Normal acromio-clavicular joint: A prospective in vivo multidetector CT morphometric and biometric study.

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Aims and objectives

Acromioclavicular [AC] joint abnormalities are increasingly recognized across different age groups varying from traumatic separations in young athletes to degenerative disease in elderly [#1,#2].

Standard comparative AC joint radiographs with and without a stress [Figure-1] are needed to confirm clinical suspicion [#1,#3]. Use of ultrasound [#4,#5] and MRI [#6,7,#8] in diagnosis of AC joint abnormalities has been well-described in literature.

Concurrently, different therapeutic injections, arthroscopic and mini-surgical approaches are increasingly used to manage AC joint abnormalities [#9,#10,#11].

Moreover, in the setting of trauma, patient intolerance and lack of standardized positions for the axial imaging as well as inter-individual anatomic variations of AC joint perplex the situation and limit the utility of these imaging tools [#12].

Multidetector Computed tomography [MDCT] is a widely available superior imaging tool for addressing osseous changes, delineation of the articular surfaces and joint alignment with ultra-short scan time. These make it invaluable station in the work up of trauma patients [#13,#14].

The gross [#15], radiographic [#3], ultrasound [#4,#5] and MR [#6,#7] anatomic description of the AC joint have been described. However, there is a paucity of CT anatomy of AC joint in literature.

A recent cadaveric model [#16] addressed the morphology of AC joint in trial to improve the clinical efficacy and diminish the potential hazards of emerging arthroscopic and surgical procedures to this articulation. To our knowledge, there is no biometric CT data exist on the ACJ in English literature.

**Purpose:**
To determine the shape and measurements of normal acromio-clavicular [AC] joint on multi-detector computed tomography [MDCT].
Images for this section:

**Fig. 1:** Comparative bilateral AC radiographs during rest (A & B) and weight bearing (C & D) showing upward displacement of the left clavicle and uncover-age of more than 50% of acromial articular surface as well as widened coraco-clavicular distance.

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Methods and materials

*Study design and research ethics:*

Our local institutional review board approved carrying out this prospective cohort study including a group of volunteers and another group of patients with suspected AC separations.

*Study population inclusion and exclusion criteria:*

Volunteers:

Thirty-three normal AC joints from 25 volunteers aged between 20 and 40 years old were included. All sharing volunteers achieved the following criteria [a] No previous history of any shoulder girdle problem and/or complaint, [b] No history of connective tissue disease that may sub-clinically affects the ACJ, and [c] No deforming musculoskeletal or neurologic disorders involving the shoulder girdle.

Patients with AC dislocation:

Seventeen patients referred to our radiology department for imaging evaluation of their AC joints for [a] clinically suspected AC dislocation with radiologic evidence of separations, and [b] patient’s with shoulder-related complaints that MRI evaluation of their shoulders showed suspected AC sprain with no other remarkable findings of their MRI.

Patients with a primary clinical diagnosis of shoulder instability, associated shoulder girdle fractures, acromio-clavicular joint degeneration, os acromiale, previous AC joint surgery were excluded from the study.

*CT examinations:*

All studies were conducted on a 16-slice MDCT scanner. All patients were supine with the upper arm in neutral position close to the body, with slight forward flexion and medial rotation. A helical volumetric acquisition of the examined shoulder was acquired starting cranially above the AC joint down to the scapular mid-body; in both bone and soft tissue settings. Axial source images were reconstructed in coronal plane, centered on the acromioclavicular joint [Figure-2] in a manner similar to previously described in MR literature [##6,7].

All studies were individually evaluated by two readers; an experienced MSK radiologist with 18 years of experience and a general radiologist with 20 years of experience. The readers were blinded to both patient’s demographics and referral data. The following variables were assessed on both axial source images and coronal reconstructs:

*Morphometric data:*
The ACJ articulating surfaces as well as their parent osseous structures were evaluated for:

a) Directions of the articular surfaces in both source axial and reconstructed coronal images are determined according to a graphical anatomic compass.

b) The visibility of relevant ligamentous structures was assessed; including: [i] acromioclavicular [superior and inferior portions] ligaments, [ii] coracoclavicular [conoid and trapezoid portions] ligaments, and [iii] coracoacromial ligament. This followed their well-established MR imaging and anatomic literature descriptions [#6,#7,#15].

c) The trapezoid and deltoid muscles were evaluated for presence or absence of tears, as they are parts of the popular Tossy [#17] and Rockwood [#18] classification of traumatic AC separations. The rotator cuff was not considered in this study approach.

