

## Research Article

# The effect of sagittal orientation of the acromion relative to the scapular spine on the location of rotator cuff tears

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## ABSTRACT

**Objective:** The aim of this study was to investigate the effect of the angle between the scapular spine and acromion in the sagittal plane on the location of chronic rotator cuff tears (RCTs).

**Methods:** The magnetic resonance images of patients who had undergone an arthroscopic shoulder surgery were evaluated. The patients were divided into two groups: patients who had undergone RCT repair and those who had experienced different shoulder surgery as a control group. The RCT group (study group) was then subgrouped in terms of the location of the tear as posterior-superior RCT type 3, 4, 5 or combination (group A) and anterior-superior RCT type 1,2,3 or combination using the Patte sagittal classification (group B). A novel angle, scapular spine-acromion angle (SSAA), was described in the sagittal plane and compared between the groups and subgroups.

**Results:** A total of 96 patients underwent an arthroscopic RCT repair with a mean age of 59.5 years (range, 36-65 years), and the control group was composed of 40 patients with a mean age of 52.5 (range, 41-63 years). Comparison the group B (mean value:  $73.41^{\circ} \pm 5.98^{\circ}$ , median:  $73.8^{\circ}$ , range:  $60.6^{\circ}$ - $89.7^{\circ}$ ) has significantly higher degrees of SSAA than group A (mean value:  $63.92^{\circ} \pm 6.82^{\circ}$ , median:  $64.8^{\circ}$ , range:  $52.3^{\circ}$ - $77.9^{\circ}$ ) [ $P < 0.001$ ].

**Conclusion:** This study demonstrated a higher incidence of posterior-superior RCTs in patients with lower SSAA and anterior-superior RCTs in patients with higher SSAA in the sagittal plane compared to the control group. So sagittal acromial orientation might influence the RCT location.

**Level of Evidence:** Level III, Diagnostic Study

## Introduction

Although several reasons regarding the etiology of chronic rotator cuff tears (RCTs) have been determined, no clear consensus has been reached yet. Previously, extrinsic and intrinsic factors were defined as possible reasons.<sup>1,5</sup> Patient-related reasons such as smoking, diabetes mellitus, older age, and poor blood supply have been associated as intrinsic factors.<sup>5,7</sup> The most commonly accepted intrinsic theory is the degenerative-microtrauma model which leads rotator cuff tendon degradation and disrupted mechanical properties resulting damage in tensile or shear tendon loads.<sup>8</sup> As extrinsic factors, Bigliani first described 3 different types of acromia and stated that type 3 (hooked) caused RCT due to an external impingement.<sup>9</sup> However, the presence of RCT in patients with type 1 (flat) acromial structure led researchers to investigate other predisposing factors.<sup>10</sup>

Recent studies investigated the acromial morphology using different methods such as acromial slope, acromial index, lateral acromial angle, and critical shoulder angle. To date, all the measurements demonstrated

the aberrations in local shape of the acromion or acromial spurs. These measurements concluded that the decrease of acromio-humeral distance or increase of acromial coverage may cause RCT.<sup>2,3,11,12</sup> However, other studies have also reported different results which did not support the general knowledge.<sup>10,13</sup>

In the present study, we sought to understand the influence of acromial anatomy on RCT. We hypothesized that sagittal acromial orientation might affect the location of RCT. To address the hypothesis, we used spinal scapula-acromion angle (SSAA) between the scapular spine and acromion on magnetic resonance imaging (MRI) on the sagittal plane. Finally, SSAA was compared between the patients with RCT including subgroups and those that did not have.

## Materials and Methods

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki

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Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. This study was approved by the Ethics Committee of the University Hospital (decision no: B.10.1.TKH.4.34.H.GP.0.01/32, dated: February 11, 2021).

A retrospective evaluation was made in 173 consecutive patients from a single institution who underwent an arthroscopic shoulder surgery from April 2013 to December 2015. In total, 7 patients with acute traumatic RCTs, 2 patients with a history of fracture around the shoulder girdle, 4 patients with glenohumeral arthritis, 8 patients with subacromial distance <7 mm, 4 patients with os acromiale, 8 patients with smoking habit, and 4 patients with diabetes mellitus were excluded from the study.

