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Rotator cuff tear incidence association with critical shoulder angle and subacromial osteophytes

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Background: The concomitant presence of a heel-type osteophyte may affect the critical shoulder angle (CSA) correlation with rotator cuff tears (RCT).

Methods: We retrospectively reviewed patients with and without a full-thickness RCT who underwent magnetic resonance imaging (MRI) and radiographic imaging of the shoulder. The patients were divided into 3 groups according to the CSA as high CSA group, >38°; middle CSA group, 33°-38°; and low CSA group, <33°. We confirmed the presence of heel-type osteophytes, quadrangular osteophytes protruding inferiorly from the undersurface of the anterolateral acromion like the heel of a shoe, and excluded other types of osteophytes.

Results: Among the patients, 84.6% in the high CSA group, 60.3% in the middle CSA group, and 68.3% in the low CSA group had a RCT ($P = .041$). In patients without an osteophyte, 76.9% in the high CSA group, 38.5% in the middle CSA group, and 52.6% in the low CSA group had a RCT ($P = .024$). In patients with an osteophyte, 92.3% in the high CSA group, 80.3% in the middle CSA group, and 92.2% in the low CSA group had a RCT ($P = .106$).

Conclusions: RCT was affected more by osteophytes than CSA when CSA and osteophytes were evaluated together as a related factor for RCT. This perhaps suggests no correlation of CSA alone with RCT. Therefore, the presence of an osteophyte must be considered when evaluating the relation of CSA to RCT.

Level of evidence: Level III; Cross Sectional Design; Epidemiology Study

Keywords: Critical shoulder angle; rotator cuff tear; osteophyte; shoulder radiograph; impingement; incidence

Critical shoulder angle (CSA) is the angle created between superior and inferior bone margin of the glenoid and the most inferolateral border of the acromion and measured on an anterior-posterior (AP) shoulder radiograph. This angle accounts for glenoid inclination and lateral extension of the acromion.

The Inje University Busan Paik Hospital Institutional Review Board approved this study (No.17-0241).

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Moor et al[8] introduced the concept of CSA and suggested that individuals with a small CSA have been predisposed to osteoarthritis (OA) and that individuals with a larger CSA are predisposed to rotator cuff pathology. They speculated that a long acromion would give the deltoid muscle an antagonistic pulling direction compared with the supraspinatus muscle, and reported that a CSA greater than 35° was associated with an increased prevalence of rotator cuff tear (RCT).

Gerber et al,[4] in their biomechanic study, suggested that larger CSAs increase the ratio of shoulder joint shear-to-compression force, thus demanding an increased compensatory supraspinatus load. However, the matched control study by Bjarnison et al[1] showed no statistically significant difference of CSA between RCT and a normal control group, and suggested contrasting results compared with earlier studies showing a relation between CSA and RCT.

Although controversy regarding the correlation between RCT and CSA remains, a series of studies[3,5,7] suggested that the CSA was an extrinsic risk factor for RCT. However, in a clinical study investigating the relation between CSA and RCT, the researchers did not consider and delineate osteophytes and did not describe the incidence of osteophytes. Subacromial osteophytes have demonstrated an association with RCTs.[11,12,14,15] On the contact area between the acromial undersurface and the supraspinatus, an osteophyte, especially protruding inferiorly from the acromial undersurface, may directly abut the humeral head to the acromion and lead to cuff attenuation and tear as well as decreasing acromial space.[11]

Considering the Gerber et al[4] study, increasing the CSA caused the deltoid to be directed superiorly in the coronal plane. In such situations, an osteophyte might affect the rotator cuff condition. Therefore, a CSA study without considering osteophytes might lead to some bias about the effect of CSA on RCTs. No study to date, however, has evaluated the incidence of RCT according to CSA and osteophytes or the relation between CSA and RCT that considers osteophytes. Thus, the purpose of this study was to compare the incidence of RCT according to the CSA, with and without osteophytes, and evaluate the relation of CSA and osteophytes with RCT.

