ORIGINAL PAPER/PŮVODNÍ PRÁCE

# Seeking a New Radiological Measure to Predict Rotator Cuff Tears: Investigating the Coracoclavicular Distance in an MRI-Based Study

## Hledání nového radiologického kritéria pro predikci trhliny rotátorové manžety: zkoumání korakoklavikulární vzdálenosti ve studii založené na MRI

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## ABSTRACT

### Purpose of the Study

Rotator cuff tears are a common disease and various radiological measurement methods are still being investigated to make the diagnosis. The aim of this study was to investigate whether the coracoclavicular distance is associated with rotator cuff tears.

### Material and Methods

Shoulder magnetic resonance imaging (MRI) examinations of 101 patients who underwent shoulder arthroscopy due to rotator cuff tears and 158 patients with normal MRI findings were evaluated retrospectively. Coracohumeral distance, acromiohumeral distance and supraspinatus volume were measured.

### Results

When the acromiohumeral distance, coracoclavicular distance and supraspinatus volume were compared between the groups, each measurement was found to be statistically significantly lower in the tear group (Group 2) ($p<0.001$). In the analysis of ROC for the detection of full-thickness supraspinatus tear, the following findings were observed: if the coracoclavicular distance measured less than 12.4 mm, a sensitivity of 89% and specificity of 73% were determined. Similarly, if the acromiohumeral distance measured less than 7.5 mm, a sensitivity of 73% and specificity of 84% were determined. In full-thickness supraspinatus tears, if the supraspinatus volume measured below 51 $cm^3$, a sensitivity of 89% and specificity of 72% were determined.

### Conclusions

Our study, conducted on a limited population, demonstrated that coracoclavicular distance is a significant metric for detecting supraspinatus tears. We believe that we have identified a new parameter that may be useful in the diagnosis of rotator cuff tears.

**Key words:** coracoclavicular distance, acromiohumeral distance, supraspinatus volüme, supraspinatus tears.

## INTRODUCTION

Rotator cuff tears (RCTs) are the primary source of shoulder pain and restricted mobility, and they represent the most prevalent surgical condition affecting the shoulder joint (16). Several radiographic shoulder measurements have been described as useful for identifying rotator cuff tears (3, 11). The acromiohumeral distance is a measuring technique that is particularly important in identifying rotator cuff tears. This measurement evaluates the potential of the subacromial

space being narrower (18,21). Recent studies indicate a connection between differences in scapular morphology and the development of degenerative rotator cuff tears (8).

Several studies have proposed an extrinsic mechanism for rotator cuff tears, attributing their occurrence to compression of the tendons as they pass beneath the coracoacromial arch (14,15). The coracoacromial ligament, a component of the coracoacromial arch, starts from the lateral edge of the coracoid process and attaches to the acromion (2). Prior research has confirmed a connection between the structure of the coracoacromial ligament and the occurrence of rotator cuff tears (1,6). Despite the established anatomical association between the coracoacromial arch and the supraspinatus tendon, the literature lacks investigation into the potential relationship between the coracoclavicular distance and the supraspinatus muscle. The coracoclavicular distance (CCD), which can be measured in different imaging planes, has been reported to be 11–13 mm on coronal scans (2). The coracoclavicular ligaments (conoid – trapezoid) originate from the base of the coracoid process and are inserted on the inferolateral surface of the clavicle (2). The current field of research on the diagnosis of rotator cuff tear investigates many measuring parameters, such as coracoacromial ligament thickness, critical shoulder angle, acromial bone thickness, and acromiohumeral distance (AHD). Nevertheless, we have not encountered a study that explores the correlation between CCD and RCT. On the other hand, we thought that the distance between the coracoid and clavicle, which is anatomically related to the supraspinatus muscle, may play a role in the pathophysiology of the tear. The main objective of this study is to acquire a novel anatomical measurement parameter that can be valuable in identifying supraspinatus rupture. Our hypothesis is that the decrease of CCD distance may be an extrinsic cause of RCT formation.

