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ORIGINAL STUDY

Correlation between shoulder radiographic parameters and supraspinatus tendon tear : acromio-tuberosity index (ATI) and acromio-tuberosity difference (ATD)

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The purpose of this study was to find the correlation between supraspinatus tendon (SSP) tear, ATI and ATD. A case-control study design was conducted in 182 patients who presenting with history of shoulder pain for more than 6 months of duration. ATI and ATD were measured on neutral anteroposterior position of conventional radiographs. SSP integrity was evaluated on MRI. The study consisted of 143 patients with SSP tear and 39 patients with no SSP tear. The median ATI of SSP tear group and no SSP tear group were 1.1 ± 0.1 and 1.2 ± 0.1 respectively. The median ATD of SSP tear group and no SSP tear group were 2.3 ± 2.2 mm and 4.3 ± 1.6 mm respectively. The result showed that ATI and ATD had good correlation for SSP tear on MRI in patient with shoulder pain(Area under curve = 0.748 and 0.746 for ATI and ATD respectively). Bursal side tear group also had lowest ATI and ATD compare to other tear pattern groups. Although results are statistically significant such a small difference, these emphasized their role as risk factors and concordance to rotator cuff pathogenesis described in previous studies.

Keywords : Rotator cuff ; supraspinatus tendon ; impingement ; radiographic ; shoulder pain.

INTRODUCTION

Rotator cuff tear is one of the most common causes of shoulder pain in adults and its prevalence increases with age *(19,32)*. Shoulder impingement syndrome is recognized as one of the important causes of rotator cuff tear *(23,24)*. Wide variety of possible etiologies and limitation of possible structure palpation make diagnosis by physical examination quite difficult *(22)*. Thus, several imaging techniques play an important role in detecting for subacromial pathologies *(11,12,14,30)*.

Impingement of humeral head with the acromion can occur during shoulder movement *(7)*. From the

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extrinsic theory of rotator cuff disease by Meyer(18), Bigliani et al. classified acromion into three types based on its anterior slope. Previous studies had demonstrated the relationship between hook type and high prevalence of rotator cuff tear *(2,4,5,9,16,23).* But this classification may vary depending on assessors *(13,26)*. Moreover, some authors believed that the change of acromion shape may result from rotator cuff tear. Moor et al postulated the concept of balanced mechanical loading shoulder. They found that Critical Shoulder Angle (CSA) more than 35 degree is assoicated with rotator cuff tears *(21)*. Relationship between Acromiohumeral interval (AHI) and rotator cuff tear was also studied. AHI of 7 mm or less on plain conventional radiograph is a sign of rotator cuff tear with high specificity(10). However, sensitivity was low and many cutoff values were used for predicting rotator cuff tear in other studies *(6,27)*. To our knowledge, there is no study on proportion between distances from humeral center of rotation to acromion and distances from humeral center of rotation to greater tuberosity.

The purpose of the present study was therefore to identify the association between supraspinatus tear and this proportion. Our hypothesis was patients with disproportion space between humeral head size and space under acromion have a higher risk for supraspinatus tears.

MATERIALS AND METHODS

Approval was obtained from the Institutional Review Board. We reviewed data of patients who had shoulder imaging in our institutoion from 2012 to 2014. The inclusion criteria were : patients with ages between 45-75 years old with shoulder pain for more than 6 months of duration, the availability of history and physical examination suggestive of supraspinatus tendon tear or impingement syndrome, a true anteroposterior radiograph with the humerus in neutral rotation, and MRI of the shoulder. The exclusion criteria were patients with a history of trauma, inflammatory disease, previous surgery on the acromion, and a tumor on the affected side. Patients with incongruent glenohumeral joint, a collapse of the humeral head, deformed humeral head and those with moderate-to-severe glenoid erosion (>15° of glenoid retroversion) were also excluded because such deformities directly affected the outcome measurement.

From institute's protocol, a true AP radiograph of the shoulder was obtained when the x-ray beam was perpendicular to the plane of the scapular body. The glenohumeral joint was profiled so that there was no overlap between the glenoid and the humeral head. The humeral head had to be in neutral position or up to 20° internal rotation for being included into the definition of true AP radiograph. The scapula position must not exceeded 20° of either external or internal rotation *(21,25)*. All radiographs were acquired with the patient in the upright position.

