ACTA ORTHOPAEDICA et TRAUMATOLOGICA TURCICA

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Research Article

Relationship between scapular body morphology and rotator cuff tears: a three-dimensional computed tomography study

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ARTICLE INFO

Article history:
Submitted November 19, 2022
Received in revised form December 17, 2023
Last revision received form March 8, 2024
Accepted April 5, 2024
Publication Date June 13, 2024

Keywords:
Rotator cuff tear
Morphology of the scapula
Inferior angle of the scapula
Scapular body

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ABSTRACT

Objective: The purpose of this study was to identify the relationship between scapula morphology and rotator cuff tears (RCT).

Methods: Hundred seventeen shoulders with and 87 shoulders without RCTs were included in this retrospective study. The critical shoulder angle (CSA) and lateral acromion angle in the coronal view, and the acromial coverage angle (ACA) and coracoid and scapular spine angle (CSSA) in the sagittal view were evaluated using 3-dimensional computed tomography. The glenoid anterior tilt, anterior acromial projection angle (AAPA), coracoid process angle, scapular spine angle (SSA), and inferior angle angle (IAA) with respect to the scapular plane were measured in the sagittal view.

Results: In univariate logistic regression analysis, CSA, ACA, AAPA, SSA, and IAA were significantly greater in shoulders with RCTs, whereas CSSA was greater in shoulders without RCTs. In multivariate logistic regression analysis, CSA and IAA were greater in shoulders with RCT and were significantly associated with this condition ($P = .00073$, $P = .0032$).

Conclusion: This study has shown us that RCTs were associated with a greater curvature of the scapular body and greater CSA and IAA.

Level of Evidence: Level III, Diagnostic study.

Introduction

Rotator cuff tear (RCT) is one of the most common shoulder disorders. However, the etiology of RCT remains unclear. The shapes of the acromion and the glenoid are related to RCT.[1-8] Several previous studies have evaluated RCT via radiography. However, the values measured on radiographs vary according to the direction of the projection, and the osteophyte boundaries are unclear on radiographs.[9] In addition, it was reported that scapular anterior tilt has been associated with shoulder disorders.[10-17] Scapular anterior tilt may be caused not only by scapular dyskinesis but also by the morphology of the scapular spine and body. However, the relationship between the morphology of the scapular spine and body and RCT remains unreported. Therefore, this study aimed to investigate the differences in the morphology of the scapula according to the presence or absence of RCT by using 3-dimensional computed tomography (3DCT), to define the scapular plane and exclude the osteophytes. The hypothesis was that in addition to acromion morphology, the morphology of the scapular spine and scapular body is also associated with RCT.

Materials and methods

This study was approved by the Ethical Committee of Research from Chugoku Rosai Hospital (Approval Number: 2020-25; Date: December 25, 2020). At the direction of the Ethical Committee of Research, we conducted a retrospective study on prospectively collected data from 2016 to 2019. This study included patients >40 years of age who underwent the following kinds of surgery: patients with documented full-thickness supraspinatus tendon tears, regardless of the presence/absence of infraspinatus and subscapularis tendon tears; patiebts who underwent arthroscopic rotator cuff repair; and patients who underwent surgery for a proximal humerus fracture without documented RCT intraoperatively. The patients were divided into the RCT group and the non-RCT group. Rotator cuff tear group consisted of patients who underwent arthroscopic rotator cuff repair, and the non-RCT group consisted of patients who underwent surgery for a proximal humerus fracture. Finally, 103 patients (69.1 ± 8.7 years; 52 women and 51 men) were included in the RCT group, and 87 patients (mean age, 68.9 ± 11.9 years; 52 women and 35 men) were included in the non-RCT group. Three-dimensional CT was performed preoperatively in all cases. The scapular plane was defined by 3 points located at the center of the glenoid, the inferior scapular angle, and the intersection of the scapular spine with the medial border of the scapula, with reference to a previous study.[9] The morphology of the scapula was evaluated using 3DCT. The acromion was evaluated, excluding the subacromial spur.

