Toivonen et al., 1995; Wang et al., 2000; Tasu et al., 2001; Anetzberger et al., 2004; Lisy et

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al., 2004). Another acromial type (type IV or convex acromion) has been proposed by some authors (Gagey et al., 1993), but it has not been related to rotator cuff tears (Natsis et al., 2007). Rotator cuff tears have also been related to a low tilting angle of the acromion, which reduces the extent of the subacromial space (Aoki et al., 1986; Edelson and Taitz, 1992; Gohlke et al., 1993; MacGillivray et al., 1998; Prato et al., 1998; Prescher, 2000; Vaz et al., 2000).

On the other hand, some authors have failed to find any link between rotator cuff tears and a type III acromion or the magnitude of the acromion tilting angle (Banas et al., 1995; Jacobson et al., 1995; Liotard et al., 1998; Hyvonen et al., 2001; Seok-Beom et al., 2001; Mayerhofer and Breitenseher, 2004; Chang et al., 2006). These results would agree with those of authors who believe that the pathogenesis of rotator cuff tears must lie in a primary degeneration or in a weakness of the muscles comprising the rotator cuff (subscapularis, supraspinatus, infraspinatus and teres minor) (Lindblom, 1939; Rathburn and Macnab, 1970; Jerosch et al., 1989; Nirsch, 1989; Lohr and Uhthoff, 1990; Ogata and Uhthoff, 1990; Warner et al., 1990; Brox et al., 1993; Bartolozzi et al., 1994; Leroux et al., 1994; Wickiewicz, 1994; Hawkins and Dunlop, 1995; Sharkey and Marder, 1995; Deutsch et al., 1996; Thompson et al., 1996; Paletta et al., 1997; Payne et al., 1997; Brox et al., 1999; Chen et al., 1999; Reddy et al., 2000; Hashimoto et al., 2003; Jih-Yang et al., 2006).

In the present study we compared different anatomical parameters of the architecture of the subacromial space in normal human scapulas and in scapulas with a facies articularis acromialis in the undersurface of the acromion, which indicates the presence of a lesion affecting the muscles of the rotator cuff. Our aim was to determine whether the morphology of the subacromial space can be related to rotator cuff tears in humans or whether other possible pathogenic causes should be considered.

Material and Methods

In the present work we have studied 112 human scapulas (68 males and 44 females) from the osteology collection of the Department of Anatomy and Radiology of the University of Valladolid. All scapulas were from legally exhumed skeletons from the cemeteries in Palencia and Valladolid (Spain), which allowed us to know the sex and age of each individual. The age range of the individuals studied was between 23 and 101 years, with an average age of 69 years. The absence or presence of a facies articularis acromialis allowed us to divide the scapulas into a group of normal scapulas (NS) and a group of pathological scapulas (PS). The NS group comprised 87 of the original scapulas, 58 of them belonging to male individuals (66.7%) and 29 to female ones (33.3%), with an average age of 66.7 years. The PS group consisted of 25 scapulas, 10 of them belonging to males (40%) and 15 to females (60%), with an average age of 77.5 years.

The maximum height (MH = the distance between the superior and the inferior angle) and the maximum breadth (MB = the distance between the centre of the glenoid fossa and the medial border at the level of the spine of the scapula) of each scapula were measured. In order to obtain a representative value of the total size of the scapulas studied, these were compared to a triangle with an MH base and MB height and hence the S value (S = MH x MB/2) for each scapula was calculated.

Following this, a picture was taken of all the scapulas from a lateral angle, parallel to the surface of the glenoid fossa, with an Olimpus B30 digital camera. Suitable positioning of the glenoid fossa, parallel to the lens of the camera, was determined by two spirit levels located over the fossa's sagittal and vertical axes. The pictures were then transferred to an image-editing computer program (analySIS), which allowed us to automatically calculate the value of the different anatomical parameters related to the architecture of the subacromial space, limited by the acromion, the spine of the scapula, the glenoid fossa, and the coracoid process (Fig. 1). In order to enclose the subacromial space superiorly, an imaginary line was drawn between the beak of the acromion and the tubercle formed by the insertion of the conoid ligament in the coracoid process. We then calculated the value of the subacromial space surface (SASS) and its relative value in relation to the total size of each scapula (SASS/S); the acromion tilting angle (ATA), the angle formed by a line joining the anterior and posterior ends of the inferior surface of the acromion (line A), and a line extending along the centre of the lateral border of the spine of

