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Relationship between Rotator Cuff Tears and Acromial Coverage of the Humeral Head on the Axial Plane

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Abstract

Purpose: Many authors have described the relationship between the radiographic morphology of the acromion and rotator cuff disease, but few studies have evaluated the relationship on the axial plane. We hypothesized that high acromial coverage of the humeral head or excessive lateral or anterior extension of the acromion would be an independent predictor of rotator cuff disease. This study aimed to clarify the relationship between rotator cuff tears and acromial coverage of the humeral head on the axial plane.

Methods: Fifty shoulders were evaluated for acromial coverage of the humeral head on axial three-dimensional computed tomography images. The shoulders were divided into two groups: group F（*n*=25; mean age, 60.48 years; range, 49–73 years）with full-thickness rotator cuff tears, and group C（*n*=25; mean age, 58.96 years; range, 40–79 years）with intact cuffs as a control group. The acromial coverage of the humeral head was analyzed to determine the difference between the groups.

Results: There was no significant difference between the groups in the acromial coverage of the humeral head.

Conclusions: High acromial coverage of the humeral head on the axial plane did not appear to be associated with full-thickness tearing of the rotator cuff.

Key words: Rotator cuff tear, Acromial morphology, Acromial coverage, Radiography, Three-dimensional computed tomography

Introduction

Controversy remains about the role of the acromion in rotator cuff tears. The question of which came first, the rotator cuff tears or the acromial morphologic changes, also remains. Neer[1] described that 95% of all tears are caused by impingement, and consequently that tears start at the bursal side secondary to wear and tear. Since these findings, many authors have focused on the relationship between the radiographic appearance of the acromion and rotator cuff tears. Specifically, the acromiohumeral distance（AHI）, lateral acromial angle[2], acromial coverage index[3], and acromion index[4] were evaluated on true anteroposterior（AP）radiographs（oblique coronal plane）, and the acromial slope[5], acromial shape[6, 7], acromial spur formation[8], and acromial angle[6, 7, 9] were evaluated on scapular Y radiographs（oblique sagittal plane）. Because axial radiographic images require the arm to be in the abducted position and the structures to be viewed are superimposed and invisible, there are few reports on the acromial coverage of the humeral head on the axial plane. We suppose that new findings may be obtained about the relationship between the acromial morphology and rotator cuff tears by evaluating the axial plane.

We hypothesized that high acromial coverage of the humeral head or excessive lateral or anterior extension of the acromion would be an independent predictor of rotator cuff disease. The purpose of this study was to clarify the relationship between rotator cuff tears and acromial

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coverage of the humeral head on axial three-dimensional computed tomography (3DCT) images.

Materials and Methods

Fifty shoulders were evaluated for acromial coverage of the humeral head on axial 3DCT images. All included patients met the following criteria: shoulder injuries or disorders evaluated by 3DCT with a diagnosis of the absence or presence of rotator cuff tears confirmed by MRI at our institution.

We excluded patients with Grade 2–4B in the Hamada classification,[10] fracture around the shoulder girdle, osteonecrosis, sequelae of infection, os acromiale, shoulder instability, and subacromial spurs measuring ≥2 mm. Measurement of the length of a spur was defined as the maximum distance from the point where the inclination of the anterior edge of the acromion abruptly increased to the tip of the spur in oblique coronal or sagittal 3DCT images, based on the method of Ogawa et al.[8] The shoulders were divided into two groups: group F (*n*=25; mean age, 60.48 years; range, 49–73 years) diagnosed with full-thickness rotator cuff tears on MRI before surgery, and group C (*n*=25; mean age, 58.96 years; range, 40–79 years) with intact cuffs documented by MRI, such as frozen shoulder, clavicle fracture, and so on, as a control group. The total population for the study comprised 20 women and 30 men, with a mean age of 59.72 years. The two groups were matched by age, body mass index, and other acromial morphologic factors, including AHI, acromial slope, and acromial shape described by Bigliani et al.[6], such that these factors on the sagittal or coronal plane had no influence on the acromial coverage on the axial plane. AHI was evaluated on true AP radiographs of the shoulders. Acromial slope was evaluated on oblique sagittal 3DCT images, in accordance with the method of Aoki et al.[5] Acromial shape[6, 7] was classified into three groups on scapular Y radiographs of the shoulders.

