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ORIGINAL ARTICLE

Magnetic resonance imaging based coracoid process morphology and its associations with isolated subscapularis tendon tears in Chinese patients

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ABSTRACT

Objectives: This study aims to assess the association between isolated subscapularis tears and coracoid morphology using magnetic resonance imaging (MRI) and to calculate the optimal cut-off values of the significant predictor to predict subscapularis tears.

Patients and methods: Between January 2018 and December 2022, a total of 60 patients (29 males, 31 females; mean age: 58.4±8.4 years; range, 18 to 80 years) diagnosed with subscapularis tendon tears who were treated as Group A and 60 patients (29 males, 31 females; mean age: 46.8±11.5 years; range, 18 to 80 years) without subscapularis tendon tears who were treated as Group B were included. Axial coracoid-humeral distance (aCHD), sagittal coracoid-humeral distance (sCHD), coracoid overlap (CO) and coracoid angle (CA) of all patients were measured. Logistic regression was used to investigate the association between subscapularis tears as variables including aCHD, sCHD, CO and CA. Receiver operating characteristic curve analysis was used to determine the diagnostic values of coracoid morphology for subscapularis tears.

Results: The mean values of CO, aCHD and sCHD in Group A were 22.16 mm, 5.13 mm, and 5.56 mm, respectively. The mean values in Group B were 16.99 mm, 7.18 mm, and 7.29 mm, respectively. The degree of CA in Group A was 95.81 and 111.69 in Group B. The differences in the above measurement values were significant between two Groups. The CO was found to be associated with higher odds of subscapularis tears. The optimal cut-off value of CO was 19.79 mm.

Conclusion: Based on our study results, CO is positively associated with isolated subscapularis tears. In addition, coracoid bursa effusion, cysts in the lesser tuberosity or a tear and malposition of long head of the biceps tendon on MRI may predict the presence of a clinically significant subscapularis tear.

Keywords: Coracoid humeral distance, coracoid morphology, coracoid overlap, magnetic resonance imaging, subcoracoid impingement.

Subscapularis tendon is the strongest and largest tendon of the rotator cuff, which plays an essential role in the motion and stability of the shoulder.[1] In general, subscapularis tendon tears as non-traumatic injuries are associated with subcoracoid impingement and intrinsic degeneration. Based on the subcoracoid impingement theory, the pathological mechanism is a structural narrowing in the subcoracoid space. This intrinsic degeneration can be caused by repeated friction between the rotator cuff or other soft tissues and bone tissue.[2,3]

The initial description of subcoracoid impingement by Goldthwait,[4] and later comprehensive recommendation and confirmation by Gerber et al.[5] in 1985 found remarkable differences in the size and shape of the coracoid process, which

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caused the subcoracoid impingement. In 2019, Zhang et al.[6] reported that the coracohumeral index (CHI) and coracoglenoid inclination (CGI) were potential valuable predictors of the types of degenerative subscapularis tendon tears. Based on standard hook coracoids, the lesions tend to appear on the articular side initially, otherwise, the subscapularis tendon tears are commonly seen on the bursal side with overlapping hook coracoids.

With the development of magnetic resonance imaging (MRI) and arthroscopy, high prevalence of subscapularis tendon tears has been detected in clinics.[7] Therefore, the researchers and clinicians paid more attention to subscapularis tendon tears in recent years. The subcoracoid space, as the coracohumeral interval between the normal coracohumeral interval to 11 mm,[8] is the space between the coracoid process and the lesser tuberosity of the humerus. Asal and Sahan[9] observed the coracohumeral distance and coracoglenoid angle decreased in subscapularis tendon pathologies on MRI. The coracohumeral interval is a poor predictor of subcoracoid impingement on MRI, although the coracohumeral interval is significantly statistically related to subcoracoid impingement.[10] However, Tan et al.[11] reviewed the MRI and computed tomography (CT) 100 shoulders, and found there were no significant differences between the coracoid morphology of patients with normal findings and patients with varying degrees of rotator cuff disease. Moreover, Çetinkaya et al.[12] compared 16 shoulders with isolated subscapularis tears and healthy shoulders of the same patients using MRI, and reported that the parameters of coracoid were no significant difference between the isolated subscapularis tear side and opposite-side healthy shoulders. However, coracoacromial ligament degeneration was present in 75% of the patients with isolated subscapularis tears.

