International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

Arthroscopic and Radiographic Measurements of Coracoid Base in Patients who Underwent Arthroscopic Assisted Acromioclavicular Joint Stabilization

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Abstract: ***Acromioclavicular joint injuries are common cause for shoulder pain among young adults and athletes. There are shift of interest towards anatomical ACJ reconstruction recently owing to perceived biomechanical and clinical advantages. Yet, double tunnels in coracoid process resulting in more complications especially iatrogenic fracture. Arthroscopic and radiographic measurements of base of coracoid process in 42 patients who underwent arthroscopic ACJ reconstruction was obtained. The mean length was then compared to each other and with patient's demographic data (age, gender, ethnicity and BMI). The data were also compared to previously published studies. The mean arthroscopic measurement of coracoid base width was 19.21±1.38mm. There was significant difference between arthroscopic and radiographic measurement, with the latter having wider length, 22.30±1.48mm. Male subjects were found to have wider coracoid base width as compared to female subjects. There was no significant difference observed in between ethnicity groups and no association found in between age and BMI with regards to coracoid base width. The mean coracoid base width in Malaysian population is smaller as compared to previous studies performed on Caucasian populations. Given the potentially narrower coracoid base width of the Malaysian population, extra precautions are required to minimize the risk of iatrogenic coracoid fractures.***

Keywords: Acromioclavicular joint, ACJ injury, Rockwood classification, arthroscopic assisted ACJ stabilization, coracoid base measurement.

1. Introduction

Acromioclavicular joint injuries are common cause for shoulder pain among young adults and athletes. The most common mechanism of injury is a fall directly onto the acromion, with the arm adducted. A fall on an out stretched hand and a downward force on the upper extremity have also been implicated in ACJ injuries. Rockwood classification is the most commonly used classification in ACJ injuries. It classifies ACJ injuries into Type I - VI taking into account not only the acromioclavicular joint itself but also the coracoclavicular ligament, the deltoid, and trapezius muscles, whilst considering the direction of dislocation of the clavicle with respect to the acromion. The vast majority of AC separations (grades I, II, III) are managed well with conservative treatment. Grades IV-VI are uncommon and are usually the result of a very high-energy injury which may require surgical intervention. Yet, there are still lack of a standard surgical technique in treating these injuries, with more than sixty different surgical reconstruction techniques described [1].The common operative techniques, includes coracoclavicular (CC) screw fixation, coracoacromial ligament transfer, and numerous methods of anatomical CC ligament reconstruction. The chronicity of the injuries will also influence the operative decision, with acute means less than 2 weeks after the injury and chronic more than 2 weeks.

Recent advances in arthroscopic techniques and improved implants coupled with better understanding of ACJ anatomy and biomechanics has led to the development of arthroscopic ACJ stabilization procedure. On the basis that the coracoclavicular (CC) ligaments are considered the prime suspensory restraint of the AC joint against superior and posterior translation of the distal clavicle with respect to the scapula, there has been a shift interest towards anatomic coracoclavicular ligament reconstructionby addressing the CC ligament complex (Conoid and trapezoid ligament) [2]. Due to the unique anatomical alignment and different function of conoid and trapezoid ligament, few authors have proposed anatomical reconstruction of the ACJ by reconstructing the two ligaments separately [3,4,5,6].

Stability and function of ACJ is theoretically more stable if the two ligaments are reconstructed separately. This technique has been biomechanically tested and was established as a successful time-zero biomechanical construct [7]. The reconstruction technique led to favorable in vitro results with equal or even higher forces than native ligaments. Initial stability in the superoinferior as well as in the anteroposterior plane was significantly higher than in the native CC ligaments. Although the ligaments are not repaired with this technique, they are expected to heal along the suture material and thus provide lasting stability. By restoration of the normal AC joint anatomy, ligament remnants are brought into contact to allow for healing. For functional outcomes, Venjakob AJ et al reported satisfactory mid-term clinical and radiological outcomes in his study with 58 months follow up [5].

In order to reconstruct conoid and trapezoid ligament separately, the surgeon is required to drill two osseous tunnels in the clavicle as well as the coracoid process. Therefore, this modern technique has introduced new

complications such as fracture of the clavicle and coracoid process. A much higher rate of complications is reported in anatomical reconstruction of the CC ligaments as compared to other techniques [8].