The 3DCT scans (Aquilion TSX-101/HA; Toshiba Medical Systems Co., Tokyo, Japan) and true AP radiographs were obtained with the arm in neutral rotation. The data sets obtained by the 3DCT scans were transferred to a 3D workstation (Ziostation; Ziosoft, Tokyo, Japan). Using the Ziostation, the axial plane was defined as the plane in which the scapula was aligned so that the infraglenoid tubercle matched the supraglenoid tubercle. The oblique sagittal plane was aligned by rotation of 90 degrees downward from the axial plane. A transmission image photography method for the humeral head was used to measure the acromial coverage of the humeral head. To avoid overlap errors while measuring the acromial coverage of the humeral head on the axial plane, the distal area from the surgical neck of the humerus was trimmed off.

The acromial coverage of the humeral head on the axial plane was quantified by measuring the acromial coverage

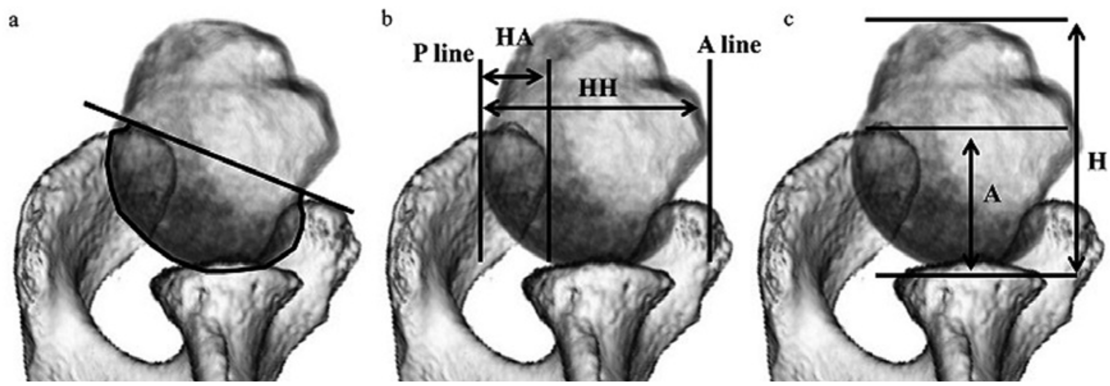

Fig. 1 (a) Diagrammatic representation of the ACAI on axial 3DCT images. First, a transmission image photographic method for the humeral head was performed. Second, the distal area from the surgical neck of the humerus was trimmed off. A coracoacromial (C-A) line was drawn connecting the lateral tip of the coracoid and the anterolateral tip of the acromion as the coracoacromial arch. The ACAI was calculated by dividing the area of the humeral head within the coracoacromial arch by the whole area of the humerus on the axial 3DCT images. (b) The AAEI was calculated by dividing the distance (HA) from the tangent line (P line) to the most posterior aspect of the humerus that was perpendicular to the glenoid plane to the most anterior aspect of the acromion by the distance (HH) from the from the tangent line (A line) to the most anterior aspect of the humerus that was perpendicular to the glenoid plane to the P line on the axial 3DCT images. (c) The AIAX was calculated by dividing the distance (A) from the most lateral aspect of the acromion to the glenoid plane by the distance (H) from the most lateral aspect of the humerus to the glenoid plane.