To the best of our knowledge, the relationship between subscapularis tendon tears and coracoid process morphology has not been well analyzed and studied in China yet. In the present study, we aimed to investigate the risk factors of the coracoid morphology with subscapularis tendon tears between inpatients diagnosed with subscapularis tendon tears and patients without subscapularis tendon tears using MRI, and to estimate optimal cut-off values for predicting subscapularis tendon tears.

PATIENTS AND METHODS

This retrospective, observational study was conducted at Ningbo First Hospital, Department of Orthopedics between January 2018 and December 2022. We conducted a pragmatic evaluation among patients delivered in the real-life setting. All the patients over the age of 18 years were examined in a clinical setting, including 60 patients (29 males, 31 females; mean age: 58.4±8.4 years; range, 18 to 80 years) diagnosed with subscapularis tendon tears who were treated as Group A (Figure 1), and 60 patients (29 males, 31 females; mean age: 46.8±11.5 years; range, 18 to 80 years) without subscapularis tendon tears who were included in Group B. Based on MRI examination, patients in Group A were required to have a Hawkin's test and lift-off test for the further identification of subscapularis tendon tears. All the eligible patients were to be assigned to Group A and Group B with the satisfaction of the below inclusion criteria.

Inclusion criteria for the patients with subscapularis tendon tears were as follows: *(i)* pain in the front of the shoulder; *(ii)* pain and tenderness at the insertion of the subscapularis tendon; *(iii)* positive abdominal compression test or positive lift-off test; and *(iv)* subscapularis tendon injury via MRI. Exclusion criteria of the patients for both groups were as follows: *(i)* history of trauma; *(ii)* previous shoulder surgery history; *(iii)* shoulder infection; *(iv)* shoulder osteoarthritis; and *v*) glenoid deformity. The criteria for selecting patients in Group B were as follows: *(i)* age over 18 years old; *(ii)* having no pain or mobility dysfunction in the shoulder joint; *(iii)* having no history of shoulder joint trauma, infection or surgery. Finally, a total of 120 patients were included in the study.

Measurements

All patients were asked to complete the standardized questionnaire, widely used in clinical setting in Zhejiang Province, during the counselling visit. The involved shoulder of each participant was scanned at the standard three angles (transverse, oblique coronal and oblique sagittal) by using the 1.5 T MRI system (Siemens AG, Erlangen, Germany). Axial coracoid-humeral distance (aCHD), sagittal coracoid-humeral distance (sCHD), coracoid overlap (CO), and coracoid angle (CA) of patients with shoulder joint were measured. Patients with subscapularis tendon tears in Group A were further investigated by arthroscopy (Figure 2). All the measurements were performed as regular examinations by two well-experienced radiologists.

Definitions

The rotator cuff tendon MRI is classification based on the Zlatkin's classification:[13] Grade 0:

