J Shoulder Elbow Surg (2019) 28, 1723–1727

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Coracohumeral distance and coracoid overlap as predictors of subscapularis and long head of the biceps injuries

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Background: Subscapularis (SS) lesions are often underdiagnosed because of an incomplete understanding of contributing factors but also because of a greater difficulty in SS tear diagnosis with magnetic resonance imaging or physical examination. In this setting, predicting factors can be useful tools in these injuries' management. The goal of this study was to determine the influence of the coracohumeral distance (CHD) and coracoid overlap (CO) in anterior rotator cuff lesions, as well as to determine the CHD and CO values that can accurately predict SS and long head of the biceps (LHB) injuries.
Methods: We performed a retrospective, controlled, single-blinded study. We analyzed 301 patients with rotator cuff pathology and magnetic resonance imaging studies; patients with SS lesions represented the study group. The CHD and CO were measured.
Results: We found that lower CHD and higher CO values were progressively related to more serious injuries of the SS and LHB. The CHD was a very strong predictor of SS injury and tear and a good predictor of LHB injuries. A CHD of 7.6 mm had a sensitivity of 84.4% and specificity of 88.6% for SS tears. The CO was also a very strong predictor of SS tears and a good predictor of LHB injury, with a CO of 16.6 mm reaching a sensitivity of 77.8% and specificity of 68.3% for SS tears.
Conclusions: The CHD is an excellent predictor of SS tears and a good predictor of LHB lesions, with the CO also being a very strong predictor of SS tears and a good model for LHB injuries.
Level of evidence: Level IV; Case Series; Prognosis Study

Keywords: Subscapularis; long head of biceps; rotator cuff tears; coracohumeral distance; coracoid overlap; shoulder; subcoracoid impingement

Rotator cuff injuries have multifactorial causes. When their etiology is traumatic, it may be due to either extrinsic or intrinsic causes. Extrinsic causes include impingement syndromes, such as subacromial and subcoracoid impingement.[2]

Institutional review board approval was not required for this retrospective prognosis study.

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1058-2746/$ - see front matter
https://doi.org/10.1016/j.jse.2019.01.012

As knowledge about the subscapularis (SS) has expanded, it has been recognized as a major participant in shoulder pathology. Unlike the supraspinatus, isolated SS tears are uncommon and most often a part of an anterior-superior rotator cuff injury.[8] SS injuries usually start within the superior third of the tendon, and the inferior portion is injured only in more complex lesions. The diagnosis of SS lesions remains a challenge as the sensitivity of the physical examination findings and imaging modalities is low; magnetic resonance imaging (MRI) remains the gold-standard test for diagnosis of suspected SS tears, despite studies showing that its accuracy is lower for SS tears than for other rotator cuff tears.[1,3,6,10,12] In this setting, tools to predict SS injury would be useful in diagnosing subcoracoid impingement as the cause of shoulder pain, as well as knowing when there is a need to perform a thorough examination of the SS during arthroscopic inspection.

Subcoracoid impingement is a relatively infrequent entity and rarely considered as a potential cause of pain.[2] It is defined by an entrapment of the SS between the lesser tuberosity of the humerus and coracoid process and is related to a decreased coracohumeral distance (CHD) and narrowing of the subcoracoid space. This narrowing can be either iatrogenic, traumatic, or due to numerous other causes such as abnormal coracoid anatomy, a calcified SS tendon, cysts, or anomalies of the lesser tuberosity. A traumatic event or previous surgical procedure can also predispose to this syndrome.[1,2,7] Subcoracoid impingement can be a cause of residual pain after rotator cuff repair or a cause of shoulder pain in patients with normal imaging studies.

The subcoracoid space includes key structures such as the SS tendon, the long head of the biceps (LHB), and the middle glenohumeral ligament, which can all undergo impingement when the CHD is compromised.[1,7] The CHD is defined as the minimal distance between the coracoid and the humeral head and is reported as normal when between 8.7 and 11 mm in MRI studies.[1,2,4] The coracoid overlap (CO) is used to describe the coracoid shape: It measures the distance from the glenoid fossa to the most prominent aspect of the coracoid process.