Materials and methods

We conducted a retrospective review of consecutive patients, aged 40 to 70 years, who underwent magnetic resonance imaging (MRI) and radiographic imaging of the shoulder from January 2012 to June 2016. Included were patients with full-thickness RCT and without RCT as a control cohort on MRI. Patients with (1) partial-thickness RCT, (2) tendinosis, (3) osteoarthritis, (4) cuff tear arthropathy, (5) previous scapular fracture, and (6) previous surgery around the shoulder (including RCT repair) were excluded.

The presence of an osteophyte was confirmed by a true anteroposterior (AP) view of the shoulder, scapular Y view on radiographs, and T2 coronal and sagittal views of the shoulder on MRI. We considered an osteophyte to be present only if the heel-type osteophyte was more than 2 mm from the level of the distal clavicle.[6] Heel-type osteophytes were defined as a quadrangular osteophyte protruding inferiorly from the undersurface of the acromion like the heel of a shoe[11] (Fig. 1). Other types of osteophytes and coracoacromial ligament hypertrophy that looked like an osteophyte on MRI were excluded.

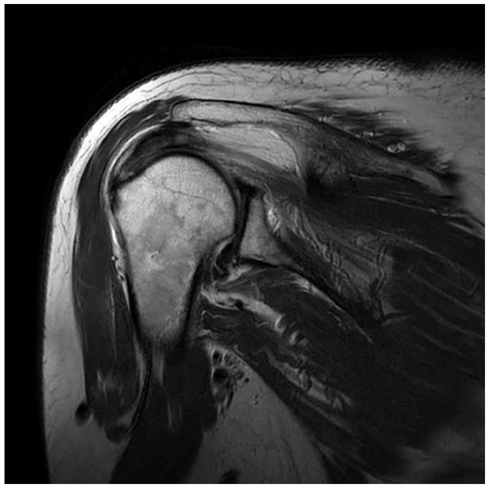

Figure 1 Heel-type osteophyte. The inferior bony projection of the acromion anterolateral undersurface on a T2 coronal view magnetic resonance image looks like the heel of a shoe.

CSA calculation

For calculating accurate CSA, patients whose radiograph showed Suter-Henninger classification[13] types A1 (perfect overlap between anterior and posterior glenoid pole) and C1 (imperfect overlap between the anterior and posterior glenoid rim in the inferior 50% of the glenoid but with overlap between the coracoid and the superior glenoid pole) were included; otherwise, the patient was excluded. CSA was measured using the Picture Archiving Communication System software (Marosis m-view; Marotech Co., Seoul, Republic of Korea) on a high-resolution liquid crystal display monitor. The minimal detectable angular change was 0.1°. Measurement was performed on the shoulder in true AP view with a digitally embedded tool. We measured the angle between a line from the inferior-most subchondral glenoid to the most inferolateral acromial edge and a line from the superior and inferior bone margins of the glenoid on an enlarged radiographic image (Fig. 2). Two independent observers measured the angle 2 times at a 1-week interval to guarantee interobserver and intraobserver reliability.

Of the 751 original patients with RCT, 214 patients were selected for the study. Among the excluded 537 patients, 2 were type A2, 1 was type A3, 38 were type B1, and 496 were type D. Of the original 258 patients without RCT, 109 were selected for the study. Among the excluded 149 patients, 2 were type A2, 2 were type A3, 11 were type B1, and 134 were type D. Finally, 323 patients, with a mean age of 56.8 ± 7.4 years, were enrolled (Table I, Fig. 3).

Statistical assessment

Statistical evaluation was performed by a specialized statistician in our institution, and IBM SPSS 22.0 software (IBM, Armonk, NY,