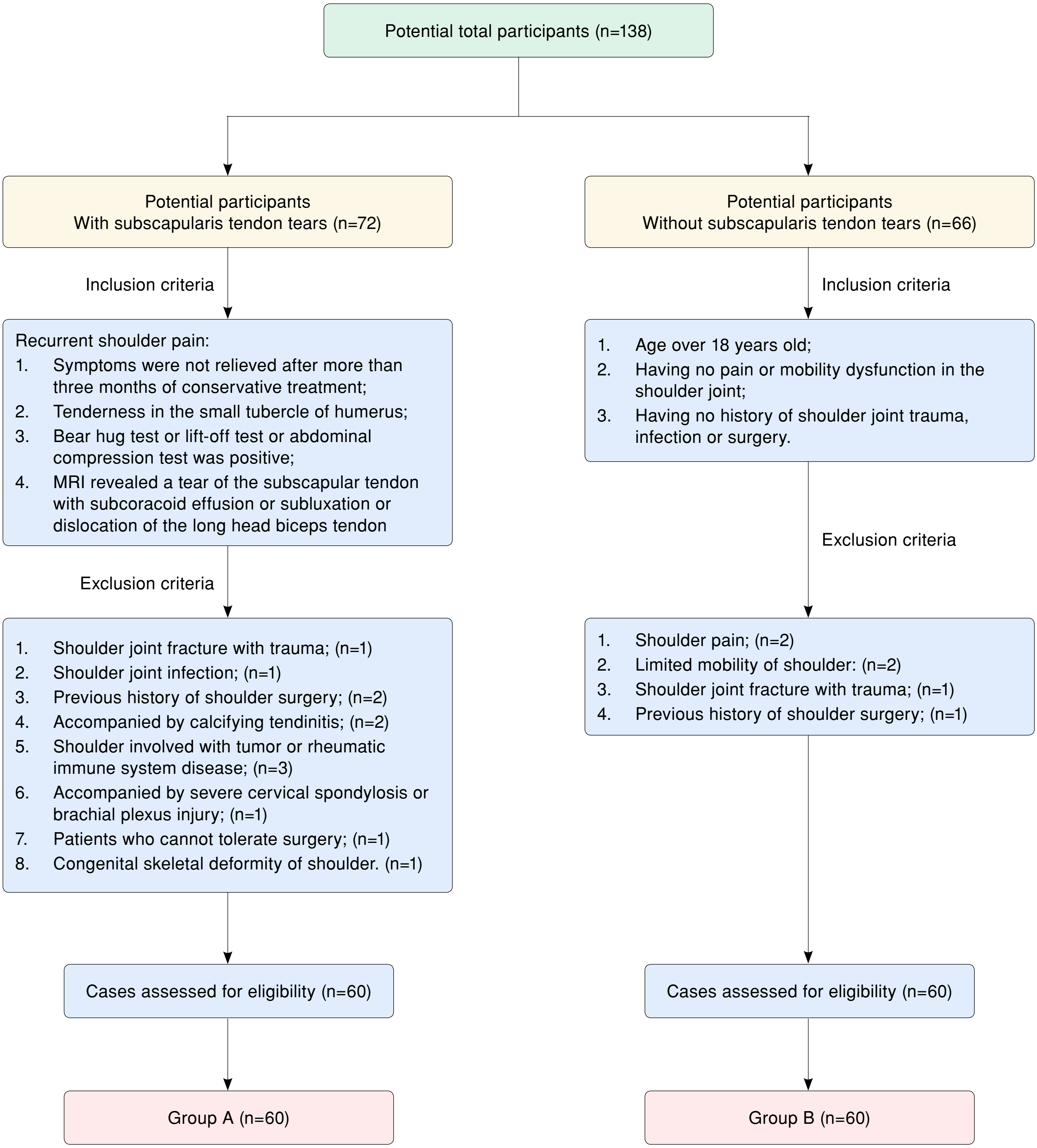

FIGURE 1. Study flowchart.
MRI: Magnetic resonance imaging.

tendon continuity intact, normal shape and tendon in normal signal; Grade 1: tendon continuity intact, normal shape, abnormal local signal in tendon, local high signal on T1 (spin-lattice relaxation time)-weighted imaging (T1WI) and proton image; Grade 2: tendon continuity abnormal tendon morphology (tendon thinning or irregularity), and increased signal limitation on T1WI and proton image;