The critical shoulder angle (CSA) was defined as the angle between the line extending from the inferior

Cite this article as: *Nakamura Y, Yokoya S, Matsubara Y, Harada Y, Adachi N. Relationship between scapular body morphology and rotator cuff tears: a three-dimensional computed tomography study. Acta Orthop Traumatol Turc., 2024;58(3):167-170.*

DOI: 10.5152/j.aott.2024.22181

glenoid to the inferolateral aspect of the acromion and the line of the glenoid fossa.[1,2] The lateral acromion angle (LAA) was defined as the angle between the line of the acromion undersurface and the line of the glenoid fossa.[3] The CSA and LAA were evaluated in the frontal view, vertical to the scapular plane and parallel to the glenoid plane, and excluding the coracoid process. The other morphology of the scapula was evaluated in the lateral view with the line connecting the intersection of the scapular spine with the medial border of the scapula and the center of the glenoid. The acromial coverage angle (ACA) was the angle formed between a line drawn from the center of the glenoid to the anterior edge of the acromion, and a line drawn from the center of the glenoid to the posterior edge of the acromion (Figure 1A). The acromion's anterior edge was the anterosuperior aspect of the acromion to exclude the subacromial spur that is generally formed at the acromion's anteroinferior aspect. The coracoid scapular spine angle (CSSA) was the angle between a line passing through the axis of the base of the coracoid process and a line passing through the axis of the scapular spine (Figure 1B). The glenoid anterior tilt was the angle between the longitudinal axis of the glenoid and the scapular plane (Figure 1C). The anterior acromial projection angle (AAPA) was the angle between a line drawn from the central of the glenoid to the anterior edge of the acromion and the scapular plane (Figure 1D). The coracoid angle was the angle between a line passing through the axis of the base of the coracoid process and the scapular plane (Figure 1E). The scapular spine angle (SSA) was the angle between a line passing through the axis of the scapular spine and the scapular plane (Figure 1F). The inferior angle angle (IAA) was the angle between a line passing through the axis of the inferior angle and the scapular plane (Figure 1G). The shapes of the scapular body were classified into 3 types: flat type, curved type, and hooked type (Figure 2).

Statistical analysis

A logistic regression analysis was performed to investigate morphological parameters of the scapula associated with RCTs. The odds ratio (OR) and 95% confidence interval (CI) were calculated. The morphological parameters of the scapula associated with RCT were investigated using univariate logistic regression analysis. Variables with a *P*-value of <.05 in univariate models were considered as potential variables. In the subsequent phase, a multivariate logistic regression was performed. The chi-square test was used to evaluate the differences in the shapes of the scapular body between the 2 groups. Furthermore, a *P*-value of <.05 was considered statistically significant.

All statistical analyses were performed with EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan).

Results

The scapular angles calculated here are presented in Table 1. The CSA, ACA, CSSA, AAPA, SSA, and IAA in the univariate logistic regression analysis were selected for the multivariate logistic regression analysis (Table 1). Critical shoulder angle (OR, 1.16; 95% CI, 1.06-1.26; *P* = .00073) and IAA (OR, 1.13; 95% CI, 1.04-1.23; *P* = .0032) were considered as factors associated with RCT (Table 2). The rate of the shapes of the scapular body was the highest in the RCT group in the order of curved type, hooked type, and flat type, and in the non-RCT group in the order of flat type, curved type, and hooked type (Table 3). A significant difference was observed between the 2 groups (*P* = .046).

HIGHLIGHTS

- The differences in the morphology of the scapula on the basis of the presence or absence of rotator cuff tear (RCT) was investigated in the present study.
- This is the first study to focus on the relationship between RCT and the scapular body.
- The results of our study revealed that the RCT cases were characterized by a greater curvature of the scapular body.