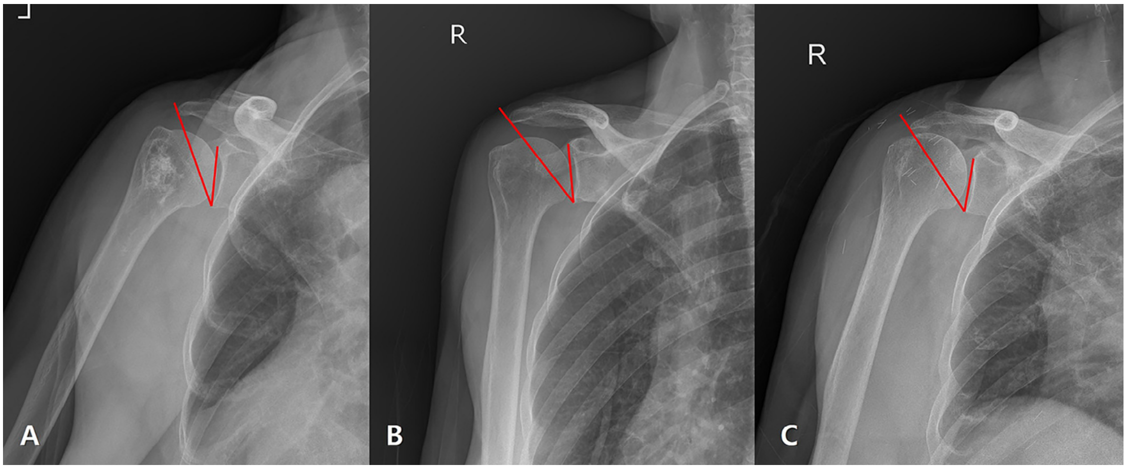

Figure 2 Example of critical shoulder angle (CSA) measurement on a true anteroposterior radiograph. (**A**) Low CSA group. The CSA for this radiograph is 25.8°, and the Suter-Henninger classification is A1. (**B**) Middle CSA group. The CSA for this radiograph is 23.8°, and the Suter-Henninger classification is A1. (**C**) High CSA group. The CSA for this radiograph is 43.7°, and the Suter-Henninger classification is C1.

Table I Demographic data of the patients

Variable	Rotator cuff tear group (n = 214)	Control cohort group (n = 109)	*P* value
Sex, No.			.487
Male	106	50	
Female	108	59	
Age, mean ± SD, yrs	57.4 ± 7.4	55.6 ± 9.3	.035
Suter-Henninger classification, No.			.998
A1	55	28	
C1	159	81	
Heel-type osteophytes, No. (%)	128 (59.8)	20 (18.3)	<.001

SD, standard deviation.

USA) was used. Intraclass correlation coefficients were used to evaluate the intraobserver and interobserver reliability of the CSA measurements and osteophyte classification. For evaluating the relation of CSA and osteophytes with RCT, the CSA value was categorized as an interval, as suggested in a biomechanical study,[4] and patients were divided into 3 groups according to CSA value: high CSA group, >38°; middle CSA group, 33° to 38°; and low CSA group, <33°. The χ^2 test was used to evaluate the difference of incidence of RCT according to the presence or absence of osteophytes in each CSA value interval. A multivariate regression test was used to evaluate the relation of CSA, osteophytes, age, and sex with RCT. All tests were analyzed with a 95% confidence level. The level of significance was set at .05.

Results

The patient characteristics of our study are described in Table I. The interobserver reliability of the CSA measurement was 0.987, and the intraobserver reliability was 0.992. The CSA measurement showed excellent reliability. The interobserver reliability of osteophyte classification was 0.856 and the intraobserver reliability was 0.892. Osteophyte classification also showed high reliability.

Comparison of incidence of RCT according to CSA with and without an osteophyte

Of the total subjects, 84.6% (22 of 26) of patients in the high CSA group, 60.3% (82 of 136) in the middle CSA group, and 68.3% (110 of 161) in the low CSA group had RCT. There was a statistically significant difference among the groups ($P = .041$). In patients without an osteophyte, 76.9% (10 of 13) in the high CSA group, 38.5% (25 of 65) in the middle CSA group, and 52.6% (51 of 97) in the low CSA group showed RCT. There was a statistically significant difference among the groups ($P = .024$). In patients with an osteophyte, 92.3% (12 of 13) in the high CSA group, 80.3% (57 of 71) in the middle CSA group, and 92.2% (59 of 64) in the low CSA group showed an osteophyte. There was no statistically significant difference among the groups ($P = .106$, Table II).