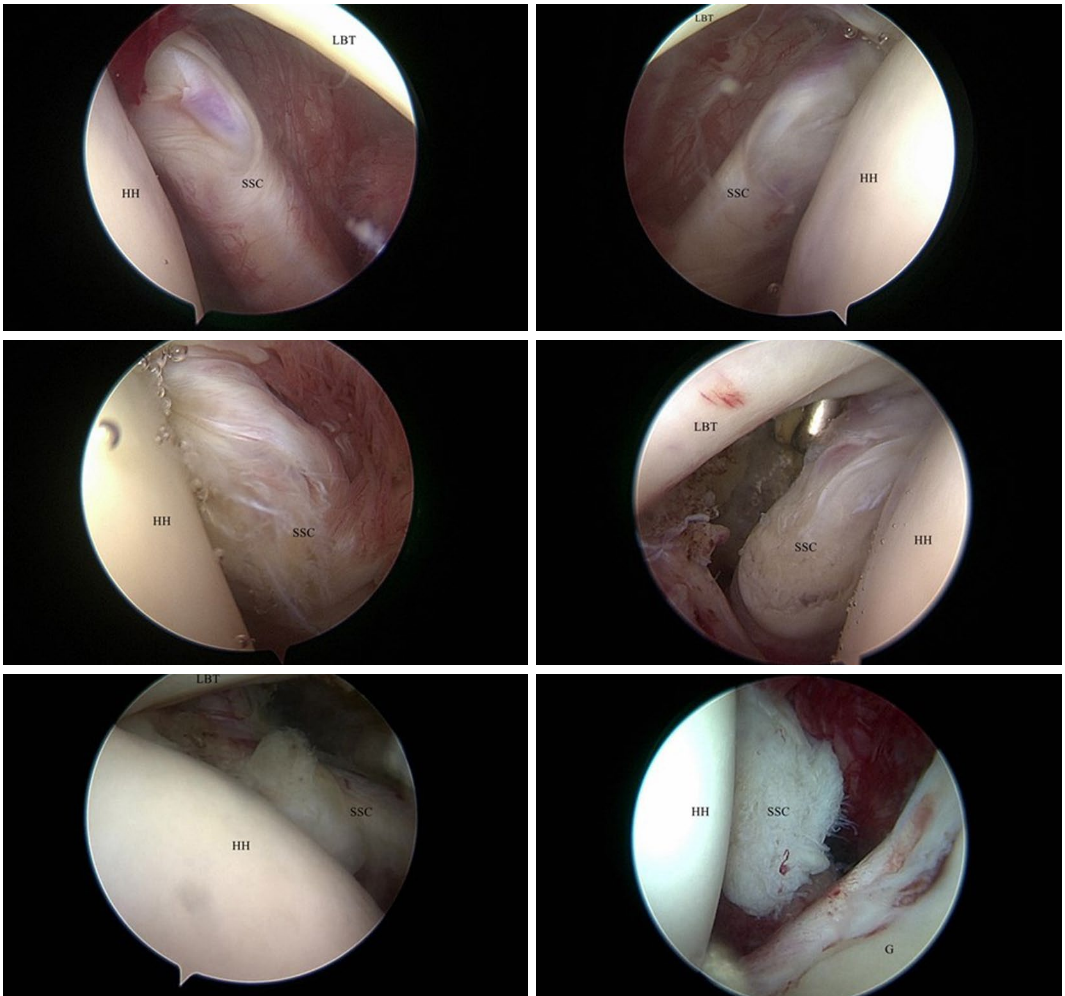

FIGURE 2. The arthroscopic view of the typical subscapularis tendon tears.

Grade 3: interrupted tendon continuity, irregular shape, partial tear or complete tear, increased signal on T1WI and proton image, and acromial downward sac effusion.

The aCHD refers to the distance between the coracoid process and the humerus on the transverse axis of MRI. The sCHD refers to the distance between the coracoid process and the humerus in the sagittal position of MRI. The CO refers to the lateral extension of the coracoid process beyond the glenoid plane on the cross-sectional MRI. None of the patients had significant glenoid deformity. The CA refers to the included angle between the axis of coracoid tip and the axis of coracoid base on MRI sagittal view (Figure 3).

The classification of coracoid morphology MRI is identified according to the Leite-Torres classification.[14] Three types of coracoid morphology with an increasing risk of subscapularis tendon tears are defined including flat coracoid with CA superior to 120°, curved coracoid with CA between 95° and 120°, and hooked coracoid with CA inferior to 95°.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 23.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD) or median (min-max), while categorical data were expressed in number and frequency. Based on the Central Limit Theorem and sufficient sample size, normal distribution was applied to data analysis. Continuous variables were analyzed and compared between two groups by the Student t-test. Logistic regression was used to investigate the association between the condition of subscapularis tendon tears in Group A as a dependent variable and independent variables including aCHD, sCHD, CO and CA, after controlling for confounding factors (sex and age),