The patients included in the study group were those with a chronic RCT and appropriate preoperative MRI images in the picture archiving system. The study group was then divided into 2 subgroups as posterior-superior RCTs (group A) type 3, 4, 5 or combination and anterior-superior RCTs (group B) type 1,2,3 or combination using the Patte sagittal classification according to MRI views. (Figure 1) (Table 1).<sup>14</sup> The control group was formed of patients who had undergone arthroscopic frozen shoulder release, Superior Labral Anterior to Posterior (SLAP) repair with intact rotator cuff and had appropriate MR images in the system.

### Radiological evaluation

The shoulders of both groups were evaluated with a General Electric MedicalSystems LLC Optima MR 450 W Gemsuite 1.5 T MRI spectrometer using an HD8-channel Shoulder Array by Neocoil. The arm was fixed to the patient's body in anatomic position. In the MRI evaluation, SAAA angle measurements were taken using Picture Archiving and Communication Systems (PACS) by an orthopedic surgeon and a radiology specialist, each blinded to the other's results. Our routine shoulder MRI protocol is as follows: axial proton density (PD) FSE Fat Sat (repetition time (TR)/ time to echo (TE): 2500/30 ms, field of view (FOV): 14 cm, slice thickness/gap:4/0.5 mm), coronal oblique short tau inversion recovery R (FSTIR) (TR/TE: 2500/40 ms, FOV: 16 cm, slice thickness/gap:4/0.5 mm, inversion time (TI): 150 ms), coronal oblique T1 SE non-Fat Sat (TR/TE: 400/11 ms, FOV: 18 cm, slice thickness/gap:4/0.5 mm), sagittal oblique PD fast spin echo (FSE) Fat Sat (TR/TE: 2500/30 ms, FOV: 16 cm, slice thickness/gap:4/1 mm), and sagittal oblique T1 spin echo (SE) non-fat Sat ( TR/TE: 400/11 ms, FOV: 16 cm, slice thickness/gap:4/1 mm).

### Measurement method

All shoulder MRI scans were performed in the supine position with the arm in mild external rotation. A T1 TSE sequence was taken in the sagittal oblique plane in addition to the routine shoulder MR protocol. Angle measurements were taken semi-automatically (lines drawn manually and the angle calculated automatically) via PACS.

### HIGHLIGHTS

- Recently the acromial morphology has become a topic of interest to better understand the relationship between acromion shape and its relation to rotator cuff tears (RCTs).
- This study was aimed to understand the influence of acromial anatomy on RCT location.
- The main results of the present study showed that acromial slope in the sagittal plane relative to the spina scapula may have a possible effect on the location of the tears in the patients with RCT.

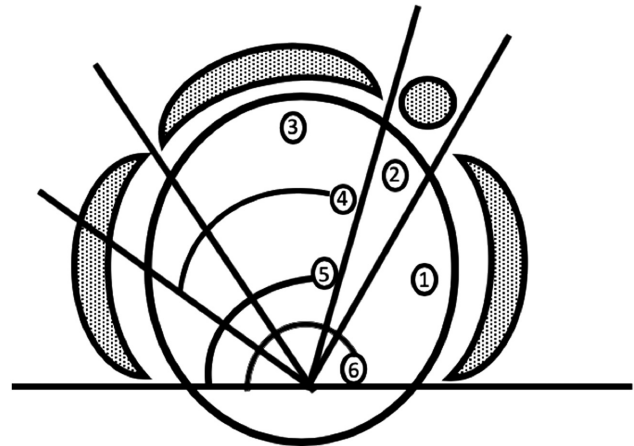


Figure 1. Topography of rotator cuff tear in the sagittal plane according to the Patte classification is shown. Section 1: subscapularis tear, section 2: coracohumeral ligament tear, section 3: isolated supraspinatus tear, section 4: tear of entire supraspinatus and one-half of infraspinatus, section 5: tear of supraspinatus and infraspinatus, section 6: tear of subscapularis, supraspinatus, and infraspinatus.