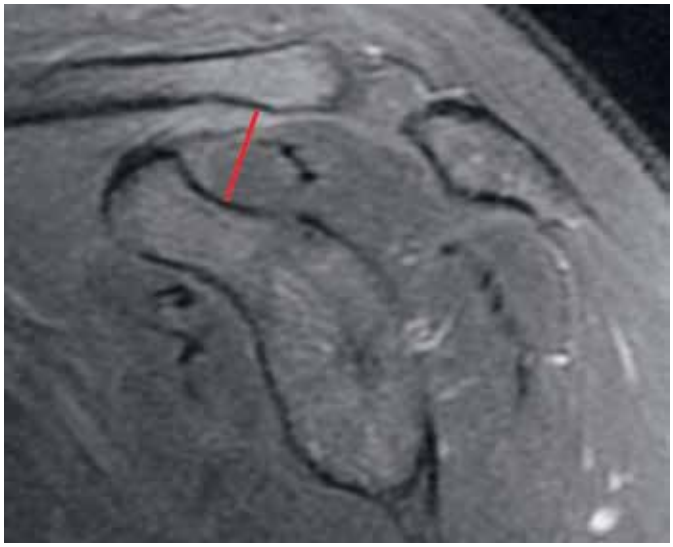

Fig. 1. **Coracoclavicular distance is shown by red line; narrowest distance between the cortex above the coracoid base and the subcortex of the clavicle.**

## MATERIAL AND METHODS

All patients between 50 to 75 years of age who were presented to the orthopedic clinic with shoulder pain were investigated. Patients underwent shoulder magnetic resonance imaging (MRI) following a provisional diagnosis of a supraspinatus tear. The measurements were evaluated simultaneously by two authors who have extensive experience in the field of musculoskeletal radiology. Two orthopedic sports physicians analyzed shoulder MRIs of all patients and categorized them into two groups: Group 1 consisted of healthy patients without any tear, whereas Group 2 included patients with a full-thickness supraspinatus tear. Within Group 2, the researchers analyzed preoperative magnetic resonance imaging (MRI) scans of patients who subsequently underwent surgery for small or medium-sized tears (up to 3 cm). To enhance the reliability of the study, Group 2 was exclusively composed of patients who had undertaken arthroscopic surgery to confirm the diagnosis. The study excluded participants who had partial tears, massive retracted tears (Patte stage 2 and stage 3), traumatic tears, supraspinatus fatty degeneration, atrophy, simultaneous tears in other rotator cuff tendons, effusion within the shoulder joint, glenohumeral arthritis, bone deformity in the humerus or scapula, presence of a ganglion cyst in the subacromial region, an improper MRI scan, and patients who are younger than 50 years of age (which may be related to the traumatic ruptures) or patients not operated on for any reason. After the evaluation of the exclusion criteria, a total of 259 patients' MRI scans were analyzed.

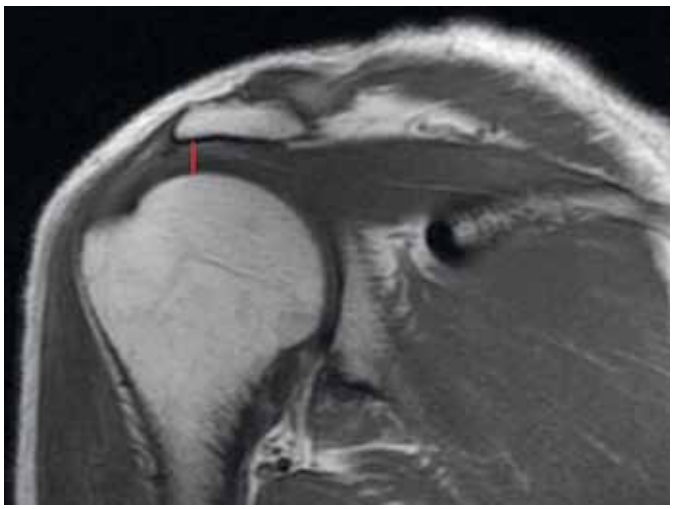

Fig. 2. **Acromiohumeral distance; The narrowest distance between the acromion subcortex and the upper humeral cortex shown by the red line.**