**Biometric measurements:**

Radiographic comparable measurements [#1,#7,#17,#18,#19,#20#] of the AC joint were obtained to asses both vertical and axial coraco-clavicular translation, including:

**AC joint space distance:**

On source axial images in the mid joint where the articular facets are well depicted, the acromioclavicular side to side distance is measured at both the most anterior and posterior point on each facet to represent the anterior and posterior joint lines; respectively. [Figure-3]

**Axial AC joint space angle:**

It is formed by the intersection of the tangential lines of the acromioclavicular articular facets on source axial images. [Figure-4] this was aiming to assess subtle axial translation.

**The gleno-acromio-clavicular angle [GACA]:**

On true axial CT image in neutral position, the GACA, described by Tauber et al [#12], is formed by the intersection of the line drawn through the glenoid articular surface and the anterior AC joint line described before. [Figure-5]

**Coraco-Clavicular [CC] distance:**

On the coronal reconstruct images of the mid AC joint mimicking the shoulder AP radiograph, the distance between the coracoid base and 90 degree opposite point on the clavicular undersurface was measured. [Figure-6] This was aiming to assess vertical translation.

**Data processing and statistical analysis:**
Data Processing and analysis was performed using the Statistical Package for Social Sciences [SPSS version 18]. For qualitative variables, Chi square test; Monte Carlo test and Fisher's Exact test of significance were used. For normally distributed quantitative variables student T-test was used and for skewed quantitative variables non parametric Mann-Whitney test of significance was used. 5% level of significance was used for interpreting all results.
Fig. 2: MDCT coronal reconstruction technique. [A] The coronal reconstruct is prescribed from source axial image along a line connecting the coracoid process tip to the lesser tuberosity to be parallel to the AC joint plane. [B] The AC joint articular surfaces will be profiled.

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Fig. 3: CT scan of a normal left ACJ in bone window setting showing side to side measurements along the anterior and posterior joint lines

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Fig. 4: CT scan of a normal left ACJ in bone window setting showing the measurement of axial AC angle formed by the intersection of the ACJ articular facets surfaces tangential lines.

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**Fig. 5:** Axial CT scan; of a volunteer; at the level of coracoid process in bone window setting showing the measurement of Gleno-Acromio-Clavicular Angle (GACA) angle formed by the intersection of the tangential line connecting the humeral lesser tuberosity (LT) and coracoid tip (paralleling the ACJ line) and a line tangential to the glenoid articular facet.

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Fig. 6: Coronal reconstructed image at the level of coracoid base showing measurement of the coraco-clavicular distance between the coracoid base and the opposite vertical point on inferior clavicular cortex.

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Results

Demographic analysis:

The mean age of the volunteers and diseased subjects was 32.94 ± 10.74 and 34.94 ± 9 years, respectively.

There was no statistical significance difference between the volunteers and diseased subjects as regard age and sex [p= 1 and 0.51; respectively].

Morphometric variables:

The acromial facet antero-medial direction was the commonest finding in both volunteers and diseased subjects. On the other side; the lateral direction of clavicular articular facet was commoner in volunteers compared to the antero-medial direction in diseased groups. However, these differences in both volunteers and diseased subjects were not statistically significant [p=0.8 and 0.7; respectively].

The visibility of the capsular stabilizing ligaments as well as extrinsic stabilizing ligaments was the commonest response for both readers in both groups [Figures 7 to 10]. However, no statistical significance was detected between both volunteers and diseased subjects as regard any of the tested morphometric variables. [Table-1].

Table-1: visual assessment of acromioclavicular ligamentous stabilizers visibility among the study population.