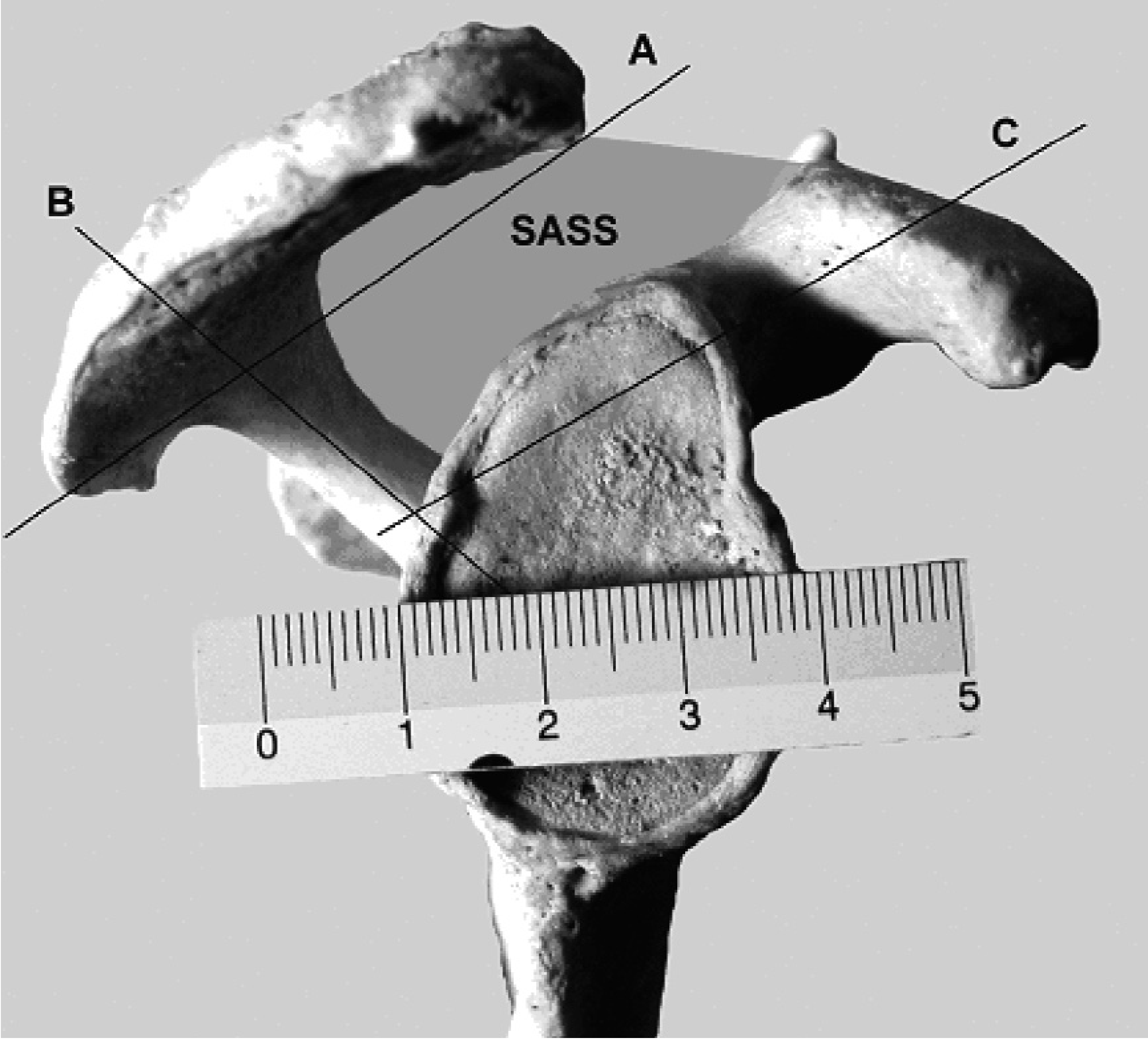

Figure 1. Lateral aspect of a human scapula. The shaded area represents the subacromial space surface (SASS), the angle between lines A and B represents the acromion tilting angle (ATA), and the angle between lines B and C represents the coracospinal angle (CSA).

the scapula (line B) (Fig. 1); the coracospinal angle (CSA), limited by a line extending along the center of the vertical segment of the coracoid process (line C) and line B (Fig. 1); the acromion radius of curvature (ARC), calculated with the ARC = $H^2+(4xC^2)/8C$, C being the length of the chord of the arch limited by the inferior surface of the acromion and H being the maximum height between this chord and the inferior surface of the acromion (Martin and Saller, 1957). These images were also used to classify the acromion of the scapulas studied according to their flat, curved or hooked morphology into types I, II or III proposed by Bigliani et al. (1986). Finally, with a manual goniometer, we calculated the glenoid fossa tilting angle (GFTA), limited by a line joining the superior and inferior part of the glenoid fossa and a line joining the inferior part of the glenoid fossa with the inferior angle of the scapula.