The main goal of our study was to confirm the correlation between the CO and CHD and the presence of an SS lesion, defining values that signal a higher risk that this pathology may actually be present when in question on MRI and eventually recommend a subcoracoid space release. We also aimed to relate these variables to LHB injuries.

Materials and methods

We performed a retrospective, controlled, single-blinded study, including the period between 2009 and 2018. Patient data were collected retrospectively from the outpatient orthopedics clinical files and included all patients with degenerative rotator cuff pathology diagnosed in this period. Patients without an MRI study or with inflammatory arthropathy, rotator cuff arthropathy, or congenital deformities were excluded.

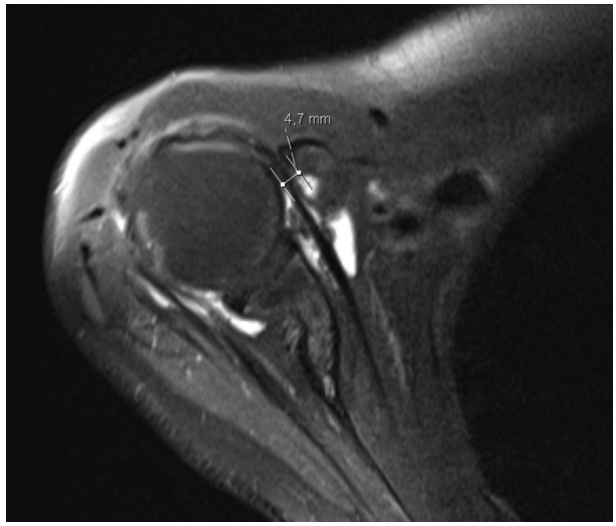

Figure 1 Transversal section of T1-weighted magnetic resonance image showing coracohumeral distance—minimal distance between humeral and coracoid cortices.

A standard MRI shoulder protocol was applied, including T1- and T2-weighted fat-saturated images, with the arm in a neutral position. All MRI scans were performed in our institution's radiology department, using similar MRI models with equivalent gantries. The CHD and CO were measured on transverse sections of T1-weighted images to take advantage of their better definition of the cortical margins. The CHD consists of the minimal distance between the humeral cortex and the coracoid cortex. The CO represents the distance from the glenoid to the tip of the coracoid process (Figs. 1 and 2). The axial images were acquired where the subcoracoid space was at its minimum, and the values correspond to the average of 3 measurements.[10]

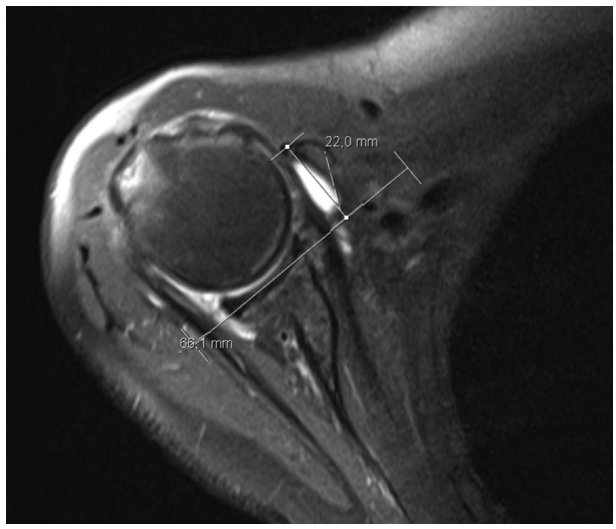

Figure 2 Transverse section of T1-weighted magnetic resonance image showing coracoid overlap—distance from glenoid to tip of coracoid process.

The measurements were recorded by an orthopedic surgeon, blinded to the MRI report. The presence and type of injury to the SS, supraspinatus, and LHB, as well as its laterality, were also recorded.