Table 1. Numbers of patients in groups A and B

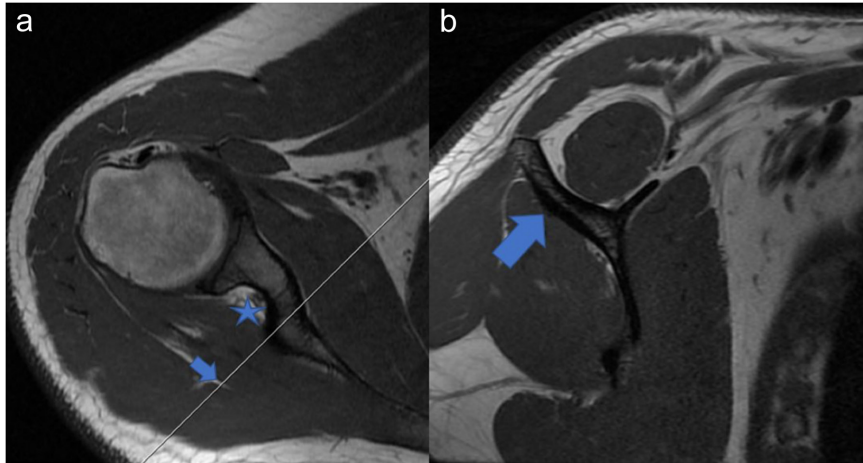
Study Groups	Patte Classification	n	%
Group A	Type 3	25	26
	Type 4+5	21	22
Group B	Type 1	35	36
	Type 1+2+3	15	16

Group A consisted of Patte (3) and (3+4) patients; group B consisted of Patte (1) and (1+2+3) patients; study groups: group A+B. n, number of patients.

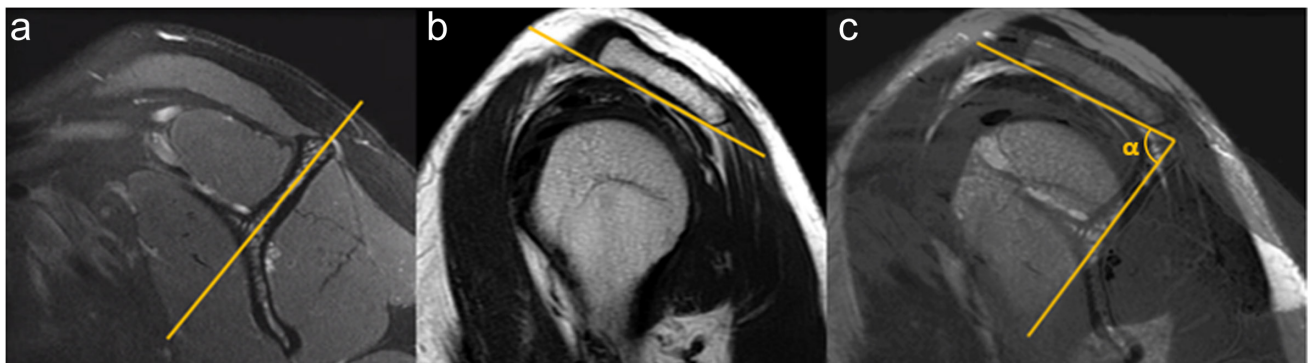
The SSAA was measured on the T1 TSE sequence images in the sagittal oblique plane. In the section where the anterior and posterior cortex of the acromion are clearly visible and the longest length in the sagittal plane, a line was drawn in the anteroposterior, parallel to the lower cortex of the acromion (*line a*). Axial plane sections were used as a reference to draw a line parallel to the spine scapula. Spinoglenoid notch was found in the axial plane (Figure 2A,B). The medial of the notch is marked. The sagittal oblique section corresponding to this section was accepted as the reference image. In this section where the spine and corpus of the scapula are seen together, a line was drawn parallel to the lower cortex of the spine (*line b*). The angle between line a and line b obtained from the 2 different sections was automatically moved to the same plane in the PACS system. The angle between the 2 lines in this plane was automatically measured as the scapular spine-acromion angle (Figure 3).