Accurate description of surgical anatomy is therefore important to prevent iatrogenic fracture during drilling the tunnels, particularly coracoid process. However, there is limited normative data on the size of the base of coracoid process in local population. We anticipate the size of coracoid process in Asian population to be smaller than the published normative value as evident in the publication by Xue et al[9], the mean width of coracoid process among Chinese is smaller than a study conducted in America [10] where predominantly the population is Caucasian and African-Americans – 14.7 ± 2.7mm vs. 24.9±2.5mm respectively, both studies are cadaveric measurement. More recent studies using CT scan measurement also produced similar result, in which the width of coracoid process in Asian populations are reported to be smaller [11,12]. Thus, possibly increasing the risk of iatrogenic fracture if more tunnels are to be drilled in Asian population.

Therefore, with proper knowledge of the width of coracoid base in Asian populations, which is thought to be smaller than Caucasians, surgeons will have a clearer picture on which surgical technique to be used to treat ACJ injuries which will reduce the risk of iatrogenic fracture of the coracoid process. The objective of our study is to determine the average size of the coracoid base width with arthroscopic and radiographic measurement in in patients who sought treatment for ACJ injuries in our hospital. Being a tertiary referral center, our patients could represent the normal population of Malaysia. We hypothesized that there is no difference in the size of coracoid base between our patients and the Caucasians.

2. Methods

All patients who underwent arthroscopic acromioclavicular joint stabilization surgery during the period of Jan 2013 till Dec 2020 in Hospital Kuala Lumpur were included in our study.Ethical approval for this study was obtained from the Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia(NMRR-21-1000-59949). Patients' name who underwent arthroscopic ACJ stabilization surgery will be traced from Departmental census and their medical records and radiological films were traced through medical record HKL. Information gathered include demographic data and details of injury (Date and mechanism of injury, date of presentation, management and classification of injury).Since 2013 it has a been a routine to measure the coracoid base for all patients who underwent arthroscopic assisted ACJ stabilization in this hospital therefore this data was readily available in the patient's clinical notes. Patients with previous fracture of the coracoid process and open ACJ stabilization surgery were excluded.

Arthroscopic measurement of coracoid process using arthroscopic graduated probe of 1 mm increment was conducted by the senior authors during arthroscopic assisted stabilization surgery. This was done by introducing the measuring tool from the antero-superolateral portal while viewing from the standard anterior portal.The measuring starts when the hook end of the probe reaches the most medial border of the coracoid process at the base. The base is identified as the transition area where the coracoid process angles down to join the scapula body. Reading is taken from the most medial border to the most lateral border at this level. The average of 3 readings were documented as Arthroscopic Measurement (AM) in mm.

Radiographs with standardized projection (standard AP view) were reviewed at conducting the study and the coracoid width measured using a ruler of 1 mm graduation. A line is drawn from the most medial border of the coracoid process at the base to the most lateral border. The base on this x-ray view is defined as the transition area where the coracoid process angles down to join the scapula body.The measurement was performed by two different investigators at different time, blinded to Arthroscopic measurement. The average of the two readings was calculated by the principal investigator and will be documented as Radiographic measurement (RM) in mm.

The obtained data was analyzed descriptively and statistically using SPSS version 23.0. The difference in between arthroscopic and radiographic measurement and the association in between demographic characteristic (age, gender) and coracoid measurement were analyzed using independent t-test. Whereas the correlation in between age, BMI and coracoid measurement is determined using Pearson correlation. A p-value of < 0.001 is considered as significant.
Results

3. Result

A total of 42 patients (39 males; 3females; mean age 39.9 years; range 25-68 years) were included in this study. The vast majority ethnicity in our study is Malay (n=32, 76.2%), followed by Chinese (n=8,19%) and Indian (n=2, 4.8%).The majority of injuries were obtained via a direct blow to the shoulder during a road traffic accident (n=33, 78.6%) whereas injuries sustained during sport comprised of only six patients (14.3%) and three patients fall from height (7.1%).

There were only 15 patients (35.7%) operated acutely (<2 weeks from the time of injury) and 27 patients (67.3%) operated more than 2 weeks from the time of injury.Twenty (47.6%) patients were classified to have a Rockwood type V injury while Rockwood type IV and type IIIinjury has 14 patients (33.3%) and 8 patients (19%) respectively. We did not encounter any Rockwood type VI injury during the period of our study.

The average arthroscopic measurement of coracoid base width in this study was 19.21 ±1.38mm and radiographic measurement was 22.30 ± 1.48mm (Table 1). There was significant difference in between arthroscopic and radiographic measurement ($p<0.001$) (Table 2).

Based on further analysis (Table 3 and Table 4), male and female have significant difference ($p<0.001$) for both type of measurement. However, no significant difference ($p>0.05$)

between ethnicity group for both type of measurements. There is no significant correlation between age and BMI with coracoid measurement (p>0.05) (Table 5).

