Original Article

Reliability of a Novel Measurement Technique for using Clavicular Length to Predict the Location of the Conoid and the Trapezoid Bundles

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Background: Accurate and reliable location of a coracoclavicular ligament needing reconstruction could help in the restoration of normal biomechanics.

Objective: Reliable measurement of the distances among bony landmarks on the clavicle can lead a good correlation and predict the exact location of the coracoclavicular ligament.

Study design: Descriptive laboratory study.

Materials and Methods: Formalin-fixed cadavers were dissected, then clavicle borders and coracoclavicular ligament attachments were identified. Total clavicular length (CL the distance from conoid (ConL) and trapezoid (TrapL) ligaments to the distal end of the clavicle were measured independently by two observers. All parameter measurements and specimen characteristics were recorded. The measurement technique used in the study was analyzed for intra and inter-observer reliability. Correlations of distances between baseline characteristics landmarks were analyzed with regression analysis

Results: Fifteen subjects were included in the study (13 males and 2 females, mean age 70.5±13.7 years) 10 right and 5 left sides. The mean length of the clavicle was 14.4 centimeters. The distances from the center of the conoid and of the trapezoid ligaments to the distal end of the clavicle were 3.9±0.5 and 2.3±0.3 centimeters, respectively. The mean distance between the conoid and trapezoid ligaments was 1.6±0.9 centimeters. Inter-observer reliability was good, with no statistically significant differences in clavicular length or conoid length (95% confidence interval -0.797 to 0.691, *p*-value 0.2749 and -1.511 to 1.871, *p*-value 0.2153, respectively). The correlation between clavicular length and other parameters (gender, side, conoid and trapezoid length) also showed no statistical significance. There was, however, a statistically significant difference in the correlation of the distance between the lateral clavicle and conoid bundle as well as the trapezoid bundle (coefficient 0.87 and standard error 0.30. The adjusted R-square was 0.3420, and *p*-value was 0.013).

Conclusion: The measurement technique in the present study showed the good reliability. The clavicular measurements described in the present study are statistically significant predictors of the location of the conoid and trapezoid bundles.

Keywords: Coracoclavicular ligament, Location, Correlation coefficient and bony landmark

J Med Assoc Thai 2018; 101 [Suppl. 3]: S9-S14
Full text. e-Journal: http://www.jmatonline.com

Coracoclavicular ligamentous injury occurs with results in cases of high-grade acromioclavicular joint (ACJ) separation. Two ligamentous components, the conoid and trapezoid bundles, are at different locations separated by interligamentous space. These ligaments are usually resorbed after 4 to 6 weeks post-injury and cannot be identified by intra-operative visualization[1,2]. Many anatomical research studies have tried to identify bony landmarks and measurement techniques which can help locate the conoid and trapezoid ligaments[3-6]. Studies searching for correlations between relevant parameters have reported

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How to cite this article: Saengpetch N, Woratanarat P, Saitongdee P, Kijkunasathian C, Limitloahaphan C. Reliability of a Novel Measurement Technique for Using Clavicular Length to Predict the Location of the Conoid and the Trapezoid Bundles. J Med Assoc Thai 2018;101;Suppl.3: S9-S14.

inconsistent results in the absence of sufficiently reliable measurements[3,6,7]. For example, Xue et al[7] reported on a dissection study of Chinese cadavers, but that study did not conduct the reliability of measurement include an evaluation of the reliability of the measurements. Another study, performed by Takase[8], concluded that the distribution of clavicular attachments was different in each patient and that there was no good measurement correlation technique. The objectives of this research were to demonstrate the reliability of coracoclavicular ligament measurements and to use regression analysis to identify correlations between conoid, trapezoid ligament, and clavicular length.

Materials and Methods

Fifteen formalin-fixed cadavers were obtained from the Department of Anatomy, Faculty of Science, Mahidol University. The bodies included all had an identifiable coracoclavicular ligament with intact clavicle and coracoid process. Pre-existing AC separation or previous fractures presented both sides of shoulders of either shoulder were excluded. Gender and age data were recorded.

The dissections were performed by the authors. All muscles around the clavicle were detached. Pectoralis muscles were also detached and the coracoid process was identified. Coracoacromial and coracohumeral ligaments were sacrificed at their coracoid insertions to access the coracoclavicular ligament. The superior and anterior acromioclavicular joint capsules were removed to identify the distal end of the clavicular border. The undersurface of the distal end of the clavicle was dissected, the conoid and trapezoid bundles of the coracoclavicular ligament were cut at their clavicular insertion. Footprints of both ligaments were identified and painted with a marking pen. The centers of both ligaments were located at half the distance between the most medial and lateral borders of the painted area. The clavicular ridge lay in the middle of between the two ligaments (Figure 1).