<table>
<thead>
<tr>
<th>Morphometric variable</th>
<th>Visibility</th>
<th>Volunteer</th>
<th>Diseased</th>
<th>Test of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N [%]</td>
<td>N [%]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior AC ligament</td>
<td>Not seen</td>
<td>3 [9.1]</td>
<td>4 [23.5]</td>
<td>P=0.2</td>
</tr>
<tr>
<td></td>
<td>seen</td>
<td>30 [90.9]</td>
<td>13 [76.5]</td>
<td></td>
</tr>
<tr>
<td>Inferior AC ligament</td>
<td>Not seen</td>
<td>4 [12.1]</td>
<td>5 [29.4]</td>
<td>P=0.24</td>
</tr>
<tr>
<td></td>
<td>seen</td>
<td>29 [87.9]</td>
<td>12 [70.6]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>seen</td>
<td>32 [97]</td>
<td>16 [94.1]</td>
<td></td>
</tr>
<tr>
<td>Conoid ligament</td>
<td>Not seen</td>
<td>0 [0]</td>
<td>1 [5.9]</td>
<td>P=0.34</td>
</tr>
<tr>
<td></td>
<td>seen</td>
<td>33 [100]</td>
<td>16 [94.1]</td>
<td></td>
</tr>
<tr>
<td>Coracoacromial ligament</td>
<td>Not seen</td>
<td>3 [9.1]</td>
<td>2 [11.8]</td>
<td>P=1</td>
</tr>
<tr>
<td></td>
<td>seen</td>
<td>32 [97]</td>
<td>16 [94.1]</td>
<td></td>
</tr>
</tbody>
</table>
Biometric variables:

The mean anterior side to side measurements of the anterior axial joint line were 0.59±0.27 and 0.88±0.3 cm for the volunteer and diseased subjects; respectively. On the other hand, the mean counters of the posterior axial joint line were 0.26±0.11 and 0.5±0.39 cm for the same groups; respectively. The axial side to side measurements of the AC joint in direct axial plane showed significant statistical difference between both volunteers and diseased subjects [p=0.002 and 0.04 for the anterior and posterior joint lines; respectively]. Thus, side to side measurement values greater than 0.59±0.3 cm; anteriorly; and 0.26±0.1 cm; posteriorly; raise the possibility of diagnosing AC separation in the proper clinical settings.

On the other hand, there was no statistically significance difference [table-2] between the volunteers and diseased subjects regarding the coraco-clavicular distances, AC and GAC angles.

Table-2: Objective assessment of tested acromioclavicular Morphometric data among the study population.

<table>
<thead>
<tr>
<th>Biometric variable</th>
<th>Volunteer Mean ± SD [in Cm]</th>
<th>Diseased Mean ± SD [in Cm]</th>
<th>Mann-Whitney Test of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC side to side measurements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>0.589±0.27</td>
<td>0.88±0.3</td>
<td>Z= -3.146</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P= 0.002*</td>
</tr>
<tr>
<td>Posterior</td>
<td>0.262±0.11</td>
<td>0.49±0.39</td>
<td>Z= -2.038</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P=0.04*</td>
</tr>
<tr>
<td>GACA</td>
<td>50.82±8.26</td>
<td>45.94±11.57</td>
<td>Z= -1.345</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P= 0.18</td>
</tr>
<tr>
<td>Coracoclavicular distance</td>
<td>0.73±.41</td>
<td>0.77±0.31</td>
<td>Z= -0.799</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P=0.42</td>
</tr>
<tr>
<td>AC angle</td>
<td>26.55±14.71</td>
<td>27.44±12.44</td>
<td>t= -0.672</td>
</tr>
</tbody>
</table>

*significant p-values.*

**Inter-observer variations:**

There was no statistically significant difference for all tested morphometric and biometric variables of the examined AC joints between both readers and for both study groups. This concordance indicates the absence of systematic error and test reliability.
Fig. 7: Coronal reconstructed CT images of a volunteer with parallel acromio-clavicular articular surface in soft-tissue window settings depicting the superior and inferior acromio-clavicular ligaments.

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**Fig. 8:** Coronal reconstructed CT images in bone window settings of a subject with GII Rockwood AC separation. The conoid and trapezoid ligaments are well depicted in a comparable manner to those seen on PDW coronal MR image in another healthy subject in Figure-9.

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Fig. 9: Coronal proton-density-weighted image shows the conoid and trapezoid portions of the coracoclavicular ligament.

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**Fig. 10:** Coronal reconstructed CT images of a volunteer with parallel acromio-clavicular articular surfaces in soft-tissue window settings depicting the coraco-acromial and trapezoid ligaments.

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Conclusion

Discussion:

Acromioclavicular joint injuries represent a common affliction across different age groups especially in young athletes [#1].