MRI—3-Tesla MRI unit (Achieva, Phillips). The shoulder was placed on both MR systems in a dedicated receive-only shoulder coil with the arm in a neutral position and the thumb pointing upward. The following sequences were acquired : in axial plain : T2- weighted fast spinecho images, Proton density weighted images, in the coronal oblique plane : T2- weighted fast spinecho images, Proton density weighted images fat saturation, and in the sagittal oblique : T1- weighted spinecho images, T2- weighted fast spinecho images.

In our study, we proposed two factors in the conventional radiography : the Acromio-Tuberosity index (ATI) and Acromio-Tuberosity Difference (ATD). The two factors were study for their correlation to supraspinatus tendon pathology. We also measure two common radiographic paramenters included Acromiohumeral interval (AHI) and Critical Shoulder Angle(CSA).

Acromiohumeral Interval (AHI) was measured on true AP radiograph with the patient in standing. The AHI was defined as the shortest distance measured between the inferior cortex (dense line) of the acromion and the humerus.

Critical Shoulder Angle (CSA) was measured on true AP radiograph with the patient in standing. The CSA was measured by drawing one line connecting the superior and inferior bony margins of the glenoid and then another line from the most lateral border of the acromion and intersected the first line at the inferior bony margin of glenoid. The angle between these two lines results in the CSA *(21)*.

Figure 1. — Radiographic film show measurement of distance from COR to Acromion (CA) and COR to tuberosity (CT) ; ATD=CA-CT, ATI=CA/CT.

ATI and ATD were measured on true AP radiograph with the patient in standing. The center of rotation (COR) was determined by picture archiving and communication system tools (PACS). First, a best-fit circle was drawn on the native humeral head. Second, perpendicular diameter lines were drawn, and their intersecting point was marked as the COR (Fig. 1).

Acromio-Tuberosity Index (ATI, CA/CT) was measured by distance from COR to most lateral part of acromion (CA) divided by distance from COR to most lateral part of greater tuberosity (CT).

Acromio-Tuberosity Difference (ATD, CA-CT) was determined from the difference between the distance from COR to most lateral part of acromion (CA) and the distance from COR to most lateral part of greater tuberosity(CT).

Two blinded radiologist and orthopedist separately measured ATI and ATD on conventional radiographs. Reviewer 1 specialized in musculoskeletal radiology. Reviewer 2 was a shoulder surgery orthopedist. ATI and ATD were measured electronically with a PACS workstation (Read version 5.2.1, Image Devices). On conventional radiographs, measurement was performed from the dense cortical bone at the inferolateral aspect of the acromion to the center of rotation of the humeral head. The shortest distance was measured. The same measurement was performed by reviewers 1 and 2.

Sample size was calculated from the preliminary data. Seventeen patients in supraspinatus tendon tear group and 9 patients in normal supraspinatus tendon group group. The required sample size was determined to be 65 subjects. This sample size allowed detection of a difference of 0.05 for ATI with 80% power and a 2-sided α value of 0.05.

For normal distribution data, continuous data were summarized as means and standard deviations and analyzed using Student's t tests or analysis of variance. Categorical variables (patient sex) were compared using Chi-square tests. For non-normal distribution data, median and IQR were calculated for continuous variables and compared by using Mann–Whitney U test. Interobserver correlation was evaluated to determine reliability using intraclass correlation coefficients (ICCs) (values greater than 0.6 are considered good agreement). For all statistical tests, $P < 0.05$ was considered significant. Statistical analysis was performed using SPSS software.

RESULTS

Three hundred and seventy-three patients were reviewed of which 182 individuals met the outlined criteria for inclusion in the study. The average age

Table I. — Demographic data of population in supraspinatus tendon tear and no supraspinatus tendon tear groups

Demographic data		No supraspinatus tendon tear (n=39)	Supraspinatus tendon tear (n=143)	*P*-value
Gender; n(%)	Male	14(7.7)	61(33.5)	0.447
	Female	25(13.7)	82(45.1)	
Age	Mean(SD), year	60.8(7.9)	58.6(6.7)	0.116
	Range, year	45-73	47-70	
Shoulder side	Right	20	82	0.436
	Left	19	61	

Table II. — Numbers and percent of lesions in each type of lesion on MRI

MRI		No.(cases)	No.(%)
No tear group		39	21.5%
Tear group	Bursal side tear	47	25.7%
	Intrasubstance tear	5	2.8%
	Articular side tear	32	17.6%
	Complete tear	59	32.4%
Total		182	100.0%

was 60.3 years (range 45-73 years). There was no difference in demographic between two groups as shown in Table I.