area index (ACAI). For the ACAI, a coracoacromial (C-A) line was drawn connecting the most lateral tip of the coracoid and the anterolateral corner of the acromion as the coracoacromial arch. The ACAI was calculated by dividing the area of the humeral head within the coracoacromial arch by the whole area of the humerus on axial 3DCT images (Fig. 1a). The acromial anterior extension index (AAEI) was defined as the value for "anterior" acromial coverage. The AAEI was calculated by dividing the distance (HA) from the tangent line (P line) to the most posterior aspect of the humerus that was perpendicular to the glenoid plane to the most anterior aspect of the acromion by the distance (HH) from the tangent line (A line) to the most anterior aspect of the humerus that was perpendicular to the glenoid plane to the P line on the axial 3DCT images (Fig. 1b). The acromial index on the axial plane (AIAX) was defined as the value for "lateral" acromial coverage. The AIAX was calculated by dividing the distance (A) from the most lateral aspect of the acromion to the glenoid plane by the distance (H) from the most lateral aspect of the humerus to the glenoid plane (Fig. 1c).

Statistical analyses were performed using IBM SPSS, version 21 (IBM, Armonk, NY). Hypothesis testing between the two groups was performed when the data were normally distributed according to a Kolmogorov–Smirnov/Shapiro–Wilk normality test (depending on the sample size). An unpaired *t*-test if the normality assumption was satisfied or a Mann–Whitney U test if the normality assumption was not fulfilled was carried out to compare the differences in age, AHI, ACAI, AAEI, and AIAX between the two groups. The χ^2 for independent testing (m × n contingency table) indicated the significance of the incidence of each acromial shape in the two groups. Values of $p<0.05$ were considered to indicate significant differences. The reproducibility of the ACAI, AAEI, and AIAX measurements was examined by intraclass correlation coefficients (ICCs) for both interobserver reliability (measurements made by two different observers) and intraobserver reliability (measurements repeated by the same observer at different time points) for repeated measurements and 95% confidence intervals. We considered ICCs of 0.7 or higher to be sufficient for the reliability.

This study was conducted at the Department of Orthopaedic Surgery, Fukuoka University Faculty of Medicine, Fukuoka, according to approved medical and ethical guidelines, and the study protocols were approved by the Fukuoka University Institutional Review Board (IRB Approval Number: 15-8-18).

Results

There were no significant differences in age, AHI, and acromial angle between the two groups ($p=0.580$, $p=0.461$, and $p=0.483$, respectively). There was no significance difference of the incidence of each acromial shape between the two groups ($p=0.836$) (Table 1).

The measurements for ACAI, AAEI, and AIAX showed high agreement for both intraobserver reproducibility and interobserver reproducibility (Table 2). The mean ACAI values were 0.538±0.07 in group F and 0.524±0.07 in group C. The mean AAEI values were 0.31±0.08 in group

Table 1. Patient demographic characteristics in the groups and acromial morphology

Group	F (n=25)	C (n=25)	P value
Age* **(years)**	60.48±8.48	58.96±10.66	0.58
Male/Female	18/7	12/13	0.41
BMI*	25.08±3.09	24.18±2.78	0.29
AHI**	10.8 (7.66 to 18.79)	10.3 (7.72 to 14.40)	0.46
Acromial angle*	26.70±3.51	27.54±4.76	0.48
Acromial shape			
Type I	3	3	
Type II	21	20	0.84
Type III	1	2	

BMI: body mass index; AHI: acromiohumeral distance.
*The normality assumption is satisfied. An unpaired *t*-test was carried out to compare the differences. The measure of the central tendency median is the mean ± SD.
**The normality assumption is not satisfied. The Mann–Whitney U test was carried out to compare the differences. The measure of the central tendency median is the median (range).
Values of $p<0.05$ were considered to indicate significant differences.