Statistical analysis

Statistical analysis was performed using SPSS software (version 24; IBM, Armonk, NY, USA). Categorical variables are presented as absolute and relative frequencies, whereas continuous variables are characterized by the mean and standard deviation. The statistical tests used were the χ^2 test to evaluate the association between categorical variables and 1-way analysis of variance test to compare means of continuous variables. To determine the best cutoff points, receiver operating characteristic (ROC) curves were designed for each studied variable and the Youden index was applied. The value with the highest Youden index was considered the cutoff with the best precision. Statistical significance was considered at $P < .05$.

Results

The sample comprised 301 shoulders, including 143 female (47.5%) and 158 male (52.5%) shoulders. The study group included 145 shoulders, representing shoulders with SS injuries (tendinopathy or tear), corresponding to 48.2% of the sample. The control group (without an SS injury) included 156 shoulders, corresponding to 51.8% of the sample. The sample comprised 158 right (52.5%) and 143 left (47.5%) shoulders.

In every patient, we evaluated the presence of supraspinatus, SS, and LHB injuries. In our sample, 90.4% of shoulders had a supraspinatus tear, 145 shoulders presented with an SS injury (48.2%), and 99 shoulders (32.9%) presented with an SS tear (complete or partial). Regarding the LHB, 93 shoulders showed lesion of this tendon (Table I). Comparing types of rotator cuff injuries in both sexes, we found a statistically significant relationship between the presence of an SS lesion and male sex ($P = .04$). Comparing the presence of simultaneous lesions of the SS and supraspinatus or the SS and LHB, we found a significant association between SS lesions and lesions of the supraspinatus or LHB ($P = .04$). We also found a significant association between more serious SS lesions (complete vs. partial tears) and more serious LHB injuries (tear and subluxation vs. tendinopathy) ($P = .01$).

The CHD and CO were measured in 301 shoulders; the average CHD value was 8.6 ± 3.0 mm, and the average CO value was 16.4 ± 4.8 mm. No significant differences between sexes were found in the CHD or CO variable. Regarding joint laterality, the CHD was significantly higher in right-sided shoulder ($P = .04$); no statistical significance was obtained in the comparison between CO and joint laterality ($P = .34$).

Comparing the CHD and CO with the presence of an SS lesion, we found that both the CHD and CO had a statistically significant association with the presence of an SS lesion or SS tear ($P < .001$). The mean CHD in the presence of an SS lesion and SS tear was 6.7 ± 2.7 mm and 5.7 ± 1.7 mm, respectively, and the mean CO was 18.6 ± 4.6 mm and 19.7 ± 3.9 mm, respectively. In the control group, the CHD and CO were 10.3 ± 2.2 mm and 14.3 ± 3.9 mm, respectively.

In our sample, as the values of CHD decreased, a progression to more serious injuries of the SS occurred (Table II). In the partial SS tear subgroup, the average CHD was 6.2 ± 1.6 mm, and in the complete SS tear subgroup, the mean CHD was 5.0 ± 1.7 mm, with this difference being statistically significant ($P < .001$).

This was also true for LHB lesions, with the CHD and CO being significantly different between patients with and without LHB lesions ($P < .001$). In the control group, the average CHD and CO were 9.2 ± 2.9 mm and 15.6 ± 4.6 mm, respectively, and in the group with LHB injuries, the mean CHD and CO were 7.1 ± 2.7 mm and 18.2 ± 4.6 mm, respectively. A statistically significant correlation ($P < .001$) between the CHD and CO was shown, with a coefficient of –52.1% ($P < .001$).

ROC curves were designed to evaluate the ability of the CHD and CO to predict SS and LHB lesions. The accuracy of the model was measured by the area under the ROC curve (AUC); an AUC of 1 would represent a perfect test. The CHD was a very strong predictor of SS injury (AUC, 87.9%) and an excellent predictor of SS tears (AUC,

Table I Tendon lesion types and frequencies

Tendon	Condition	Frequency	%
Supraspinatus	Normal	29	9.6
	Rupture	272	90.4
Subscapularis	Normal	156	51.8
	Tendinopathy	46	15.3
	Partial tear	63	20.9
	Complete tear	36	12.0
Long head of biceps	Normal	208	69.1
	Tendinopathy	46	15.3
	Dislocation	19	6.3
	Rupture	28	9.3

Table II CHD and CO for subscapularis lesions

Subscapularis condition	CHD	CO
Normal		
n	156	156
Mean, mm	10.3 ± 2.2	14.3 ± 3.9
Tendinopathy		
n	46	46
Mean, mm	8.9 ± 3.0	16.2 ± 5.0
Partial tear		
n	63	63
Mean, mm	6.2 ± 1.6	19.7 ± 3.9
Complete tear		
n	36	36
Mean, mm	5.0 ± 1.7	19.9 ± 3.9

CHD, coracohumeral distance; *CO*, coracoid overlap.