A vernier caliper was used to measuring distances in centimeters (Figure 2). Two observers independently measured the three parameters: the distance from the medial to the lateral edge of clavicle (clavicular length-CL), the distance from center of the conoid bundle to lateral clavicle (conoid length-ConL), and the distance from the center of the trapezoid bundle to the lateral clavicle (trapezoid length-TrapL). Then a random selection of 5 of the 15 subjects were measured one week after the first measurement by a second observer to evaluate intra-observer reliability.

Statistical analysis

The STATA 12.0 Program was used for the analysis. All parameters were recorded.

Measurement reliability was calculated with Bland and Altman limits of agreement. The coefficients of correlation between CL, ConL, TrapL, and distance between ConL and TrapL were calculated including 95% confidence intervals. The *p*-values <0.05 were considered statistically significant. Sample size was calculated based on alpha error 0.05, power of the study 0.8, effect size 0.35, and the number of predictors (one). The total number of samples from the A-Priori Sample Size Calculation for Multiple Regression was 25.

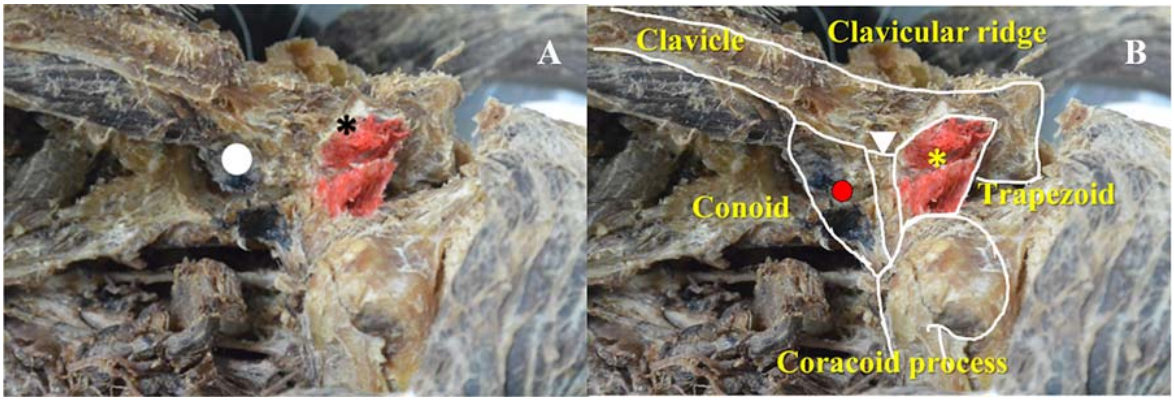

Figure 1. (A) Intact coracoclavicular ligament (the black asterisk is the trapezoid ligament and the white dot is the conoid ligament). (B) Outline of bony landmarks and the two ligaments painted with a marking pen (the triangle is the clavicular ridge).

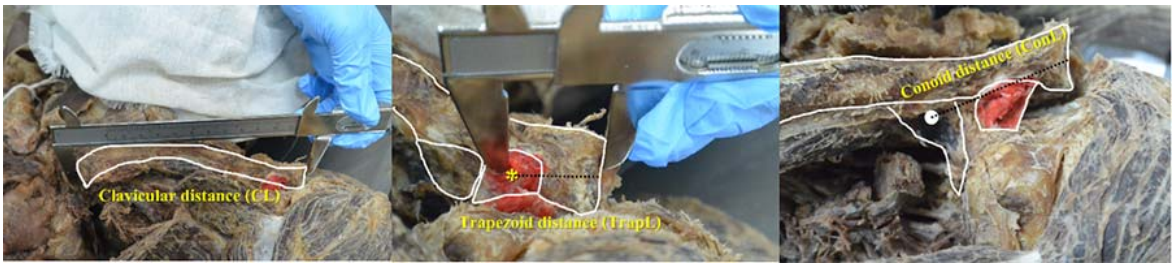

Figure 2. Technique for measurement of (A) the clavicular distance (CL), (B) the trapezoid distance (TrapL), and (C) the conoid distance (ConL).

Results

All the cadavers were Thais, 2 females and 13 males. Their mean age was 70.5 years. Ten samples were on the right side, and five on the left.

Average clavicle length was 14.4±0.6 cm, average conoid length was 3.9±0.5 cm, and average trapezoid length was 2.3±0.3 cm. The average distance between the conoid and the trapezoid was 1.6±0.2 cm. Results of intra-observer reliability by limits of agreement using the Bland and Altman method are shown in Table 1. With observer 1, there were no significant differences in reliability for any of the parameters, but in the case of observer 2, there was a significant difference in reliability of conoid length measurements (95% confidence interval -0.684 to 0.884, *p*-value <0.0051).