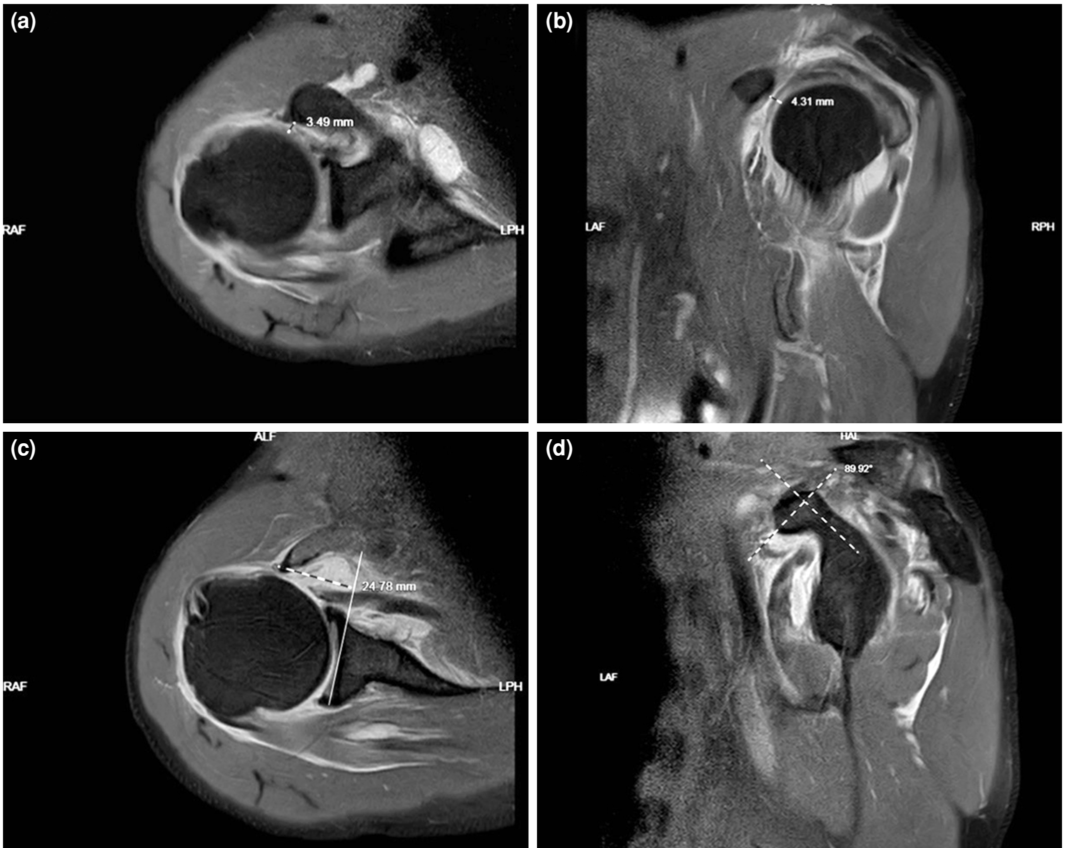

FIGURE 3. (a) Axial coraco-humeral distance (aCHD), **(b)** sagittal coraco-humeral distance (sCHD), **(c)** coracoid overlap (CO), **(d)** coracoid angle (CA).
aCHD: Axial coracoid-humeral distance; sCHD: Sagittal coracoid-humeral distance.

involved shoulder (left/right) and interactions. Due to the collinearity, aCHD and sCHD were examined in the separate models. All the interactions between confounding factors and independent variables were examined in the models. Only significant interactions were maintained in the model. Receiver operating characteristic (ROC) curve analysis was used to determine the diagnostic values of coracoid process morphology for subscapularis tendon tears. A two-tailed *p* value of <0.05 was considered statistically significant.

RESULTS

Characteristics of the study population

A total of 120 patients with shoulder MRI scans included in this study were divided into two groups.

TABLE I
Clinical characteristics of 120 patients

	Group A (n=60)			Group B (n=60)			Total (n=120)		
No	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD
Age (year)			58.4±8.4			46.8±11.5			52.6±11.6
Sex									
Male	29	48.33		29	48.33		58	48.33	
Involved shoulder left	30	50		30	50		60	50	
Hawkin's test		98.33			-			-	
Lift-off test		96.67			-			-	

SD: Standard deviation.