The values obtained were entered into a computer program (SPSS 11) for statistical evaluation. A Kolmogorov-Smirnov test was performed to determine whether they had a normal distribution. In order to compare the values of the variables in the two groups examined (NS and PS) and determine whether there were any statistically significant differences between them, we used the Mann-Whitney non-parametric test for the variables that did not have a normal distribution (age, S, SASS, ARC, CSA, ATA and GFTA). Yates' Chi-square test was used to statistically compare the values of the qualitative variable represented by the morphological type of acromion (AT) in the different groups examined. A chi-square test was also used in order to statistically compare the number of males and females in both groups. In all cases we considered the differences in which the statistical tests used gave a result of $p \geq 0.05$ as non-significant.

Results

The results obtained in this study (Table 1) confirm that the total size of the scapulas was significantly larger (p = 0.045) in the normal group than in the pathological group, the average S value being 7288.2 mm^2 in the NS group and 6814.5 mm^2 in the PS group.

Table 1. Average values, standard deviations and statistical significance of the parameters obtained in normal and pathological scapulas (see text for abbreviations).

VARIABLE	NORMAL SCAPULAE	PATHOLOGIC SCAPULAE	SIGNIFICANCE
AGE (years)	66,7 (14,9)	77,5 (11,7)	*
S (mm2)	7288,2 (1065,7)	6814,5 (843,5)	*
SASS (mm2)	407,3 (76,4)	366,8 (106,5)	*
SASS/S	0,06 (0,01)	0,05 (0,01)	NS
CSA (º)	111,9 (9)	110,4 (10,5)	NS
ATA (º)	72,4 (7,3)	71 (9,1)	NS
GFTA (º)	131,3 (5,3)	130,2 (4,7)	NS
ARC (mm)	18,3 (2,8)	17,3(2,9)	NS
AT	21,8% I / 77% II / 1,2% III	24% I / 76% II / 0% III	NS

* $P<0.05$; NS, non-significant.

Regarding the anatomical parameters studied in relation to the architecture of the subacromial space, the SASS parameter was also significantly larger (p = 0.038) in the normal group than in the pathological one, with an average value of 407.3 mm^2 in the NS group and 366.8 mm^2 in the PS group. However, the relative SASS/S value did not have statistically significant differences (p = 0.195) in the two groups studied, with an average value of 0.06 in the NS group and 0.05 in the PS group.

The value of the different angles that limit the anatomical structures of the subacromial space (acromion, spine of the scapula, glenoid fossa and coracoid process) did not show, in any case, statistically significant differences between the normal and the pathological groups. Thus, with regard to the CSA parameter, the average value in the NS group was 111.9º, whereas in the PS group it was 110.4º (p = 0.475); the ATA parameter had an average value of 72.4º in the NS group and 71º in the PS group (p = 0.417). Regarding the GFTA parameter, its average value in the NS group was 131.3º whereas in the PS group it was 130.2º (p = 0.383).

The two parameters studied in relation to the anatomy of the acromion, the radius of curvature and its flat, curved or hooked morphology did not reveal any significant difference between the group of normal scapulas and the group of pathological scapulas. The ARC parameter had an average value of 18.3 mm in the NS group and 17.3 mm in the PS group (p = 0.113). In the NS group the acromion type most commonly found was type II (77%), followed by type I (21.8%), and there was only one type III acromion (1.2%). In the PS group, the most common acromion type was also type II (76%), followed by type I (24%), but no type III acromion was identified. The differences observed between acromion types in the two groups were not statistically significant ($p>0.05$). We were unable to identify any type IV or convex acromion in either of the two groups studied.

Finally, there was a statistically significant difference (p = 0.001) in the age of the individuals in the NS and the PS groups. The average age in the NS group was 66.7 years whereas in the PS group it was 77.5 years. We also found statistically significant differences ($p<0.05$) in the sex of the individuals distributed in the two groups studied. In the NS group there was a significant predominance of male individuals (66.7%), whereas in the PS group female individuals predominated (60%).