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Fig. 3. **Measurement method of supraspinatus muscle volume via MRI.**

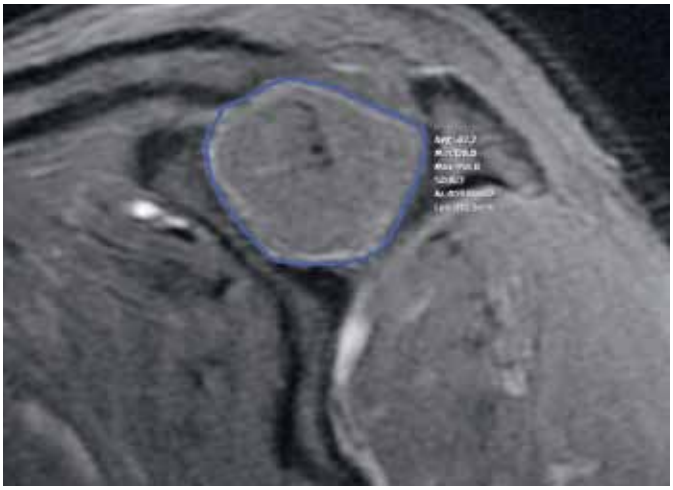

Fig. 4. **In the Y-view, the area of the supraspinatus muscle was measured and shown as ROI.**

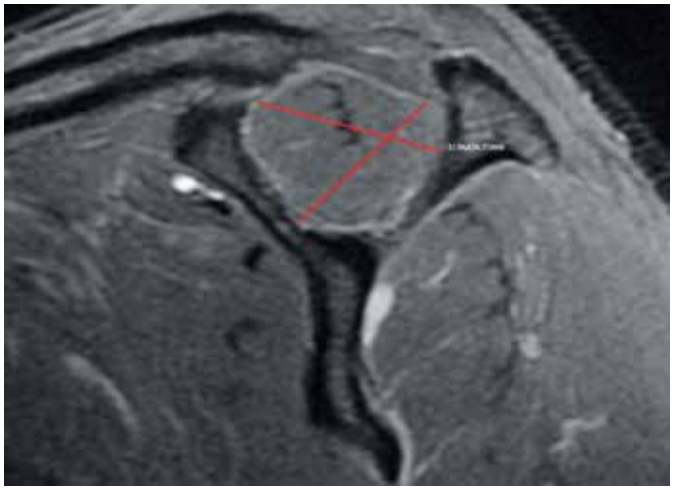

Fig. 5. **Method of measuring the multiplication value on the supraspinatus muscle in the sagittal oblique plane in the Y-view.**

During the MRI scan, all patients were positioned in a supine position with the arm at the side of the body and in neutral rotation, and all MRI examinations were conducted using the same device (Signa Explorer 1,5 Tesla – GE HealthCare®) T1-weighted and fat-suppressed proton density-weighted images in the coronal oblique plane, fat-suppressed proton density-weighted images in the axial plane, and T1-weighted/fat-suppressed proton density-weighted images in the sagittal oblique plane were assessed.

MRI scans were examined and the acromiohumeral and coracoclavicular distances were measured and recorded. In the sagittal oblique plane, the coracoclavicular distance is the narrowest distance between the cortex above the coracoid base and the subcortex of the clavicle. This distance is correlated with the level approximately 1 cm medial to the glenoid joint surface in the coronal plane (Fig. 1). In the coronal plane, the narrowest distance between the acromion subcortex and the upper humeral cortex was measured to register AHD (Fig. 2). In addition, supraspinatus muscle volume, glenoid length, supraspinatus muscle area (ROI) in the sagittal oblique plane, and the multiplication value of the cross distances in the sagittal oblique plane, with the supraspinatus muscle furthest away, were recorded by measuring.