### Statistical analysis

Statistical analyses were performed using IBM Statistical Package for the Social Sciences version 21.0 software (IBM SPSS Corp., Armonk, NY, USA). Quantitative variables were stated as mean  $\pm$  standard deviation values. In the cases where the assumption of normality and homoscedasticity were met, the parametric Student's *t*-test was used to compare the differences in groups. Statistical significance was established as  $P = .05$ . For each measurement, the interclass correlation coefficient (ICC) and 95% CI were reported. Correlation was classified as poor (0.00-0.20), fair (0.21-0.40), moderate (0.41-0.60), good (0.61-0.80), or excellent (0.81-1.00). The power analysis calculation was performed using G\*Power 3 software (Heinrich Heine Universität, Dusseldorf, Germany). The power of the study was 99% when the number of 46 cases was taken in each group (type 1 error ( $\alpha$ ) of 0.05).



**Figure 2. a, b.** (a) On the axial plane section, the reference line in the oblique plane with respect to the glenoid bone is seen (short blue thick arrow). (b) Spinoglenoid notch (blue star) and spina scapula are observed in the sagittal oblique plane section obtained (thick blue arrow)



**Figure 3.** In the first image, a line was drawn through the body of the spina scapula, and in the second image, a second line was drawn underneath the acromion body on the left shoulder sagittal magnetic resonance imaging. The final image shows that by superimposing the 2 different images, the alpha angle ( $\alpha$ , spina-acromial) between the 2 lines was calculated. Line a and line b are in different sequences to emphasize the bony landmarks.

**Results**

In this study, 96 patients (42 males and 54 females) with chronic RCT (study group) and 40 patients (14 males and 26 females) with intact rotator cuff (control group) were included in the study. The mean age of the study group and the control group was 59.5 years (range, 36-65 years) and 52.5 years (range, 41-63 years) respectively. The study group consisted of 46 patients who had posterior-superior RCTs (group A) and 50 patients who had anterior-superior (group B) RCT.

The interclass correlation coefficient of the observers for the radiological measurements was 0.96 which showed excellent reliability. In comparison, group B (mean value,  $73.41^\circ \pm 5.98^\circ$ ) has significantly higher degrees of SSAA than group A (mean value,  $63.92^\circ \pm 6.82^\circ$ ) ( $P < .001$ ) (Table 2).

**Table 2.** Comparison of the patients in terms of SSAA

	Mean $\pm$ SD		P
	RCT Group	Control Group	
SSAA	68.86 $\pm$ 7.92	70.0 $\pm$ 5.91	.0356***
	68.2 (52.3-89.7)	69.8 (57.9-89.6)	
SSAA	63.92 $\pm$ 6.82	73.41 $\pm$ 5.98	< 0.001***
	64.8 (52.3-77.9)	73.8 (60.6-89.7)	

\*\*\*Student's t-test. RCT group (group A+ group B). SSAA, Spina scapula-acromion angle; SD, standard deviation.

**Discussion**

The main results of the present study showed that acromial slope in the sagittal plane relative to the spina scapula may have a possible effect on the location of the tears in the patients with RCT. Furthermore, a novel measurement method of SSAA described in this study has excellent reliability between researchers.

Bigliani<sup>9</sup> first stated that a hooked acromion structure has a reliable role in RCTs. However, Balke et al<sup>10</sup> stated that the acromial type according to Bigliani<sup>9</sup> was not associated with rotator cuff lesions. In years, several radiological studies were performed about possible relationships between acromion, humeral head, and glenoid morphology. In the coronal plane, different studies investigated the possible effects of lateral acromial angle (LAA) between the glenoid and acromion or the lateral extension of the acromion (acromial index, AI).<sup>3,12,15,16</sup> In a similar manner, Moor et al<sup>2</sup> reported the critical shoulder angle (CSA), the measurement between glenoid inclination and lateral extension of the acromion, has a greater value in patients with RCT. However, most recently, Chalmers et al<sup>13</sup> investigated the association between various previously described angles and RCTs. The results of the study did not find a significant relationship between CSA, LAA or acromial index, and RCTs. The authors concluded that acromial coverage did not influence the RCTs. In the sagittal plane, Chalmers et al<sup>13</sup> also examined the association between anteroposterior angulation of the acromion and RCTs. Sagittal orientation was assessed using sagittal acromial tilt, acromial anterior-posterior

coverage, and scapular spine angle. The authors stated that they did not find any association between these factors and RCTs. Our findings pointed out a potential relation between the SSAA and the RCT location as a significant difference that anterior-superior RCTs associated with higher SSAA and posterior-superior RCTs with lower SSAA.