93.8%) (Fig. 3). CHD was also a good predictor of LHB tears, with an AUC of 79.0%. By use of the CHD–SS tear ROC curve, a cutoff value of 8.0 mm had a sensitivity of 89.9% and specificity of 84.2% for SS tears. The CHD partial vs. total SS tear ROC curve was a good predictor of partial vs. total SS tears, with an AUC of 0.73 and with a sensitivity and specificity of 73.0% and 66.7%, respectively, for a CHD of 5.3 mm.

The CO was a very strong predictor of SS tears and a good predictor of SS injury, with AUCs of 0.81 and 0.76, respectively. Applying the CO–SS tear ROC curve, we found that the value of 16.6 mm had a sensitivity of 78.8% and specificity of 68.3% (Fig. 4). The CO was also a good predictor of LHB ruptures, with an AUC of 0.73. However, for LHB lesions and ruptures, we achieved a better ROC curve with the CO/CHD ratio (AUCs of 71.0% and 79.0%, respectively). For a CO/CHD ratio of 2.3, we could predict an LHB rupture with a sensitivity of 82.1% and specificity of 68.9%.

Regarding the SS lesions, none of the ratios were superior to the CHD alone in predicting these injuries. To differentiate between the risk of partial SS tears and the risk of total SS tears, we created a CHD ROC curve, which was a good predictor of partial vs. total SS tears, with an AUC of 72.7%. For a CHD value of 5.3 mm, we could differentiate between a partial tear and complete tear with a sensitivity of 73.0% and specificity of 66.7%.

Discussion

The search for subcoracoid impingement risk factors and SS and LHB lesion predictors is increasing. We chose to assess the CHD and CO, as the first measurement translates the available space for these structures and the second measurement represents the distance by which the coracoid process overlaps the glenoid toward the humeral head.

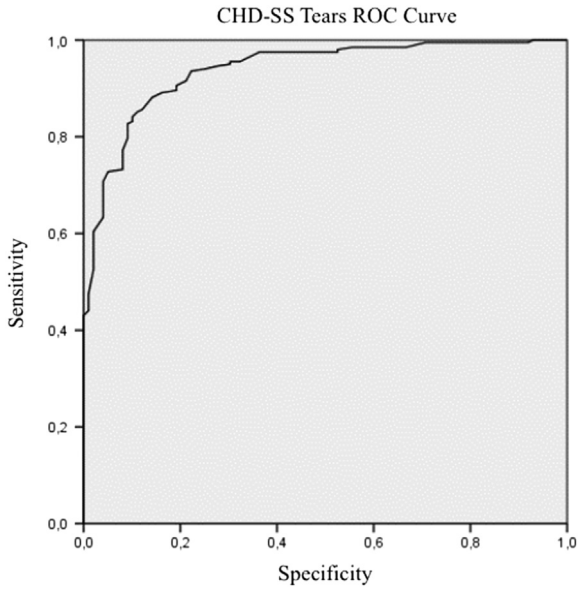

Figure 3 Coracohumeral distance (*CHD*)–subscapularis (*SS*) tear receiver operating characteristic (*ROC*) curve, with an area under the ROC curve of 93.8%; a cutoff value of 7.95 mm had a sensitivity of 89.9% and specificity of 84.2% for SS tears.