Table 1: Coracoid data measurement

Measurement	Millimeter (mm) Mean (sd)
Arthroscopic measurement	
AM1	19.31 (1.60)
AM2	19.24 (1.79)
AM3	19.07 (1.47)
AM average	**19.21 (1.38)**
Radiographic measurement	
Rater 1	22.17 (1.34)
Rater 2	22.43 (1.54)
RM average	**22.30 (1.48)**

Table 2: Different between arthroscopic measurement and radiographic measurement

Measurement	Millimeter (mm) Mean (sd)	Mean diff. (sd)	p-value
Arthroscopic measurement	19.21 (1.38)	3.09 (0.92)	< 0.001*
Radiographic measurement	22.30 (1.48)		

Independent t-test
*Significant if p value <0.05

Table 3: Demographic characteristics and arthroscopic measurement

Characteristics	Measurement Millimeter (mm) Mean (sd)	p-value
Gender[a]		
Male	19.49 (0.94)	<0.001*
Female	15.56 (1.02)	
Ethnicity[b]		
Malay	19.11 (1.54)	0.486
Chinese	18.67 (0.00)	
Indian	19.71 (0.60)	

[a]Independent t-test
[b]One-Way ANOVA test
*Significant if p value <0.05

Table 4: Demographic characteristics and radiographic measurement

Characteristics	Measurement Millimeter (mm) Mean (sd)	p-value
Gender[a]		
Male	22.58 (1.10)	<0.001*
Female	18.67 (0.76)	
Ethnicity[b]		
Malay	22.17 (1.65)	0.561
Chinese	22.25 (0.35)	
Indian	22.81 (0.59)	

[a]Independent t-test
[b]One-Way ANOVA test
*Significant if p value <0.05

Table 5: Correlation between Age, BMI and coracoid measurement

Characteristics	Measurement			
	Arthroscopic		Radiographic	
	r	p-value	r	p-value
Age (years)	0.040	0.800	-0.155	0.325
Body Mass Index (kg/m^2),	-0.229	0.145	-0.241	0.124

r: correlation coefficient
Pearson correlation
*Significant if p value <0.05

4. Discussion

Several cadaveric and radiographic studies discussing the anatomy of the coracoid process have been reported (Table 6). In our study, a cohort of 42 patients with high grade ACJ disruption is presented. Males of the young productive age group more commonly suffered from high grade ACJ disruption than females, as shown in previous studies [13,14]. Similarly, most of our patients (n=27, 64.3%) belong to the young age group (below 40 years old). There were also only 3 female patients in our cohort.(Male: Female ratio of 13:1).

The most common mechanism of injury in our cohort was road traffic accident (n=33,78.6%). This is contradicted to other reports [15,16,17] where sport injury was the most common mechanism. We reported only 6 patients (14.3%) who sustained ACJ disruption during sport activity. This may be due to lesser collision sport activity among our population (Example rugby, ice hockey, boxing and American football), which may contribute to a direct force of impact to anterior shoulder.

Amongst the high grade ACJ injuries, Rockwood type V injuries are the most frequently reported and Rockwood type VI injuries are very rare [15]. The commonest Rockwood type injury in our study is Rockwood type V (n=20,47.6%) and there is no patient presented with Rockwood type VI.

Known as the safe-zone 'lighthouse' during surgery, this tiny portion of the scapula has been widely used by surgeons to treat acromio-clavicular (AC) joint disruptions, Bankart lesion in shoulder instability and many more shoulder conditions [10,12,18,]. However, these surgeries may also contribute to fracture of the coracoid process and implant failure. Hence, more journals are now focusing on the anatomy of the coracoid process.

With current shift of interest towards anatomical ACJ reconstruction owing to perceived biomechanical and clinical advantages, twotunnels are being drilled into this tiny portion of bone in the scapula. With limited normative data on the size of coracoid base width in local

Table 6: Previously reported Coracoid Base Width measurements

Study	Year	Reported Coracoid base width (mm)	Type of study	Purpose of study	Population
Rios et al	2007	24.9±2.4	Cadaveric	CC ligament reconstruction	Caucasian, African-American
Salzman et al	2008	14.1 ±2.9	Cadaveric	Anatomic study	Caucasian
Coale et al	2013	27.9±2.5	CT scan	CC ligament reconstruction	Caucasian

Xue et al	2013	14.7± 2.7	Cadaveric	Anatomic study	Asian
Fathi et al	2017	22.82±0.78 – 25.48± 1.45	Cadaveric	Anatomic study	Asian
Imma et al	2017	18.96± 3.71	CT scan	Anatomic study	Asian
Jen et al	2020	14.8 ±2.54	CT scan	CC ligament reconstruction	Asian
This study	2021	19.21±1.38 22.30 ±1.48	Arthroscopic measurement Radiographic measurement	CC ligament reconstruction CC ligament reconstruction	Asian Asian

population, risk of iatrogenic fracture would be anticipated.