Comparison of incidence of RCT according to CSA group

In the low CSA group, RCT was found in 92.2% of patients with an osteophyte and in 52.6% of patients without an osteophyte. The difference between the groups was statistically significant ($P < .001$). In the middle CSA group, RCT were found in 80.3% of patients with an osteophyte and in 38.5% of patients without an osteophyte, which was also a significant difference ($P < .001$). In the high CSA group, RCT was found in 92.2% of patients with an osteophyte and in 76.9% of patients without an osteophyte. The difference was not statistically significant ($P = .593$, Table III).

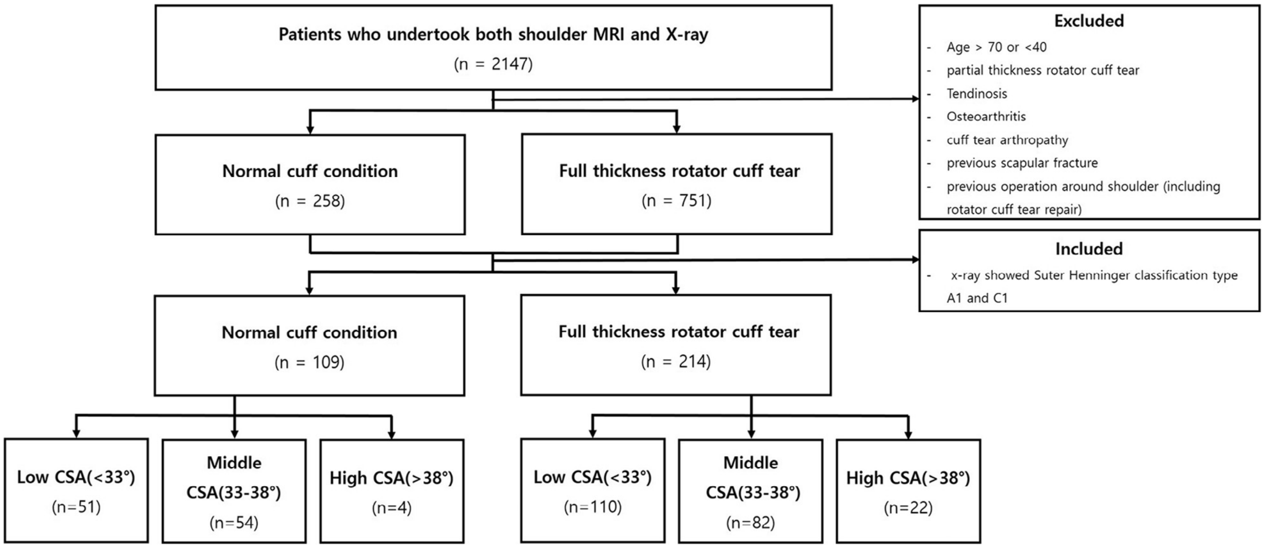

Figure 3 A flow chart of the study. *MRI*, magnetic resonance image; *CSA*, critical shoulder angle.

Table II Results of incidence of rotator cuff tear according to critical shoulder angle and the presence of an osteophyte

Variable	Rotator cuff tear incidence, No. (%)			*P* value	Post hoc analysis*
	High CSA	Middle CSA	Low CSA		
Total	22/26 (84.6)	82/136 (60.3)	110/161 (68.3)	.041	High CSA-middle CSA: 0.049
Osteophyte (+)	12/13 (92.3)	57/71 (80.3)	59/64 (92.2)	.106	
Osteophyte (–)	10/13 (76.9)	25/65 (38.5)	51/97 (52.6)	.024	High CSA-middle CSA: 0.033

CSA, critical shoulder angle.
* Post hoc analysis was performed using the Bonferroni method.

Table III Results of incidence of rotator cuff tear according to presence of an osteophyte in the critical shoulder angle group

Group	Rotator cuff tear incidence, No. (%)		*P* value
	Osteophyte (+)	Osteophyte (–)	
High CSA	12/13 (92.3)	10/13 (76.9)	.593
Middle CSA	57/71 (80.3)	25/65 (38.5)	<.001
Low CSA	59/64 (92.2)	51/97 (52.6)	<.001

CSA, critical shoulder angle.