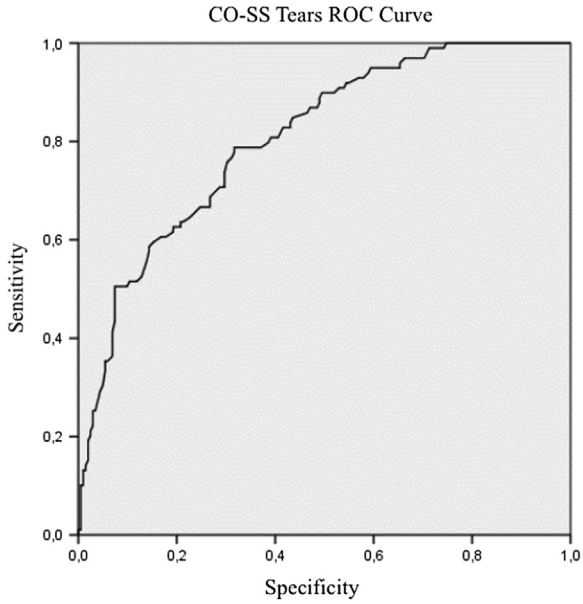

Figure 4 Coracoid overlap (*CO*)–subscapularis (*SS*) tear receiver operating characteristic (*ROC*) curve, with an area under the ROC curve of 80.6%; a value of 16.6 mm had a sensitivity of 78.8% and specificity of 68.3%.

To our knowledge, our study has the largest sample on this topic, including 301 patients, fairly evenly distributed between the study and control groups. In addition, this study is the first to use both the CHD and CO as injury predictors.

The average CHD in the control group (10.3 $\pm$ 2.2 mm) is within the sparse values presented in the literature.[1,7,9] Our sample achieved a significant difference between the control and study groups, with the CHD being significantly smaller and the CO being significantly higher in the presence of SS and LHB lesions. In the presence of SS lesions (including tendinopathy), the CHD and CO were 6.7 mm and 18.6 mm, respectively; and when only the SS tear subgroup was considered, the CHD and CO were 5.7 mm and 19.7 mm, respectively.

To our knowledge, only 1 other study has focused on the CO as an important parameter in subcoracoid impingement: In the study by Çetinkaya et al,[2] the CO was statistically the most important test in predicting SS tears, with an AUC of 65.6% and with a sensitivity of 62.0% and specificity of 64.0% for a value of 22.9 mm. In our study, the CO–SS tear ROC curve had an AUC of 80.6%, and for a value of 16.8 mm, it had a sensitivity of 77.8% and specificity of 68.3%. Our study found a CO value with superior diagnostic accuracy (AUC of 80.6%) and higher sensitivity (77.8%) and specificity (68.3%).

The close relationship between the SS and LHB has been well established, often with simultaneous injuries owing to their anatomic proximity. So, it is crucial to

determine whether the SS pathologic factors have the same effect on the LHB tendon.[5,11]

Our study is also the first to explore the impact of the CHD and CO on LHB lesions, with both variables being good predictors of LHB pathology with AUCs of 79.0% and 72.6%, respectively. We achieved an even better predictor curve for LHB lesions or ruptures with the CO/CHD ratio (AUCs of 76.0% and 79.3%, respectively). For LHB rupture, there was a sensitivity of 64.3% and specificity of 68.9% for a CO of 18.9 mm and a sensitivity of 78.6% and specificity of 68.1% for a CHD of 7.7 mm.

However, there are some limitations to our study. Although our MRI protocol stated that the arm should be in a neutral position, variation in patient positioning was a possibility and may have influenced the measurements. In addition, our study was designed as a retrospective study with its inherent limitations.

This study is, to our knowledge, the first study to compare both the CHD and CO with the presence of SS and LHB tears. This study also had the largest sample, including 301 patients. Moreover, this study is the only one focusing on LHB injuries, as well as on the differences in the CHD and CO according to different types of SS lesions. Finally, our study is the first to postulate values for the CHD and CO with a high specificity and sensitivity for SS and LHB tears, as well as cutoff values to determine the risk of partial and complete SS tears.

Conclusion

This study shows that the CHD is an excellent predictor of SS tears and a good predictor of LHB lesions, with the CO also being a very strong predictor of SS tears and a good model for LHB injuries.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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