Discussion

This study was the first to focus on the relationship between RCT and the scapular body. The relationship between RCT and acromion and glenoid morphology has already been extensively reported. Bigliani et al[4] classified the acromion shape using lateral radiographs and reported that RCT is more prevalent in patients with a hooked acromion than in those with a curved or flat acromion. Aoki et al[18]measured the acromial slope on skeletal preparations in the sagittal plane and found that a low acromial slope is a predisposing factor for subacromial impingement. Moreover, Banas et al[3] described LAA on oblique coronal magnetic resonance imaging and discovered that lower LAAs are associated with RCT. Nyffeler et al[5] proposed the acromion index (AI), which is the ratio between the distance from the glenoid to the lateral edge of the acromion and the distance from the glenoid rim to the lateral edge of the humeral head, to quantify the lateral extension of the acromion on true anteroposterior radiographs; they found that a large AI is associated with full-thickness RCT. Torrens et al[6] also proposed the acromial coverage index, which is a different measurement method, and reported that the lateral extension of the acromion is higher in patients with RCT than in those with an intact rotator cuff. Glenoid inclination has been measured on anteroposterior radiographs or CT using various methods. Some studies showed that glenoid inclination correlates with RCT,[7] whereas other studies came to the opposite conclusion.[19] Moor and Gerber et al[1] described CSA as a measure of the glenoid inclination and of the lateral extension of the acromion on anteroposterior radiographs; they found that a smaller CSA is associated with osteoarthritis, whereas a larger CSA is associated with RCTs.[2] The anteroposterior acromial coverage is reportedly not related to RCT.[8,20] In a cadaveric study, individuals with RCT had a greater anterior acromial projection.[8] Altun et al[21] described a higher incidence of posterior–superior RCTs in patients with a lower angle between the scapular spine and acromion in the sagittal plane and anterior–superior RCTs in patients with this higher angle. In the present study, the results of univariate analysis revealed that the RCT group had a larger CSA, ACA, AAPA, SSA, and IAA and a smaller CSSA than the non-RCT group. However, ACA, CSSA, AAPA, and SSA were not significantly different in the presence or absence of RCT in the multivariate analysis, but the CSA and IAA were related to RCT. The present study is the first to report not only high CSA but also the inclination of the inferior angle of the scapula and the bending of the scapular body in RCT cases.

The bending of the scapular body in RCT may be explained by the idea that the morphology of the scapular body affects scapular motion. The inferior part of the trapezius generates a scapular posterior tilt and upward rotation. Decreased trapezius activity reportedly causes insufficient elevation of the acromion and scapular anterior tilt, resulting in subacromial impingement.[10-12] The serratus anterior is the primary muscle that stabilizes the medial border and inferior