Interobserver correlation between two reviewers with these measurement methods was good (r=0.67 for ATD, r=0.66 for ATI). The study consisted of 143 patients with supraspinatus tendon tears and 39 patients with an MRI proven absence of supraspinatus tendon tear. All MRI images of the supraspinatus tendon were reviewed by an experienced musculoskeletal radiologist. The patients also sub-classified, by the same radiologist, according to supraspinatus lesion as no tear, bursal side tear, intrasubstance tear, articular side tear and complete tear (Table II).

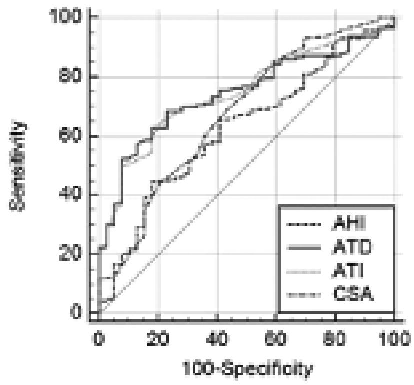

Figure 2. — Comparision of ROC curves between AHI, ATD, ATI and CSA for supraspinatus tendon tear.

The median of Acromio-tuberosity index (ATI) were 1.1 ± 0.1 in patients who had supraspinatus tear and 1.2 ± 0.1 in patients who did not have supraspinatus tear. The median of Acromio-tuberosity difference (ATD) were 2.3 ± 2.2 mm in patients who had supraspinatus tear and 4.3 ± 1.6 mm who did not have supraspinatus tear. The mean of Acromiohumeral interval (AHI) were 7.8 ± 2.3 mm in group with supraspinatus tear and 8.6 ± 1.9 mm in the group without supraspinatus tear. Eventhough

Table III. — Value of parameters in supraspinatus tendon tear and no supraspinatus tendon tear groups

Outcomes	Supraspinatus tendon tear (n=143)	No supraspinatus tendon tear (n=39)	*P*-value
ATD ;median(IQR)	2.3(2.2)	4.3(1.6)	<0.001
ATI ;median(IQR)	1.1(0.1)	1.2(0.1)	<0.001
AHI ;mean(SD)	7.8(2.3)	8.6(1.9)	0.059
CSA ;mean(SD)	42.1(4.9)	38.7(4.7)	<0.001

ATD=Acromio-Tuberosity Index ; ATI=Acromio-Tuberosity Difference ; AHI=Acromio-humeral Interval ; CSA=Critical Shoulder Angle ; IQR=Interquartile range ; SD=Standard deviation.

Table IV. — Area under the ROC curve (AUROC) in each parameters for supraspinatus tendon tear

Measurement	AUROC	Standard Error	95% Confidence interval	*P*-value
ATD	0.746	0.038	0.670-0.821	
ATI	0.748	0.039	0.672-0.824	0.7549(vs. ATD)
AHI	0.627	0.049	0.532-0.722	0.0036(vs. ATD)
CSA	0.678	0.050	0.605-0.746	0.2741(vs. ATD)

ATD=Acromio-Tuberosity Index ; ATI=Acromio-Tuberosity Difference ; AHI=Acromio-humeral Interval ; CSA=Critical Shoulder Angle.

Table V. — Sensitivity and specificity of cut-off value in each parameters for supraspinatus tendon tear

Measurement	cut off	Sensitivity	specificity
ATD	3	66%	78%
ATI	1.0	53%	92%
AHI	7	34%	85%
CSA	35	89%	20%

ATD=Acromio-Tuberosity Index ; ATI=Acromio-Tuberosity Difference ; AHI=Acromio-humeral Interval ; CSA=Critical Shoulder Angle.

AHI had no statistical difference between two groups (P = 0.059), the differences of ATI, ATD and CSA between the two groups were statistically significant (P < 0.001).(Table III)

Area Under the Receiver Operating Characteristic curve (AUROC) of ATD was 0.746. AUROC for ATI, AHI and CSA were 0.748, 0.627 and 0.678 respectively. (Fig 2 and Table IV) The sensitivity and specificity of ATI and ATD for supraspinatus tear were calculated at the best cut-off points in this study (Table V). AHI less than 7 mm, as in previous study, has 34% sensitivity and 85% specificity. CSA more than 35, as in previous study, has 89%, 20% for sensitivity and specificity respectively.