The volume of the supraspinatus muscle was assessed by examining all sections in the axial plane using a specialized approach. The imaging was conducted on the coronal section, and the muscle circumference was delineated on the sections where the muscle was present. This process was repeated for each section in which the muscle was visible within the image, and the volume of the available sections was calculated. The volume was calculated by measuring the distance between the sections and the circumference of the muscle using the existing software (Simplex Information Technologies RBS PACS). In order to obtain these measurements, the available sections were used both axially and coronally. The volume menu was then defined in the software, after which the free ROI was measured. Upon completion of all sections, the volume measurement was obtained and the corresponding value was recorded (Fig. 3). The glenoid length was measured as the longest distance at the upper and lower ends in the section where the joint surface was fully visible in the sagittal oblique plane. When the scapula was in Y-view on the sagittal oblique plane, the ROI was automatically calculated by tracing a line around the supraspinatus muscle (Fig. 4). The multiplication value was obtained by multiplying the lengths of two lines drawn at an angle of 40-60 degrees in the longest direction within the muscle while the supraspinatus muscle was in the Y-view position in the sagittal oblique plane (Fig. 5). The measurement data in both groups were recorded in millimeters (mm) or centimeters (cm) and analyzed using statistical methods.

The IBM® SPSS® programme, version 26.0.0.0, was used for statistical analysis. Both analytical (Kolmogorov-Smirnov Test) and visual (histogram and probability plots) techniques were used to assess the suitability of the variables for normal distribution. All other continuous variables were skewed, but the ROI and acromiohumeral distance variables were normally distributed. For normally distributed variables, descriptive statistics were expressed as mean, standard deviation, and minimum-maximum values; for skewed variables, as median, interquartile range, and minimum-maximum values; and for categorical data, as percentage frequencies. Independent Two-Sample T-Test was used for between-group comparisons of the ROI and acromiohumeral distance variables, and Mann-Whitney U Test was used for between-group comparisons of the remaining continuous variables. Chi-squared tests were used to compare categorical data and Fischer's Exact Test was used in cases where the assumption of the chi-square is not fulfilled. The ROC Curve analysis was used to determine

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Table 1. **Demographic profile of the patients**

| | | GROUP 1: SHOULDER WITHOUT RUPTURE (N=158) | GROUP 2: FULL-THICKNESS SUPRASPINATUS RUPTURE (N=101) | P |
|---|---|---|---|---|
| **Age (years)*** | | 56.53±5.263 (50–72) | 57.44±5.201 (50 – 73) | 0.125 |
| **Gender** | **Female** | 86 (54.4%) | 66 (65.3%) | 0.082 |
| | **Male** | 72 (45.6%) | 35 (34.7%) | |
| **Side** | **Right** | 75 (47.5%) | 62 (61.4%) | 0.029 |
| | **Left** | 83 (52.5%) | 39 (38.6%) | |

P – statistical significance value, n – number of patients, * – descriptive statistics were expressed as mean ± standard deviation (minimum-maximum values). All other categorical data were expressed as frequency (percentage) values.

the sensitivity and specificity of the radiological parameters in identifying full-thickness supraspinatus tears, and Spearman Correlation Analysis was used to investigate the correlation between the radiological parameters evaluated. A value of p below 0.05 was considered statistically significant.

## RESULTS

With a total of 259 shoulder MRIs, Group 1 consisted of 158 (61%) MRI scans and Group 2 consisted of 101 (39%) MRI scans. The mean age in Group 1 was 56.5 ±5 years (ranging from 50 to 72), with 54.4% of the participants being female. The mean age in Group 2 was 57.4 ±5 years (ranging from 50 to 73), with 65.3% of the participants being female. There was no statistically significant difference detected when comparing the average age and gender (p>0.05). However, a statistically significant difference was observed between the groups in terms of the side (p=0.029). Table 1 displays the demographic data of the categories.