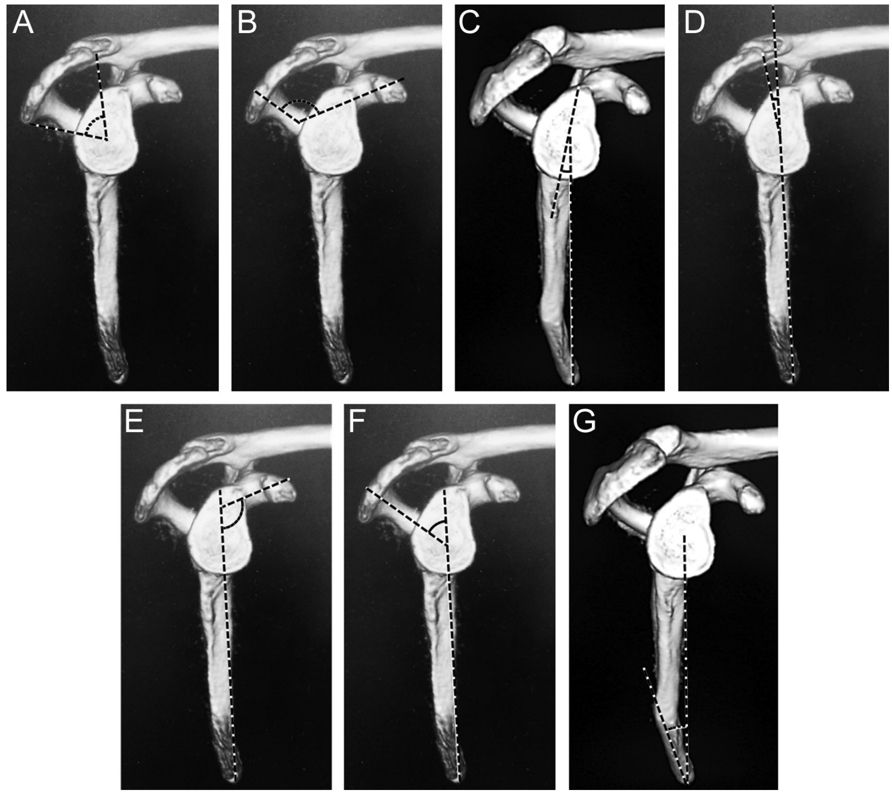

Figure 1. A: Acromial coverage angle, B: coracoid scapular spine angle, C: glenoid anterior tilt, D: anterior acromial projection angle, E: coracoid angle, F: scapular spine angle, G: inferior angle angle.

angle of the scapula to prevent scapular winging and anterior tilt.[13] Ludewig et al[14] reported that the scapula shows an anterior tilt when the serratus anterior is dysfunctional, as evaluated using surface electromyography, thus causing subacromial impingement.[15] Cases of impingement syndrome reportedly have lesser upward rotation and external rotation of the scapula.[22] Hébert et al[16] quantified the contribution of each scapular rotation to the scapular total range of motion in impingement syndrome; the results suggest that patients with impingement syndrome have a lesser posterior tilting of the scapula in the symptomatic shoulder than in the asymptomatic contralateral shoulder. According to Smith et al,[23] the movement of the scapula into a protracted or retracted position results in reduced isometric shoulder elevation strength. Kijima et al[17] compared the 3-dimensional scapular kinematics during scapular-plane abduction of symptomatic RCTs, asymptomatic RCTs, and healthy shoulders

Table 1. Univariate logistic regression analysis

	RCT group	Non-RCT group	OR	95% CI	*P*
CSA	32.8 ± 4.2	29.9 ± 4.0	1.19	1.10-1.28	.000015*
LAA	79.1 ± 6.5	81.0 ± 7.4	0.96	0.92-1.00	.069
ACA	67.5 ± 7.4	65.0 ± 6.7	1.05	1.01-1.10	.017*
CSSA	109.6 ± 7.7	113.7 ± 9.1	0.94	0.91-0.98	.0014*
GAT	11.7 ± 6.1	10.4 ± 5.2	1.04	0.99-1.10	.105
AAPA	0.45 ± 6.3	−3.5 ± 5.9	1.10	1.06-1.17	.00005*
CA	118.2 ± 7.3	117.7 ± 7.7	1.01	0.97-1.05	.667
SSA	132.2 ± 6.5	128.6 ± 5.9	1.10	1.05-1.16	.00019*
IAA	13.4 ± 4.2	10.9 ± 4.0	1.16	1.07-1.25	.00014*

Data are presented as the mean ± standard deviation.
AAPA, anterior acromial projection angle; ACA, acromial coverage angle; CA, coracoid angle; CI, confidence interval; CSA, critical shoulder angle; CSSA, coracoid scapular spine angle; GAT, glenoid anterior tilt; IAA, inferior angle angle; LAA, lateral acromion angle; OR, odds ratio; RCT, rotator cuff tear; SSA, scapular spine angle.
*Statistically significant.

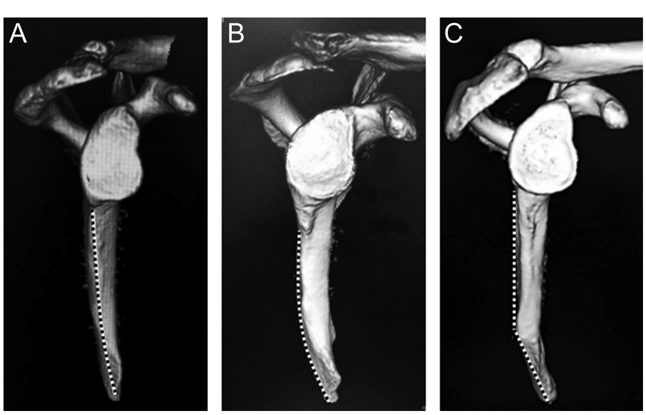

Figure 2. A: Flat type of scapular body, b: curved type of scapular body, c: hooked type of scapular body.