In addition, the bursal tear group were isolated for comparing with no tear group and other partial tear group (intrasubstance tear + articular side tear) in Table VI. Both ATI and ATD were statistically significant lower in bursal side tear group when compare to other tear partial groups. But there was no difference of mean AHI and mean CSA between bursal side tear group and other partial tear group (P = 0.083, 0.311 for AHI and CSA respectively)

DISCUSSION

Impingment shoulder can be correlated to several factors and leads to rotator cuff pathology *(15,28)*. Shubuta et al. correlated MRI in shoulder abduction position with shoulder impingement. They showed that patients with shoulder impingement syndrome had higher rate of encroachment of the acromion to rotator cuff than patients who had no impingement syndrome *(29)*. Acromion morphology has been described in many aspects. The slope of the inferior surface of the acromion on oblique coronal plane on MRI was described as "Lateral acromion angle" (LAA). Decreasing in LAA is significantly related to rotator cuff disease *(1,3)*. Also, the influence of large lateral extension of acromion on rotator cuff tear has been proposed by Nyffeler et al. *(25)*. They described it as the "Acromion index"(AI). A high AI corresponded to a large lateral extension of the acromion *(31)* and a rotator cuff tear *(17)*. More recently, Moor et al proposed the Critical Shoulder Angle (CSA) with the concept that a healthy shoulder undergoes balaned mechnical loading. This measurement combines the measuremnts of glenoid inclination and lateral extension of the acromion *(21)*.

In this study, the results showed statistically significant difference of ATI, ATD and CSA between the patients with a supraspinatus tendon tear group and without a supraspinatus tendon tear group (P < 0.05). Theoretically, regardless to the individual acromion shape and AHI, the correlation between the distances from COR to greater tuberosity (CT) and COR to acromion (CA) played an important role in

Table VI — Comparing each parameter between bursal tear and other tear groups

Measurement	no tear (n=39)	Bursal tear (n=47)	Other tear (n=37)	P-value (no tear vs bursal)	P-value (bursal vs Other)
ATD ; median(IQR)	4.3(2.1)	1.8(3.4)	3.2(3.1)	<0.001	0.009
ATI ; median(IQR)	1.2(0.1)	1.1(0.1)	1.1(0.1)	<0.001	0.016
AHI ; mean(SD)	8.6(1.9)	7.7(2.0)	8.6(2.7)	0.042	0.083
CSA ; mean(SD)	38.7(4.7)	40.8(4.3)	41.6(4.3)	0.036	0.311

ATD=Acromio-Tuberosity Index ; ATI=Acromio-Tuberosity Difference ; AHI=Acromio-humeral Interval ; CSA=Critical Shoulder Angle ; IQR=Interquartile range ; SD=Standard deviation.

supraspinatus tendon pathology. This measurement represents the shortest distance in the subacromion space while the shoulder is moving. This might help to assess the risk for a supraspinatus tendon tear in patients with shoulder pain. The ATD had a higher overall performance to predict a supraspinatus tendon tear compared to AHI (AUROC = 0.746 and 0.627 respectively, $P < 0.05$). One explantion for this discrepancy could be the differences in each individual patient in regards with the varying space under the acromion and the humerus size *(8,20)*. The subacromial space should be consistent with the humeral size in a patient.The ATD less than 3 mm had 66% sensitivty and 78% specificity to detectd supraspinatus tendon tear. In particular, bursal side tear group had lowest mean ATI and ATD among all groups. This result might represent how a narrow subacromial space could predispose a bursal side tear of the supraspinatus tendon.

The strength of this study is that it had an adequate sample size. However, there are some limitations to this study. The measurements in radiographs were static measurements and may not represent actual subacromion space in moving shoulders. The difference of ATI and ATD value among the groups were small and we were not able to relate these measurements to the supraspinatus tear size. Thus, clincal application from these results may be limited. The study was a case-control study and it may come with limitation and associated biases. We could not demonstrate if disproportion is a precondition of rotator cuff tear. However, the aim of this study was to emphasize that the disproportion between humeral head size and space under acromion had an important role in prediciting supraspinatus tears especially bursal side tear pattern. A prospective cohort study to include normal control group is warranted in a future study.

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