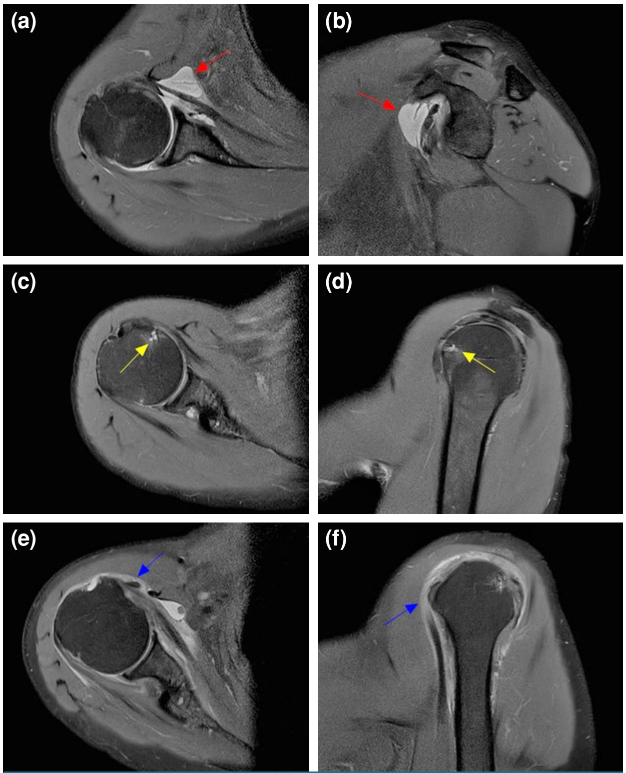

FIGURE 4. (a) The red arrow indicated coracoid bursa effusion in the transverse position of the involved shoulder MRI; **(b)** The red arrow indicated coracoid bursa effusion in the oblique coronal position of the involved shoulder MRI; **(c)** The yellow arrow indicated cysts in the lesser tuberosity in the transverse position of the involved shoulder MRI; **(d)** The yellow arrow indicated cysts in the lesser tuberosity in the oblique coronal position of the involved shoulder MRI. **(e)** The blue arrow indicated dislocation of LHBT in the transverse position of the involved shoulder MRI. **(f)** The blue arrow indicated dislocation of LHBT in the oblique coronal position of the involved shoulder MRI.
MRI: Magnetic resonance imaging; LHBT: Long head of the biceps tendor.

There was a significant difference in the mean age between the groups. However, there was no significant difference in the sex and the involved shoulder. The Hawkin's test and lift-off test results were positive in 98.33% and 96.67%, respectively in Group A (Table I).

Magnetic resonance imaging associated features of subscapularis tendon tears

The final recorded values were the average of separate measurements by two well-experienced radiologists. The presence of coracoid bursa effusion, presence of cysts in the lesser tuberosity, presence of dislocation of long head of the biceps tendon (LHBT) in the standard two planes (transverse and oblique coronal) were also recorded (Figure 4).

Relationship between subscapularis tendon tears and its risk factors

Table II shows the differences in the measurements between Group A and Group B. In Group A, the mean values of all the measurements for CO, aCHD, sCHD, and CA were significantly different from those in Group B ($p<0.001$). The mean value of CO was higher in Group A, while the values of the other measurements were higher in Group B.

The associations between subscapularis tendon tears with CO, aCHD, sCHD and CA were further investigated by logistic regression. After controlling for confounding factors, involved shoulder and significant interactions, only CO in Group A was found to be associated with 4.42-time higher odds of getting subscapularis tendon tears (Table III), compared to CO in Group B.

The optimal cut-off values of CO for subscapularis tendon tears

In the ROC curve analysis, the area under the curve of ROC values for CO predicting subscapularis tendon tears was calculated as 0.956. The optimal cut-off value of CO was 19.79 mm with 87% sensitivity and 95% specificity (Figure 5).

TABLE II
The results measurement of coracoid overlap, axial coraco-humeral distance, sagittal coraco-humeral distance and coracoid angle

	Group A	Group B	
	Mean±SD	Mean±SD	*p*
CO (mm)	22.2±2.3	17.0±1.9	<0.001*
aCHD (mm)	5.1±0.6	7.2±0.6	<0.001*
sCHD (mm)	5.6±0.6	7.3±0.6	<0.001*
CA (°)	95.8±4.8	111.7±10.6	<0.001*

SD: Standard deviation; CO: Coracoid overlap; aCHD: Axial coraco-humeral distance; sCHD: Sagittal coraco-humeral distance; CA: Coracoid angle; * Statistically significant difference between the groups was obtained from Student's t-test.