Relation of CSA and an osteophyte with RCT

Univariate regression analysis showed the CSA group (odds ratio, 2.551; $P = .049$) and presence of an osteophyte (odds ratio, 6.623; $P < .001$) were correlated with the RCT. However, age ($P = .062$) and sex ($P = .292$) were not related with RCT. Multivariate logistic regression analysis was performed using age, CSA group, and presence of an osteophyte, which were variables with $P < .2$ in univariate regression analysis. Among these variables, the CSA group showed no significant relation with RCT ($P = .671$). However, presence of an osteophyte showed a significant relation with RCT ($P < .001$). The odds ratio of an osteophyte was 6.571.

Discussion

The CSA has been reported as an independent risk factor for RCT. Moor et al[8] introduced a concept of CSA that reflects acromial coverage as well as glenoid inclination and reported that RCT is associated with significantly larger CSAs compared with an asymptomatic normal shoulder. In their study, they compared RCT patients and a normal control group and suggested that the mean CSA value of the normal control group and RCT group were 33.1° and 38°, respectively; further, the cutoff value for discriminating between the normal and RCT groups for the CSA was 35.3°.

Gerber et al,[4] in their biomechanical study, measured and compared joint reaction force on RCT-associated high CSA (38°) and normal CSA (33°) and suggested that the difference in CSA leads to a substantial difference in joint reaction forces, with decreased compressive and increased shear forces with increasing CSA. They therefore reported that a high CSA biomechanically predisposes to decreased superoinferior joint stability and provided a mechanical explanation for the known association between RCT and characteristic scapular anatomy.

In the current study, we divided CSA into 3 intervals and evaluated RCT incidence according to the interval. Our results showed that the incidence of RCT was higher in high CSA group (>38°) than the middle CSA group (33°-38°, $P = .049$). Univariate logistic analysis showed the CSA interval had a significant relation with RCT (odds ratio, 2.551; $P = .049$). These findings are in line with previous studies that supported a high CSA as a predictive factor for RCT.

Bjarnison et al,[1] however, suggested contrary results with previous studies that CSA is associated with RCT. In their case-control study, mean CSA was 33.9° in the RCT group and 33.6° in the normal control group; thus, there was no statistical difference with mean CSA with the normal control group. They suggested that no causal relationship was found between RCT and CSA and called into question the association of CSA with RCT.

Chalmers et al[2] also questioned the relationship of CSA with RCT. Especially in their study, only 21% (326 of 1552 patients) were of sufficient quality to measure the CSA; further, CSA was not related with tear size or tear progression. They concluded that there was no specific association between the CSA and rotator cuff disease.

Likewise, there is controversy about the relation of CSA with RCT, but previous CSA studies did not consider the presence of an osteophyte in the evaluation of the relation of CSA with RCT. CSA might be an extrinsic factor correlated with RCT, and other extrinsic factors could affect the rotator cuff mechanically. Although there is controversy about whether an acromial spur can be the cause or the result of RCT, osteophytes are reported to be an associated extrinsic factor for RCT.[10,11,13,14]

Neer et al[9] suggested that an acromial spur decreases the subacromial space and consequently leads to an increase in the possibility of RCT. Ogawa et al[10] also reported that large spurs have diagnostic value because of the high rate of association with bursal side and complete RCT. Oh et al[11] speculated that an acromial spur apparently formed by traction of the coracoacromial ligament was related to RCTs. The acromial spurs were detected more commonly in patients with a full-thickness tear (83 of 106 patients [78%]) vs. control subjects (59 of 102 patients [58%]). Especially, heel-type spurs were detected in 95 of the 208 subjects (46%) and were observed more frequently in the full-thickness tear group than in the control group. This finding was similar in our study. Heel-type osteophytes were found in 59.8% in the full-thickness RCT group but in 18.3% in the normal cuff condition group. There was a statistical difference ($P < .001$).

Considering previous studies about the CSA that found that high CSAs led to increased shear force and decreased compression force and that acromial spurs (osteophytes) reduced subacromial space and consequently increased the risk of RCT, we raised the following questions:

1. Does the presence or absence of an osteophyte affect RCT incidence according to CSA?
2. Does the presence of osteophyte affect cuff condition even in the same as CSA compared with the absence of osteophyte?