Discussion

Our study has not allowed us to confirm the existence of statistically significant differences between the different parameters related to the architecture of the subacromial space in scapulas with and without a facies articularis acromialis. Thus, although the SASS parameter is significantly lower in the PS group than in the NS group, this correlates with the larger size of the scapulas in the normal group than in the pathological one. Indeed, when the SASS value is corrected by scapula size (SASS/S) the statistically significant differences between the two groups disappear. The differences observed in the scapula size of normal and pathological individuals can be explained by a higher incidence of rotator cuff tears in women than in men (Chard et al., 1991; Lehman et al., 1995), as observed in our study, in which women represented 60% of the individuals in the PS group and only 33.3% in the NS group.

With respect to the value of the angles limited by the different structures comprising the subacromial space (acromion, spine of the scapula, glenoid fossa and coracoid process), no statistically significant differences between the normal and the pathological groups were observed either. As mentioned above, one of these angles, the acromion tilting angle (ATA), has been proposed as a possible cause of subacromial impingement and rotator cuff tears since low values narrow the subacromial space (Aoki et al., 1986; Edelson and Taitz, 1992; Gohlke et al., 1993; MacGillivray et al., 1998; Prato et al., 1998; Prescher, 2000; Vaz et al., 2000), whereas other authors have failed to find any connection between the ATA value and the frequency of rotator cuff tears (Hyvonen et al., 2001). In our results there are no significant differences in the ATA parameter between the scapulas belonging to the NS group and those belonging to the PS group. This result is consistent with the fact that we did not find any differences between the SASS relative value in the two groups studied either. Moreover, we did not find any significant differences between the NS and the PS group with respect to the angle limited by the coracoid process and the spine of the scapula or any differences as regards the value of the glenoid cavity tilting angle.

Concerning the morphology of the acromion, we did not find any significant differences between the normal and the pathological group. In both groups, the curved or type II acromion predominated in a very similar proportion (77% in the NS group and 76% in the PS group). The flat or type I acromion was less frequent but it also accounted for a similar proportion in the two groups (21.8% in the NS group and 24% in the PS group). We only identified a hooked or type III acromion in the whole sample and it belonged to the NS group. This seems to support the opinion of those authors who defend the lack of connection between rotator cuff tears and a type III acromion (Banas et al., 1995; Jacobson et al., 1995; Liotard et al., 1998; Hyvonen et al., 2001; Seok-Beom et al., 2001; Mayerhofer and Breitenseher, 2004; Chang et al., 2006) but is contrary to the opinion of other authors who see a connection between these two parameters (Bigliani et al., 1986; Morrison and Bigliani, 1987; Gohlke et al., 1993; Farley et al., 1994; Toivonen et al., 1995; Wang et al., 2000; Tasu et al., 2001; Anetzberger et al., 2004; Lisy et al., 2004). Our results even allow us to support the opinion of some authors (Freese, 1998) who claim that a type III acromion appears in humans less frequently than what has been proposed by Bigliani et al. (1986). The qualitative aspect of Bigliani's classification is probably responsible for its low reliability when used by different authors (Haygood et al., 1994; Jacobson et al., 1995). In order to give quantitative values to the acromion degree of curvature we calculated the acromion radius of curvature in all the scapulas studied, but no significant differences between the normal and the pathological group were found either, and hence it may be concluded that there is no connection between the degree of curvature and the possibility of developing a rotator cuff tear.

Finally, we found a statistically significant difference between the age of the subjects in the NS group and the subjects of the PS group. The age of the subjects with normal scapulas had an average value of 66.7 years whereas the subjects with pathological scapulas had an average value of 77.5 years. This suggests that the presence of a facies articularis acromialis must be related to a primary degeneration of the rotator cuff, rather than to the architectural characteristics of the subacromial space. This observation is consistent with the findings of authors who defend a musculotendinous pathogenesis as the main cause of rotator cuff tears (Lindblom, 1939; Rathburn and Macnab, 1970; Jerosch et al., 1989; Nirschl, 1989; Lohr and Uhthoff, 1990; Ogata and Uhthoff, 1990; Warner et al., 1990; Brox et al., 1993; Bartolozzi et al., 1994; Leroux et al., 1994; Wickiewicz, 1994; Hawkins and Dunlop, 1995; Sharkey and Marder, 1995; Deutsch et al., 1996; Thompson et al., 1996; Paletta et al., 1997; Payne et al., 1997; Brox et al., 1999; Chen et al., 1999; Reddy et al., 2000; Hashimoto et al., 2003; Jih-Yang et al., 2006). In this case, the older the individual, the greater the chances of developing a rotator cuff tear and a facies articularis acromialis.

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