TABLE III
The association between subscapularis tendon tears and measurements of CO, aCHD, sCHD and CA

	Subscapularis tendon tears		
	OR	95% CI	*p*
CO (mm)	4.42	1.88-10.40	<0.001
aCHD (mm)	0.00	0.00-0.04	0.006
sCHD (mm)	0.00	0.00-0.03	0.005
CA (°)	0.72	0.58-0.90	0.004

CO: Coracoid overlap; aCHD: Axial coraco-humeral distance; sCHD: Sagittal coraco-humeral distance; CA: Coracoid angle; OR: Odds ratio; CI: Confidence interval.

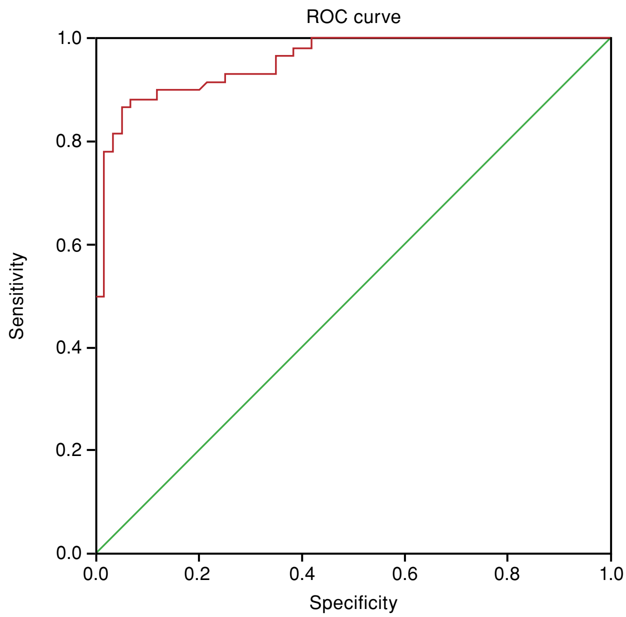

FIGURE 5. Receiver operating characteristic (ROC) curve of the coracoid overlap (CO) measurements at the cut-off value of 19.79 mm, the sensitivity and the specificity were 87% and 95% respectively.

DISCUSSION

The present study is the first retrospective, observational study in the real-life setting investigating the measurement of coracoid process morphology, its associations with subscapularis tendon tears, and the estimation of the optimal cut-off value for predicting subscapularis tendon in China.[15] Narrowed aCHD, sCHD and a longer CO together with a smaller CA were observed among patients with subscapularis tendon tears in Group A. Only CO was associated with higher odds of subscapularis tendon tears. In our study, the optimal CO cut-off value of 19.79 mm, was suggested to be the strongest parameter predicting any potential subscapularis tendon tears. In addition, coracoid bursa effusion, cysts in the lesser tuberosity, or tears and malposition of LHBT in MRI Zlatkin Grade 1-3 was a strong indication of a subscapularis tendon tear.

Evidence has shown a longer CO and narrow CHD in patients with subscapularis tendon tears compared to patients without subscapularis tendon tears.[16,17] A comparison study conducted on Turkish patients with a subscapularis tear (intervention group) and those with other pathologies (control group) showed similar results as ours (mean CO: 24.01 mm for study group *vs.* 21.29 mm for control group).[18] Likewise, Leite et al.[19] reported the mean CO of consecutive Portuguese patients 45 years or older was 19.7 mm and 14.3 mm for the subscapularis tendon tears group and the control group, respectively, examined through similar methods as ours.