When the acromiohumeral distance, coracoclavicular distance, supraspinatus volume, ROI value, and multiplication value were compared between the groups, each measurement was found to be statistically significantly lower in the tear group (Group 2) (p<0.001). When comparing the glenoid distance between the groups, no statistically significant difference was observed (p=0.261). The values of measurements made in the groups are shown in Table 2.

In the analysis of ROC for the detection of full-thickness supraspinatus tear, the following findings were observed: if the coracoclavicular distance measured less than 12.4 mm, a sensitivity of 89% and specificity of 73% were determined. Similarly, if the acromiohumeral distance measured less than 7.5 mm, a sensitivity of 73% and specificity of 84% were determined. Lastly, if the supraspinatus volume measured below 51 $cm^3$, a sensitivity of 89% and specificity of 72% were determined.

Correlation analysis revealed a moderate correlation between coracoclavicular and acromiohumeral distance (r=0.562, p<0.001) and a weak correlation between coracoclavicular distance and supraspinatus volume (r=0.486, p<0.001). A significant correlation was observed between the ROI value and supraspinatus volume (r=0.716, p<0.001), as well as between the product value and ROI value (r=0.835, p<0.001).

## DISCUSSION

Despite the prevalence of rotator cuff injuries diagnosing them may still prove challenging. No previous study has

Table 2. **Statistical information of the data recorded in the groups**

| | GROUP 1: SHOULDER WITHOUT RUPTURE (N=158) | GROUP 2: FULL-THICKNESS SUPRASPINATUS RUPTURE (N=101) | P |
|---|---|---|---|
| Supraspinatus volume ($cm^3$) | 59.6 (12.6) (42.5–86.5) | 47.4 (9.8) (28.9–67.8) | <0.001 |
| ROI* ($cm^2$) | 7.1±1.1 (4.3–9.9) | 6.5±1.1 (4.1–9.1) | <0.001 |
| Acromiohumeral distance* (mm) | 8.06±0.75 (6.52–10.34) | 7.09±0.78 (5.28–11.02) | <0.001 |
| Coracoclavicular distance (mm) | 14.03 (1.66) (9.63–17.8) | 11.53 (2.5) (7.42–15.8) | <0.001 |
| Glenoid distance (mm) | 40.74 (5.78) (32.8–49.25) | 39.81 (4.98) (34.09–49.82) | 0.261 |
| Multiplication value ($cm^2$) | 9.7 (3.41) (5.01–17.21) | 8.3 (2.57) (4.78–14.96) | <0.001 |

P – statistical significance value, n – number of patients, * – descriptive statistics were expressed as mean ± standard deviation (minimum-maximum values). All other variables were skewed distributes and descriptive statistics were expressed as median (interquartile range) (minimum-maximum values).

revealed a relationship between coracoclavicular distance and rotator cuff tear. The statistically significant difference between the presence of a full-thickness supraspinatus tear and the decrease in coracoclavicular distance is the most significant aspect of our study.

Although the normal values of the coracoclavicular distance have been mostly investigated in the coronal plane in the literature, the measurement method in the sagittal plane is also specified (4). Acromioclavicular separation in the coronal plane can be caused by trauma and results in an increase in coracoclavicular distance (22). However, in our study, we evaluated the coracoclavicular distance by measuring it from the part associated with the supraspinatus muscle in the sagittal oblique plane, rather than in the coronal plane.

AHD is a valuable measurement parameter for the diagnostic and prognostic follow-up of rotator cuff injuries and is frequently used (9). Rotator cuff injuries have been significantly associated with AHDs of less than 7 mm on X-ray imaging (7,20). Although AHD measurement is often performed on X-ray, measurements made via MRI can also predict tendon tears (20). According to a study involving patients similar to ours, the assessment of AHD (acromiohumeral distance) in MRI scans of rotator cuff injuries was determined to be 8.3 mm (19).