The biomechanical basis of the current study is based on the change in the orientation of the acromion, which is the origo of the deltoid muscle. Degenerative RCTs were traditionally believed to begin at the anterior part of the supraspinatus tendon, adjacent to the long head of the biceps tendon. The anterior portion was believed to transmit most of the contractile load, and because more stress would be applied routinely, this tendon would be at high risk for a tear. Our results may also address a similar mechanism. Accompanying with the supraspinatus, the deltoid muscle, consists of 3 parts and adheres to the anterior clavicle, the middle acromion, and the posterior spina scapula, has been proven to be the primary mover of the shoulder during abduction.<sup>17</sup> In the first 30° of abduction of the shoulder, supraspinatus muscle acts as the dominant role as a starter, whereas between 30° and 90° of abduction, the deltoid is the primary muscle.<sup>17</sup> The rhythmic movement of the deltoid and rotator cuff muscles is essential for proper shoulder abduction. Insufficient power for abduction produced by deltoid may overburden the rotator cuff inducing a tear. Acromion morphology, the origin of the deltoid muscle, acts as a force arm point during shoulder abduction. So the force produced by deltoid may change due to sagittal acromial positioning according to insertion of the deltoid. Several authors reported the priority of the deltoid muscle for abduction compensation patients with RCT.<sup>18,19</sup> In that study, anterosuperior and posterosuperior cuff tear simulations demonstrated that deltoid needs to generate more power to maintain the abduction movement and to stabilize the glenohumeral joint stability.<sup>18</sup> We believe that the strong arm of the deltoid muscle will change with the increase/decrease of the sagittal acromial slop, and accordingly, the localization of the tear may change. Considering the aforementioned mechanisms which are different from acromial compression as a cause of RCTs lead the surgeons that acromial reshaping procedures such as acromioplasty may not be necessary for rotator cuff surgery.

Technically closest method used to measure the SSAA in this study is a method described by Aoki et al<sup>11</sup>, the angle between the acromion and the line passing through the coracoid tip in sagittal orientation.<sup>11</sup> However, the anatomical variations of the coracoid process have been previously described and may prevent the standardization of these measurements.<sup>20</sup> Therefore, for the current study measurements, the determination of spina scapula as a reference point was effective in achieving standardization.

This study has some limitations. First, measurements of the angles were only made on MRI, whereas combining with CT could have yielded more precise and accurate results. Second, researchers who clarify the tear type and measurement were not blinded in this study.

In conclusion, this study demonstrated a higher incidence of posterior-superior RCTs in patients with lower SSAA and anterior-superior RCTs in patients with higher SSAA in the sagittal plane compared

to the control group. So sagittal acromial slope relative to the spina scapula might have an influence on the RCT location.

**Ethics Committee Approval:** Ethics committee approval was received from the Ethics Committee of the University of Health Sciences, Ümraniye Training and Resesif Hospital, (Approval no: B.10.1.TKH.4.34.H.GP.0.0/32), (Date:11.02.2021).

**Informed Consent:** Written informed consent was obtained from all participants who participated in this study.

**Author Contributions:** Concept - G.A., İ.T.; Design - K.B., G.A.; Supervision - H.Ç., İ.T.; Funding - G.A., İ.T.; Materials - İ.T., G.A.; Data Collection and/or Processing - D.K., K.B., S.S.D.B.; Analysis and/or Interpretation - G.A., S.S.D.B.; Literature Review - D.K., H.Ç.; Writing - G.A., İ.T., H.Ç.; Critical Review - K.B., H.Ç.

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

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