Table 2. Multivariate logistic regression analysis

	OR	95% CI	*P*
CSA	1.16	1.06-1.26	.00073*
ACA	1.03	0.97-1.10	.28
CSSA	0.97	0.93-1.02	.21
AAPA	1.03	0.95-1.12	.47
SSA	1.05	0.97-1.15	.21
IAA	1.13	1.04-1.23	.0032*

Data are presented as the mean ± standard deviation.
AAPA, anterior acromial projection angle; ACA, acromial coverage angle; CI, confidence interval; CSA, critical shoulder angle; CSSA, coracoid scapular spine angle; IAA, inferior angle angle; OR, odds ratio; SSA, scapular spine angle.
*Statistically significant.

Table 3. Shapes of the scapular body

	Flat type	Curved type	Hooked type
RCT group (n=103)	30 (29.1%)	39 (37.9%)	34 (33.0%)
Non-RCT group (n=87)	40 (46.0%)	28 (32.2%)	19 (21.8%)

P =.046 - Statistically signifcant RCT, rotator cuff tear and suggested that the posterior tilt of the scapular was smaller in the symptomatic RCTs than in the healthy shoulders. These previous studies identified an anterior tilt of the scapula in individuals with shoulder impingement or symptomatic RCTs. The increased anterior tilt of the scapula might result in a decrease in the subacromial space, between the greater tuberosity and the acromion, which may aggravate symptoms. In the present study, which investigated the morphology of the scapula, the angle between the inferior angle and the scapular plane was larger, and the scapular body was bent in cases with RCT. The serratus anterior originates from the ribs and inserts on the medial border and inferior angle of the scapula. In other words, the inferior angle of the scapula corresponds to the insertion of the muscle that stabilizes the scapula in the thorax. When the inferior angle is inclined and the scapular body is bent, the scapula's superior part may be more likely to tilt anteriorly, leading to impingement, which may be related to the pathogenesis of RCT and pain.

Another possible reason for the bending of the scapular body may be related to the thorax. Kebaetse et al[24] reported that a slouched position reduced the posterior tilt of the scapula during scapular plane abduction and was associated with a decreased active shoulder abduction range of motion and muscle force. Culham et al[25] also reported that the scapula tilts more anteriorly as the slope of the upper thoracic axis increases. However, the relationship between the thoracic shape and the scapular body curvature remains unconfirmed. Therefore, it remains unclear why the scapular body was bent in the cases with RCT.

This study has several limitations. First, the tear size and location varied in the RCT group. Second, the thoracic shape and scapular dynamics were not examined. Further investigation considering the thorax and dynamic analyses are required to clarify why the scapular body is bent in RCT cases. Third, considering that the subacromial spur was excluded from the analysis, whether the subacromial spur existed before or after the RCT remains unclear. Evaluating the subacromial spur would have given different results. Fourth, there is no clear definition between flat type, curved type, and hooked type in the shapes of the scapular body.

Focusing on the relationship between scapular body morphology and RCT, the multivariate analysis results revealed that the RCT cases were characterized by a larger curvature of the scapular body in addition to CSA. Further investigation using thorax and dynamic analyses is required to clarify this issue.

Ethics Committee Approval: This study was approved by the Ethical Committee of Research from Chugoku Rosai Hospital (approval number: 2020-25; date: December 25, 2020).

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – Y.N.; Design – Y.N., S.Y.; Supervision – N.A.; Resources –Y.N.; Materials – Y.N.; Data Collection and/or Processing – Y.N., Y.M.; Analysis and/or Interpretation – Y.N., S.Y., Y.H.; Literature Search –Y.N.; Writing – Y.N.; Critical Review – S.Y., N.A.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declare that this study received no financial support.

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