Table 2. Intraobserver and interobserver reproducibilities for each parameter

	Intraobserver reproducibility		Interobserver reproducibility	
	ICC	95% CI	ICC	95% CI
ACAI	0.98	0.96–0.99	0.96	0.93–0.98
AAEI	0.94	0.89–0.97	0.85	0.76–0.91
AIAX	0.97	0.95 to 0.98	0.90	0.76–0.95

CI, confidence interval; ICC, interclass correlation coefficient.

Table 3. Acromion coverage values on axial 3DCT images

Group	F (n=25)	C (n=25)	P value
ACAI	0.54±0.07	0.52±0.07	0.47
AAEI	0.31±0.08	0.28±0.09	0.35
AIAX	0.66±0.05	0.68±0.08	0.28

ACAI: acromial coverage area index; AAEI: acromial anterior extension index; AIAX: acromial index on the axial plane. The normality assumption is satisfied. An unpaired *t*-test was carried out to compare the differences. The measure of the central tendency median is the mean ± SD. The normality assumption is not satisfied. The Mann–Whitney U test was carried out to compare the differences. The measure of the central tendency median is the median (range).Values of $p<0.05$ were considered to indicate significant differences.

F and 0.28±0.09 in group C. The mean AIAX values were 0.66±0.05 in group F and 0.68±0.08 in group C. There were no significant differences in ACAI, AAEI, and AIAX between the two groups ($p=0.473$, $p=0.346$, and $p=0.278$, respectively) (Table 3).

Discussion

The acromial morphology as a risk factor for rotator cuff tears remains controversial. In 1972, Neer[1] reported that subacromial impingement syndrome on the rotator cuff was caused by alterations to the undersurface of the anterior one-third of the acromion. Aoki et al.[5] found that patients with impingement had a more acute acromial slope compared with normal volunteers. Prato et al.[11] supported these studies with findings that the mean acromial slope in 78 shoulders with a rotator cuff tear was significantly smaller than that in 165 shoulders with an intact cuff. Bigliani et al.[6] studied acromial structures in cadavers, and found a high correlation between spur formation with type II and III acromial structures and concomitant rotator cuff tears. Hirano et al.[12] reported that the type III acromion was the most common structure in patients with a rotator cuff tear. Torrens et al.[3] described that patients with a cuff tear had a significantly higher acromial coverage index than a control group. Nyffeler et al.[4] introduced the acromion index, and described that the acromion in patients with a full-thickness rotator cuff tear appeared to have a more lateral extension than that in patients with an intact cuff. Their results support the presence of a close relationship between rotator cuff tears and narrowing of the supraspinatus outlet or high acromial coverage.[3–7, 11, 12]

In these previous studies[3–7, 11, 12], the acromial morphology was evaluated on oblique coronal or sagittal planes. There are few reports on the acromial morphology on the axial plane[17]. It is difficult to evaluate the relationship between the acromial coverage of the humeral head and rotator cuff tears on the axial plane of plain radiographs, MR images, and 2DCT images. Therefore, we used a transmission image photography method for the humeral head to evaluate the relationship on axial 3DCT images.

Evaluations of the acromial coverage on the axial plane have two essential advantages. First, we can simultaneously evaluate a lateral extension of the acromion as well as an anterior extension. Second, the ACAI obtained on axial 3DCT images can represent the comprehensive acromial coverage of the humeral head, including the coverage by the coracoacromial ligament.