CSA studies, however, have not described the patient enrollment or inclusion and exclusion with regard to the presence or absence of osteophytes. In our results, the incidence of RCT according to the CSA interval showed a difference in patients with and without an osteophyte. The incidence of RCT in all patients and in patients without an osteophyte showed a statistical difference according to the CSA interval ($P = .041$ and $P = .024$, respectively). However, in patients with an osteophyte, the incidence of RCT showed no statistical difference ($P = .106$). In addition, in the low and middle CSA groups, the incidence of RCT showed a difference according to the presence and absence of an osteophyte (both $P < 0.001$), but in the high CSA group, the incidence of RCT showed no difference ($P = .593$).

From these results, we were concerned that the presence of an osteophyte would be closely associated with RCT and thus lead to a bias effect in evaluating the relation of CSA with RCT. We therefore performed a multivariate analysis to clarify the role of the CSA group with the presence of an osteophyte, age, and sex in RCT. We found that in the CSA group, age and sex were not related with RCT ($P = .178$ and $P = .591$, respectively). However, the presence of an osteophyte was significantly related with RCT ($P < .001$).

Because, no study, as far as we know, has investigated the association of CSA with RCT considering the presence of an osteophyte, we cannot delineate the cause of our results in this study. However, we speculated that osteophytes, which are often concomitant with RCT, are more closely related with the incidence of RCT compared with the relation of CSA. Therefore, there is a difference of incidence of RCT according to the CSA interval when compared between individuals with and without an osteophyte as well as a difference of RCT incidence in each CSA interval according to the presence or absence of an osteophyte. In addition, the CSA group is correlated with RCT in univariate analysis but is not in multivariate analysis. The present findings inform the clinically important suggestion that although CSA might be correlated with RCT, a CSA study without considering presence of an osteophyte should be interpreted with caution.

This study has several limitations. First, a proper shoulder radiograph for CSA measurement can be affected by many factors, such as beam projection, entry and plate position, patient position, and scapular position. Although the same standardized protocol was used at our single institution, these factors cannot be completely controlled. To minimize this problem and increase the reliability of measurement, we used strict criteria for proper selection by excluding malrotated radiographs and selecting the highest quality radiography. We used the Suter-Henninger grading scale,[13] which classifies whether the true AP shoulder radiographic view obtained is perfectly orthogonal to the glenoid mediolaterally and superoinferiorly. Like Chalmers et al[2] suggested, we selected only A1 and C1 type shoulder AP radiographs. In the evaluation of interobserver and intraobserver reliability, we applied strict criteria, and our findings showed excellent reliability.

Second, there is likely some selection bias because patients who had properly obtained radiographs were selected for CSA measurement (323 of 1009 patients [32%]); thus, we may have excluded patients that had an association between RCT and CSA and the presence of osteophytes. However, our study has a retrospective design and was intended to evaluate the relation of CSA with RCT; therefore, strict criteria were necessary for correct evaluation.

Third, the etiology for RCT is multifactorial, composed of intrinsic and extrinsic factors. In this study, we only considered and controlled the variables of osteophyte presence and CSA. Other intrinsic and extrinsic factors were not controlled.

Fourth, we considered a meaningful osteophyte as the heel-type osteophyte and evaluated its relation with RCT. Although the heel-type osteophyte is acknowledged as a closely related factor with RCT, other osteophyte types may also be associated with RCT. We also performed qualitative analysis of the presence of osteophytes, not the quantitative analysis based on the size of the osteophyte.

Fifth, the number in the high CSA group is smaller than that of low or middle CSA groups. There may also be a possibility that the small number in the high CSA group affected statistics. Therefore, the statistical results may change if the number in the high CSA group increases, so it may be necessary to collect further data and perform additional analysis.

Conclusion

RCT was affected more by osteophytes than CSA when CSA and osteophytes were evaluated together as related factors for RCT. This may suggest no correlation of CSA alone with RCT. Therefore, the presence of an osteophyte must be considered when evaluating the relation of CSA to RCT.

Disclaimer

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