The inter-observer reliability by limits of agreement was analyzed using the same method and is shown in Table 2. There were no statistically significant differences. CL had a mean difference of -0.053±0.380 with a 95% confidence interval of -0.797, 0.691 and *p*-value of 0.2749. ConL had a mean difference of 0.180±0.863 with a 95% confidence interval of -1.511, 1.871 and *p*-value of 0.2153. TrapL had a mean difference of -0.120±0.667 with a 95% confidence interval of -1.427, 1.187 and *p*-value of 0.3056. The correlation coefficients of CL and ConL were 0.902 and 0.044, respectively; TrapL had a negative correlation coefficient of -0.221 and a standard error of 0.236.

Measurement parameters included in the regression analysis are shown in Table 3. Correlations between clavicular length [CL] and both conoid length [ConL] and trapezoid length [TrapL] were not statistically significant with *p*-values (F-test) of 0.4295 and 0.5925, respectively. Analysis of ConL and TrapL found no correlation with CL (adjusted R-square 0.0692, *p*-value (F-test) 0.5925). There was no significant correlation between any of the parameters (ConL, TrapL, male, right side) (adjusted R-square 0.0173, *p*-value (F-test) 0.4244). Only the correlation between ConL and TrapL was statistically significant with a coefficient of 0.87 and a standard error of 0.30 (adjusted R-square 0.3420, *p*-value 0.013).

Discussion

A missing coracoclavicular ligament [CCL] in chronic acromioclavicular joint [ACJ] separation is a common occurrence which has been regularly been treated by CCL reconstruction to restore the biomechanics using the Weaver-Dunn technique[9-12]. A new method, anatomic CCL reconstruction, was introduced later and has been found to provide better biomechanical advantage than the Weaver-Dunn technique which requires the sacrifice of the coracoacromial ligament [CAL]. Several studies[4,13-15] have demonstrated that the centers of the trapezoid and the conoid ligament insertions are located 2.5 cm and 4.6 cm from the lateral edge of the clavicle, respectively, although those studies do not report on evaluation of the validity of the measurement methods.

Rios et al[4] also conducted a study of fresh frozen cadavers, determining the correlation between clavicular length and the distance from the medial border of both bundles to the medial clavicle. That study found these indices were constant for both sexes. The present study hypothesized that the distance from the center of the conoid and the trapezoid bundles in the Thai population may be smaller than in the population in the Rios study. In fact, this study found that the average distances from the conoid and the trapezoid footprint centers to the lateral clavicle were 3.9±0.5 and 2.3±0.3 centimeters, respectively.

Many anatomic and radiographic parameters have been used in efforts to accurately identify the location of CCL footprints for ligamentous reconstruction[4,7,8]. Previous research[4,5]

Table 1. Intra-observer reliability by limits of agreement (Bland and Altman)

Variable	Measurement (n = 15)		Correlation coefficient (standard error)	Limits of agreement		*p*-value
	First (n = 15)	Second (n = 5)		Mean difference, (SD)	95% confidence interval	
Observer 1						
Length (cm), mean (SD)						
Clavicle	14.40 (0.66)	14.40 (0.69)	0.995 (0.006)	0 (0.071)	-0.139, 0.139	0.6863
Conoid	3.92 (0.45)	3.76 (0.48)	0.756 (0.230)	0.160 (0.288)	-0.405, 0.725	0.6038
Trapezoid	2.32 (0.26)	2.38 (0.39)	0.136 (0.508)	-0.060 (0.439)	-0.921, 0.801	0.7376
Observer 2						
Length (cm), mean (SD)						
Clavicle	14.32 (0.97)	14.38 (0.61)	0.909 (0.051)	-0.060 (0.351)	-0.747, 0.627	0.1096
Conoid	4.26 (0.61)	4.16 (0.22)	0.602 (0.096)	0.100 (0.400)	-0.684, 0.884	0.0051*
Trapezoid	2.82 (0.51)	2.60 (0.29)	0.236 (0.400)	0.220 (0.497)	-0.754, 1.194	0.4453

* *p*-value <0.05 (suggested possible unreliable measurement)

Table 2. Inter-observer reliability by limits of agreement

Variable	Measurement (n = 15)		Correlation coefficient (standard error)	Limits of agreement		*p*-value
	Observer 1	Observer 2		Mean difference, (SD)	95% confidence interval	
Length (cm), mean (SD)						
Clavicle	14.40 (0.66)	14.32 (0.97)	0.902 (0.047)	-0.053 (0.380)	-0.797, 0.691	0.2749
Conoid	3.92 (0.45)	4.26 (0.61)	0.044 (0.241)	0.180 (0.863)	-1.511, 1.871	0.2153
Trapezoid	2.32 (0.26)	2.82 (0.51)	-0.221 (0.236)	-0.120 (0.667)	-1.427, 1.187	0.3056