However, we need to take into account the effects of both age and secondary degenerative changes when evaluating the acromial morphology. Ogawa et al.[8] showed a relationship between age and acromial spurs, using a combination of control patients, surgically-treated patients, and cadaveric specimens. MacGillivray et al.[13] reported that age distribution from the second to eighth decades demonstrated a generally consistent and gradual translation from a flat acromion in the younger decades to a more hooked acromion in the older decades. Balke et al.[15] concluded that there was a good correlation between acromial shape and acromial slope on standard radiographs from 50 patients with full-thickness rotator cuff tears, 50 patients with subacromial impingement, and 50 controls without subacromial pathology. Hirano et al.[12] described that the occurrence rate of the type III shape in patients with rotator cuff tears was not significantly high when age-matched patients with and without rotator cuff tears were compared, and implied that the hook type might be an age-related degenerative change. Moses et al.[16] described that the acromial slope reported by Aoki et al.[5] would be an indirect measure of the presence of an acromial spur or hooked morphology in a 3D analysis of the acromion. Aoki et al.[5] and Prato et al.[11] did not describe acromial spur formation. However, we occasionally felt that an increasing length of spur was associated with a decreasing angle of the acromial slope. Therefore, we compared the acromial coverage with age-matched normal controls and standardized the secondary degenerative morphologic conditions of the acromion resulting from rotator cuff tears, e.g., acromial spur[8], acromial slope[13], and AHI, between the groups.

In addition, evaluations of the acromial coverage on the axial plane have the disadvantage of being influenced by individual morphologic narrowing in the subacromial space. This is because the narrowing results in attrition between the rotator cuff and the coracoacromial arch during abduction or flexion of the arm. Therefore, we found it necessary to standardize the morphologic features of the acromion, e.g., acromial slope[5] and acromial shape described by Bigliani et al.[6], between the two groups.

Thus, we consider that it is important to standardize groups, such that complexly intertwined factors have no influence on the target factor. An explanation for our contradictory results with regard to previous studies[1–7, 9, 12, 13, 16, 17] may be that age-related degenerative changes and secondary degenerative conditions after rotator cuff tears could be excluded in the present study.

Surprisingly, the type III acromial shape was only observed in one (4%) of 25 shoulders with full-thickness rotator cuff tears with exclusion criteria for acromial spurs. Because acromial spurs cannot be measured accurately on plain radiographs or MR images, these methods may lead investigators to make mistakes over groupings of acromial shapes under the influence of acromial spurs. Therefore, we evaluated the acromial shapes on plain radiographs after measurement of the acromial spurs on 3DCT images to avoid this mistake. Additional studies are required to clarify the reproducibility of diagnosis for the acromial shape between plain radiographs and 3DCT images.

The results of several studies[18–21] and our previous study[22] have brought into question the biomechanical theory proposed by Nyffeler et al.[4] of a relationship between a large acromion index and rotator cuff disease. From our findings, we conclude that there is no significant difference in the AIAX between the rotator cuff tear group and the intact cuff group matched by age-related factors, including age and acromial spurs, thus supporting the previous studies[18–21]. A lateral extension of the acromion may be a degenerative change after a rotator cuff tear, but a definitive conclusion has not yet been reached with regard to this matter.

Sakoma et al.[23] reported that a greater anterior acromial projection was observed in the tear group (n=7) compared with the normal group (n=35) in an unmatched study for age, acromial shape, and AHI, based on a macroscopic examination of 42 cadaveric shoulders on the oblique sagittal plane. However, we found that there was no significant difference in the anterior acromial projection between the tear group (n=25) and the normal group (n=25) in our matched study by age, acromial shape, and AHI. Age may lead to morphologic changes of the acromion or coracoid. In addition, the acromial shape may affect the measurement size of a circle fitted to the undersurface of the coracoacromial arch. The AHI value may have a great effect on the measurement, and they also recognized this limitation[23].

The strong points of the present study are that it is the first to evaluate the relationship between rotator cuff tears and acromial coverage of the humerus on axial 3DCT images, and the first to perform evaluations in groups matched by other acromial morphologic factors, which can have an influence on the values of the acromial coverage.

This study had some limitations. First, the sample size was small. To be able to standardize multiple factors between the groups and fulfil the exclusion criteria, we could not obtain a large sample size. Second, the study was retrospective. Third, partial-thickness rotator cuff tears were not included in the study.

Conclusions

High acromial coverage of the humeral head on the axial plane did not appear to be associated with full-thickness tearing of the rotator cuff.

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「The authors declare no conflict of interest.」