Rios et al[10]performed adry osteology studyof Caucasian and African-American population of 120 cadaveric clavicles and scapulae to define the anatomy specific to anatomical ACJ reconstruction and determined that the mean medial to lateral width of the base of the coracoid was 24.9 ± 2.4mm. Coale et al[19], in their study with CT scan measurement of base of coracoid process in Caucasianpopulation, showed even larger value, with mean measurement of 27.9 ± 2.5mm. In our study, the mean arthroscopic measurement of the coracoid base width is 19.21 ± 1.38mm, which is significantly smaller than their reported values, raising the possibility that the Asian coracoid base width is narrower.

Imma et al[12] studied coracoid process morphology using 3D-CT imaging in a Malaysian population and they report a mean coracoid base width of 19.96 ± 3.71mm whichcorresponds to our reported value.

Xue et al [9] reported aneven smaller coracoid base width of 14.7 ± 2.mm in their study with cadaveric measurement while studying coracoclavicular ligament attachment in Chinese population. Their reported value is significantly smaller than our study and Caucasian. This is supported by Jen et al [11] who described anatomy of coracoid process and clavicle using CT scan measurement, with mean coracoid width base of 14.8 ± 2.54mm.

In a cadaveric study describing anatomic variation in morphometry of coracoid process among Asian population, Fathi et al [20] measured coracoid base width of different ethnicity including Indian, Chinese and Myanmarese population and reported mean measurement of 25.48 ± 1.49mm, 23.90 ± 0.76mm and 22.82 ± 0.78mm respectively. Their reported value is significantly larger than other studies involving Asian population. This inconsistency may be because these studies measured the width from different defined points or the point was undefined.

In this study, there is significant difference in between Arthroscopic and Radiographic measurement ($p<0.01$). Radiographic measurement is larger as compared to arthroscopic measurement, 22.30±1.48mm vs 19.21±1.38mm respectively. This may be due to the magnification effect of the x ray image. Hence, x ray measurement to predict coracoid base width before the surgery must be used in caution.

There is a difference detected in coracoid base width measurement with regards to gender ($p<0.01$)in present study (Table 3). Female coracoid base width is smaller as compare to male measurement, 15.56±1.02mm vs 19.49± 0.94mm respectively. All studies on table 6 (except Coale et al [19]) also showed similar finding, withmale coracoid base width is generally larger than female. Therefore, surgeons must keep this in mind while performing an anatomical ACJ reconstruction in female patients.

However, we could not find any significant difference between coracoid base width and other demographic data (ethnicity, age and BMI). Rios et al [10] in their study also reported no difference in between Caucasians and African-American group. In the other hand, Fathi et al [20] has showed that there is difference in coracoid size in between different ethnicity. In their study, Indian ethnicity has significant larger coracoid base width as compared to Chinese and Myanmarese ethnicity.

Being a tertiary center for the country, our patients could represent the normal average population for Malaysians. The fact that this country is multiethnic, this data could be used to represent the Asian population.This is further supported by our data showing no significant difference between coracoid base width and ethnicity.

To our knowledge, we were unable to identify any studies measuring coracoid base via arthroscopic technique. Arthroscopic measurement eliminates any possibility of measurement error arise from measurement from a CT image. The measurement in our study is performed in a live patient and with direct visualization of the coracoid base from arthroscopy.

We acknowledge that our study has several limitations. Firstly, being a retrospective study, magnification of radiographs could not be determined. We utilize the standard magnification used in performing plain radiographs in our hospital. The sample size is also small, comparing the measurements in three different ethnic groups. Finally, most of the patients included in our study is male, because they are the most common group involved in motor vehicle accident.

5. Conclusion

In conclusion, there is a difference in the size of coracoid base between our patients and the Caucasians. Our study showed that Asian coracoid base width is smaller than Caucasians. Therefore, the risk of iatrogenic fracture is higher if two tunnels are to be drilled in anatomic ACJ reconstruction in Asian populations. Moreover, the width of coracoid base is also smaller in female patients, subjecting them to a much higher risk of iatrogenic fracture. There were no significant association in between coracoid base width and other demographic data (age, ethnicity and BMI).

6. Acknowledgement

We would like to thank the Director General of Health Malaysia for his permission to publish this article

7. Conflict of interest

We have no conflict of interest in conducting this research.

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