The consistency in maintaining the identical shoulder-arm position and patient posture during conventional radiographs has resulted in conflicts questioning the reliability of the acromiohumeral distance. In fact, studies has indicated that AHD values obtained using MRI and computed tomography (CT) are more dependable (13). Our work aimed to enhance the dependability of the newly established parameter (CCD) by conducting measurements using MRI.

In a study examining the correlation between the coracoacromial arch angle and rotator cuff tear, it was observed that the AHD and coracohumeral distances were narrower in the group of individuals with tears (5). The study we conducted revealed a high probability of finding a complete tear in the supraspinatus muscle when there was a decrease in the coracoclavicular distance. A decreased coracoclavicular distance may serve as a risk factor for RCT. While the extrinsic mechanism explanation suggests that tears develop gradually, further research is required to determine whether the narrowing of the coracoclavicular distance is the cause or the consequence of tear formation (14). Indeed, we believe that conducting extensive investigations that compare the healthy and torn shoulders of the same patient will enhance the significance of the CCD-RCT association.

While prior study has acknowledged the association between tears and the supraspinatus outlet region due to its inclusion of the tendon region, the specific distance between the coracoid and the clavicle, through which a portion of the supraspinatus muscle goes, has not been previously examined (23). In our study, we assessed the volume of the supraspinatus muscle and measured the coracoclavicular distance.

Our investigation revealed that the tear group showed a reduced volume of the supraspinatus muscle. Simultaneously, the torn group had statistically lower values for both the ROI (area of the supraspinatus muscle in a single slice) and the multiplication value. According to the results from our study, we believed that the ROI and multiplication value could accurately represent the volume. This is because the imaging system requires specialized technology to assess the supraspinatus volume, and the measuring process is labor-intensive. Our study shown that the occurrence of a tear can be accurately predicted by evaluating the supraspinatus muscle area.

At the same time, we observed a decrease in the amount of the supraspinatus muscle among patients whose coracoclavicular distance decreased. Our data is supported by a research indicating that tear formation may be caused by a reduction in muscle volume (10). Our study attempted to evaluate the population with acute tears by examining non-retracted tears. We found a significant difference in supraspinatus volume values between the groups with and without tears. However, a separate investigation indicated that muscle atrophy advances gradually in cases with chronic rotator cuff tears (12).

In our study, we observed that the ratio of right shoulder tears was much higher than left shoulder tears in the shoulder MRIs that were reviewed. While the literature does not specify the most common side of the shoulder where tears occur or where surgery is typically performed, studies indicate that the dominant arm typically regains normal function within 12 months after surgery (17).

The absence of statistical difference in glenoid lengths shown in our study is noteworthy, as it indicates that the participants in our study share similar characteristics. However, further radiological analyses with a larger sample size are necessary.

The limitations of our study are as follows, first of all this study is that it is a retrospective study. The sample size of the study is adequate for a clinical investigation, but it may not be representative of the overall population. Despite the expertise of the two orthopedic specialists who conducted the tests, the coracoclavicular distance assessment in this study is influenced by individual characteristics and may introduce biased results. Unfortunately, we were unable to acquire comprehensive clinical data regarding the onset of shoulder discomfort in the individuals involved in the trial, which prompted the need for an MRI.

## CONCLUSIONS

While acromiohumeral distance measurement is frequently used to assess rotator cuff tears, coracoclavicular distance is not commonly used for this purpose. Our study, conducted on a limited population, demonstrated that coracoclavicular distance is a significant metric for detecting supraspinatus tears. ■

**Ethical Review Committee Statement:**
Our study was approved by the Sancaktepe Sehit Prof. Dr. Ilhan Varank Training and Research Hospital Scientific Research Ethics Committee with file number 141.

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