Previous retrospective studies showed supporting results comparing subscapularis tendon tears group and control group.[10,17] A retrospective cohort study in American patients with the similar methods as our study reported that the average CHD in the subscapularis tendon tears group was 5.0 mm,[17] which is similar as our measurement results (aCHD: 5.1 mm and sCHD: 5.6 mm) in Group A. Asal and Sahan[9] showed that the mean CHD was 6 mm in Turkish patients with subscapularis tendon tears and 7.8 mm in healthy patients. However, a cohort study including 83 German patients with degenerative subscapularis tendon tears showed opposite results (10.2 mm in degenerative subscapularis tendon tears group *vs.* 10.4 mm in the control group).[20] A retrospective, controlled, single-blinded Portuguese study included 232 shoulders with subscapularis tendon tears demonstrated the mean CA in subscapularis tendon tears group was significantly smaller than control group (subscapularis tendon tears group: 97.4° *vs.* control group 123.8°) The findings supported our study (Group A: 95.8° *vs.* Group B: 111.7°; p<0.001), according to the Leite-Torres classification of the coracoid.[14]

To date, the association of subscapularis tendon tears is still unclear and under debate.[21-23] Evidence has indicated CO as a stronger predictor for subscapularis tendon tears.[18,19] Cetinkaya et al.[18] conducted a retrospective study between 2004 and 2015 including 219 Turkish patients (141 in the subscapularis tendon tears group *vs.* 78 in the control group), and CO was suggested as the most valuable parameter predicting any potential subcoracoid impingement among patients. Similarly, Leite et al.[19] suggested that the CO was a very strong predictor of subscapularis tendon tears in Portuguese patients. In our study, only CO was found to be significantly associated with developing subscapularis tendon tears. Therefore, the cut-off value of CO for the purpose of predicting developing subscapularis tendon tears was further examined. The CO was suggested as the most valuable parameter predicting any potential subcoracoid impingement, and it was reported that the most appropriate cut-off values of CO were 22.85 mm among Turkish patients[18] and 16.6 mm among Portuguese patients.[19] which is close to the cut-off value among Chinese patients (19.79 mm).

A very interesting phenomenon was observed in our study. When subcoracoid effusion encountered MRI subscapularis tendon tear signal, the subscapularis tendon tears were further detected and identified by arthroscopy. In line with our results, Sarıkaya et al.[24] reported that subcoracoid effusion in Turkish patients was a more specific finding for subscapularis tendon tears than other rotator cuff pathologies. Due to the small sample size, we did not even find patients with Lafosse type V of subscapular tendon tears in Group A. The majority of them were classified into Lafosse type 1 and type 2.[25] Therefore, the presence of subcoracoid effusion in MRI Zlatkin Grade 1-3 was a strong indication of subscapularis tendon tear. Further, Studler et al.[26] reported his findings supporting ours that many cysts in the lesser tuberosity were found on shoulder MRI which were relatively specific for subscapularis tendon tears. In addition, we also observed that eight patients had a tear and dislocation of LHBT in Group A. Therefore, a tear and malposition of LHBT on MRI may predict the presence of a clinically significant subscapularis tendon tear, as Kim et al.[27] reported.

The etiology and mechanism of subscapularis tendon tears are still uncertain, although various factors are involved including trauma, intrinsic tendon degeneration and subcoracoid impingement.[28] Impingement can be classified into two categories: soft tissue and bony stenosis. Soft tissue impingement is usually aggravated by bony pathology, which further perpetuates stenosis. Subcoracoid stenosis and subcoracoid impingement causing a "roller-wringer effect" on the subscapularis tendon may contribute to the pathogenesis of subscapularis tendon tears partially.[29] However, the pathology of subscapularis tendon tears needs further study and discussion.[30,31]

Nonetheless, there are some limitations to our study. First, the sample size in this clinical study is small. Second, we collected the data of MRI with the patient in the neutral position, rather than in internal rotation. Third, the study was designed as a retrospective study with its inherent limitations. In addition, there was no follow-up study of coracoplasty and the efficacy of coracoplasty is unknown.

In conclusion, the CO is potential valuable predictor of subscapularis tendon tears with an optimal cut-off value of 19.79 mm. Moreover, subcoracoid effusion, cysts in the lesser tuberosity or a tear and malposition of LHBT on MRI may predict the presence of a clinically significant subscapularis tendon tear. Further randomized-controlled trials and follow-up studies are needed to validate the association between predictors and subscapularis tendon tears in multi-center patients.

Ethics Committee Approval: The study protocol was approved by the Ningbo First Hospital Ethics Committee (date: 15.07.2019, no: 20190715). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: The concept and design of the study, data collection and analysis: YF.M.; Drafting the article or revising it critically for important intellectual content: Y.L.; Final approval of the version to be submitted: YF.M., B.C. All authors have read and approved the manuscript.

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