In concordance with recent literature data [#21,#22], our study showed high prevalence of acromioclavicular injuries among young males as in our group of clinically suspected AC injury.

Proper grading of the AC injuries relied upon detection of joint widening on conventional radiography [#3]. However, inconsistency about imaging planes and debate of applying stress [#23]; especially in traumatized patients; bias the sensitivity and specificity of this imaging tool. One the other hand, role of computed tomography [CT] is well established in skeletal trauma [#13,#14].

The current study showed no significant statistical differences in the frequency of AC joint articular facet orientations. This is comparable to the results of Colegate-Stone et al [#16] who found no significant difference between three morphologic shapes of the AC joint in their CT analysis correlated with cadaveric dissections.

The capsular [superior and inferior acromio-clavicular] as well as extra-capsular [coraco-clavicular and coraco-acromial] ligaments were successfully identified in the majority of our study population in both groups. The interobserver agreement validates the utility of MDCT in identifying the integrity of these ligaments in a comparable way to their MR descriptions [#6,#7,#8].

The current study assessed the mean AC joint distances at the anterior and posterior joint lines off the articular facets in true axial plane. The derived results showed nearly double measurements at the anterior than the posterior joint lines. These measurements portray a near conical shape of the AC joint in axial plane. Moreover, there was a statistically significant difference of these measurements between volunteers and subjects with AC joint separation. The inter-observer agreements validate its use as reproducible measurements not to miss the AC joint separation on MDCT examinations of traumatized patients.

These measurements may be more practical than using the integrals of cranio-caudal AC joint inter-space measurements in earlier literature [#19,#20] with lack of standardized views and impracticality in trauma settings.

The trapezoidal and conoid components of the coraco-clavicular ligament are well recognized AC joint stabilizers [#1,#17,#18]. The normal coraco-clavicular distance is
11-13 mm on plain radiography [#1,#17,#18,#19,#20,#23]. Detection of coraco-clavicular ligament injury is a main determinant in patient management [#1,#17,#18,#19,#20,#23].

In our model, we did not found significant difference between volunteers and subjects with AC separations as regard coraco-clavicular distance. This could be explained by lack of gravity effect in radiographic examinations held in upright position compared to supine position on our CT protocol with no stress.

We proposed a new angular measurement, the axial acromio-clavicular angle in a similar way to other skeletal regional measurements [#25]. We aimed to test its validity to detect axial acromioclavicular translation in subjects with AC separation. Its mean value in normal subjects lying supine with neutral arm position was 26.55±14.71. However, no significant difference was found in subjects with AC separation. Further evaluation may be needed as this angle may be different if scanning patients under stress as in internal rotation.

Our study evaluated the glenoacromioclavicular angle [GACA] recently described by Tauber et al [#12] to quantify horizontal instability of the distal clavicle on dynamic radiography in supine patients. We found its mean values are slightly lower in volunteers with no statistically significant difference from the diseased subjects. This conflict may be expounded by the different methodology where our subjects were examined in neutral resting position.

We acknowledge some limitations to the current study. Our sample size is small as we were concerned with radiation exposure issues. Our study lacks surgical confirmation in the diseased group. Further assessment with a larger sample might powerfully validate our results.

Also, our subjects were scanned in the supine position with the arm resting in neutral position. This eliminated the gravity-assisted displacement classically used in radiographic classification schemes of AC separation. Further studies assessing these measurements while the peri-articular ligaments under stress e.g. in internal rotation may be desired for more validation of clinical applicability of the method. Lack of MR correlation of AC capsular and peri-articular ligaments may be another limitation. Yet the imaging anatomy of these structures is already well established in imaging, orthopedic and anatomic literatures.

The morphometric parameters and angular measurements may be biased by the variable bony anatomy, associated dysplasias, fractures and/or concomitant arthritic changes. Also we did not assess the intra-observer variability of these variables.

**Conclusion:**

In spite of these limitations, our study confirms the great variability of AC joint articular facet morphology yet it portrayed a near conical morphology of the AC joint in axial plane. The capsular and peri-capsular AC joint ligaments could be depicted on CT studies.
Axial anterior and posterior AC joint distances greater than 0.59± 0.3 and 0.262± 0.1 cm; respectively are predictors for AC separation on axial CT images of supine patients in neutral resting position.
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