Table 3. Correlation between conoid and trapezoid ligaments with clavicular length (from regression analysis)

Variable (n = 15)	Coefficient	Standard error	*p*-value	Adjusted R-square	*p*-value (F-test)
Regress on clavicular length (cm)				-0.0768	0.9764
Conoid length (cm)	-0.01	0.46	0.976		
Constant	14.82	1.79	<0.001*		
Regress on clavicular length (cm)				-0.0245	0.4295
Trapezoid length (cm)	0.51	0.62	0.429		
Constant	13.50	1.56	<0.001*		
Regress on clavicular length (cm)				-0.0692	0.5925
Conoid length (cm)	-0.39	0.58	0.512		
Trapezoid length (cm)	0.85	0.82	0.316		
Constant	14.18	1.88	<0.001*		
Regress on clavicular length				0.0173	0.4244
Conoid length	-0.22	0.57	0.705		
Trapezoid length	1.50	0.88	0.119		
Male gender	1.22	0.72	0.122		
Right side	0.47	0.47	0.350		
Constant	10.73	2.68	0.003*		
Regress on conoid length				0.3420	0.0130*
Trapezoid length	0.87	0.30	0.013*		
Constant	1.74	0.76	0.039*		

* Significant *p*-value <0.05

involved sophisticated measurement methods such as the distance from the medial borders of both bundles, the width of the bundles or the thickness of the bundles. Those methods were not reproducible because the specified locations might be misplaced for each operator. Takase[8] investigated the undersurface clavicular attachment of the CCL, but the reported footprint dimensions were larger than the tendon graft diameter in the reconstructive procedure. There can be an error of measurement of the distance between the two centers of clavicular insertions if the center of one ligament were used as a reference to create the other reference point. Having a constant correlation can help the surgeon more accurately identify a precise location.

Although the conoid tubercle can be identified either by direct palpation or by intra-operative fluoroscopy as performed by Carofino et al[6], a standard of 20 to 25 mm anterolateral to the conoid tubercle for the location of the trapezoid insertion does not necessarily represent the correct trapezoid insertion point for all patients.

The measurement method in this study used simple identifiable landmarks for centers of each bundle and correlated those with the length of the clavicle. It has previouslybeen demonstrated that there is no standard correlation between clavicular length and either conoid or trapezoid length. The only statistically significant?] correlation in this study was between the conoid and the trapezoid length, of where the average value was 0.87$\pm$0.30 cm [* and the distance between the conoid and the trapezoid ligaments where the average was 1.6$\pm$0.9 cm. Thus the measurement technique described in this paper could be used to locate either footprint even if only one bundle (conoid or trapezoid) still exists.

Harris et al[5] classified conoid ligament variants into 3 types based on the variant of the scapular (coracoid) attachments. In that study, the anatomical conformity of the clavicular attachment described as being consistent. Because there are a number of different bony landmarks and reference locations in the CCL anatomy, there has been no generally agreed upon method for creating clavicular tunnels for ligamentous reconstruction. Coracoid insertions have been investigated in an anatomic study by Salzmann et al[13] in which it was reported that there are also separate footprints for each of the ligaments indicating the stites for clavicular insertions.

Limitations of this anatomic study include the small sample size, the older age of the subjects (average 70.5 years), and the predominance of males. Another limitation is that in formalin fixed cadavers the

ligamentous contours may shrink, thus presenting a smaller than actual distance. Additionally, there was no evaluation of the sagittal location of the two ligaments. It has previously been demonstrated that the conoid ligament is located relatively more posteriorly and the trapezoid ligament located more anteriorly[4].

Conclusion

The distance between the conoid and trapezoid ligaments and the distal end of the clavicle is significantly correlated. The distance from the center of either the conoid or the trapezoid ligament to the distal end of the clavicle when either only one ligament remains can be used to predict the location of the other ligament precisely. CLL distance can be different in different populations. Knowing the correct anatomic correlation could help achieve optimal shoulder biomechanics after robust CCL reconstruction.

What is already known on this topic?

The dimension of coracoclavicular ligament's clavicular attachment was studied on Caucasians population that had a bigger dimension. There was no study measure the dimension with observer reliability test like this study.

What this study adds?

The distance between conoid and trapezoid bundle that has a significant correlation (16.0±1.9 mm).

Potential conflicts of interest

The authors declare no conflict of interest.

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