Less than 9.5-mm coracohumeral distance on axial magnetic resonance imaging scans predicts for subscapularis tear

Thomas Reichel, MD[a,*], Stefan Herz, MD[b], Mohammed el Tabbakh, MD[a], Thorsten Alexander Bley, MD[b], Piet Plumhoff, MD[a], Kilian Rueckl, MD[a]

[a]Department of Orthopaedic Surgery, University of Wuerzburg, Wuerzburg, Germany
[b]Department of Diagnostic and Interventional Radiology, University Hospital Würzburg, Würzburg, Germany

Background: Diagnosis of subscapularis (SSC) tendon lesions on magnetic resonance imaging (MRI) can be challenging. A small coracohumeral distance (CHD) has been associated with SSC tears. This study was designed to define a specific threshold value for CHD to predict SSC tears on axial MRI scans.
Methods: This retrospective study included 172 shoulders of 168 patients who underwent arthroscopic surgery for rotator cuff tear or glenohumeral instability. Diagnostic arthroscopy confirmed an SSC tear in 62 cases (36.0%, test group a), rotator cuff tear tears other than SSC in 71 cases (41.3%, control group b) and glenohumeral instability without any rotator cuff tear in 39 cases (22.7%, zero-sample group c). All patients had a preoperative MRI of the shoulder (1.5T or 3T). Minimum CHD was measured on axial fat-suppressed proton density-, T2-, or T1-weigthed sequences. Receiver operating characteristics analysis was used to determine the threshold value for CHD, and sensitivity and specificity were calculated.
Results: CHD measurement had a good interobserver reliability (Intraclass correlation coefficient 0.799). Mean CHD was highly significantly ($P < .001$) less for test group a (mean 7.3 mm, standard deviation $\pm$ 2.2) compared with control group b (mean 11.1 mm, standard deviation $\pm$ 2.3) or zero-sample group c (mean 13.6 mm, standard deviation $\pm$ 2.9). A threshold value of CHD <9.5 mm had a sensitivity of 83.6% and a specificity of 83.9% to predict SSC tears.
Conclusion: A CHD <9.5 mm on MRI is predictive of SSC lesions and a valuable tool to diagnose SSC tears.

The subscapularis (SSC) is the largest and strongest muscle of the rotator cuff and crucial for shoulder stability and function. In recent years, surgeons have increasingly recognized its major role in shoulder pathology and refined the treatment for tendon lesions.[18]

Preoperative diagnosis of SSC tears remains challenging. Clinical examination has only low sensitivity and tears are frequently missed even on magnetic resonance imaging (MRI).[15,22,25]

Similar to subacromial impingement, in subcoracoid impingement, the SSC tendon can become entrapped between the lesser tuberosity and the coracoid.

A small coracohumeral distance (CHD) can promote a subcoracoid impingement of the SSC tendon. The proposed "roller-wringer effect" of the coracoid causes degenerative changes and ultimately tears of the SSC tendon.[13] Consistent with this, a small CHD is associated with SSC tears.[1,12,13,17]

Several radiological modalities have been described to evaluate the CHD including plain radiology, fluoroscopy, computed tomography, ultrasound, and MRI.[3,8,11,17]

This study was designed to define a specific threshold value for CHD to predict SSC tears on standard MRI scans.

Methods

The present study evaluated 172 consecutive shoulders in 168 patients who underwent arthroscopic surgery for rotator cuff tear (RCT) or glenohumeral instability (GI) between 2010 and 2018 in our institution. We intentionally included patients with no evidence of RCT on MRI and diagnostic arthroscopy (GI, group c) serving as a zero-control group. Preoperative MRI was performed in all cases and 172 shoulders (100%) were eligible for this study. For patient demographics, refer to Table I.

Intraoperatively, SSC tears were classified according to Fox and Romeo[7] (grade 0 = no tear, grade 1 = partial tear, grade 2 = full tear

of upper 25%, grade 3 = full tear of upper 50%, grade 4 = full tendon tear).

Patients with previous shoulder surgery, advanced omarthrosis, rotator cuff arthrosis, inflammatory arthropathy, and post-traumatic or congenital deformities of the humerus and/or scapula were excluded.

Radiographic analysis

A senior radiologist and a senior shoulder surgeon evaluated all MRIs. The minimal CHD was measured on axial fat-suppressed proton density-, T2-, and T1-weigthed sequences and recorded in millimeters (mm). The smallest distance between the cortex of coracoid back surface and the cortex of the humeral head was recorded as CHD (Fig. 1). Measurements were performed by 1 orthopedic surgeon and 1 radiologist blinded to the results. Each investigator performed 3 measurements and calculated the average. This method is established and was used before.[23] One independent investigator repeated his CHD measurements on 40 randomly chosen MRIs to calculate intraobserver reliability.

Statistical analysis

Descriptive statistics were performed to describe means and range for all variables. Kolmogorov-Smirnov or Shapiro-Wilk-test was used to identify normal distribution of variables. Levene test was used to test for homogeneity of variances. CHD results were parametric, nondependent, and normally distributed, and Student's t-test was applicable to identify significance differences in means. intraclass correlation coefficient (ICC) was applied to measure interobserver and intraobserver reliability for CHD measurements. Receiver operating characteristics analysis was used to determine the threshold value for CHD, and sensitivity and specificity were calculated. Statistical analysis was performed for a 95% confidence interval. Results with P values <.05 were considered statistically significant; results with $P < .01$ were considered highly significant. Standard deviation (SD) for CHD was previously calculated to be 0.18-0.20 mm[3]. Power calculation for an alpha failure of $\alpha = 0.05$, an effect size of 1, and an aimed power $(1-\beta)$ of 95% required a sample size of 54 patients. All statistical analyses were performed using IBM SPSS Statistics software, version 24.0.0.0 (IBM, Armonk, NY, USA). Power calculation was performed with G*Power, version 3.1.9.2.[6]

Results

Diagnostic arthroscopy confirmed a SSC tear in 62 cases (36.0%, test group a) and RCT tears other than SSC in 71 cases (41.3%, control group b). In all 39 cases (22.7%, zero-sample group c) that were operated on for GI, diagnostic arthroscopy ruled out RCT in any case. The right shoulder was affected in 103 patients (59.9%) and the left shoulder in 69 patients (40.1%). The mean age at time of MRI was 53.9 years (range 14-79, SD 16.5), 50 patients (29.1%) were

female and 122 (70.9%) were male. There was no significant difference in mean age between group a (SSC tear, mean age 62.4 years, SD 1.2) and group b (RCT other than SSC, mean age 60.2 years, SD 1.1); group c (GI, 28.7 years, SD 1.4) had a significantly lower mean age.

CHD measurements showed a good intraobserver (ICC 0.948) and interobserver (ICC 0.799) reliability.

The mean CHD for group A (7.3 mm, SD 2.2) was highly significantly ($P < .001$) less compared with group C (13.6 mm, SD 2.9) or group B (11.1 mm, SD 2.3) (Fig. 2).

There was a highly significant ($P < .001$) difference in CHD between no SSC tear (12.1 mm, SD 2.9) and any SSC tear (7.9 mm, SD 2.9).

There were no significant differences in CHD between partial, incomplete, or complete tears (Fox and Romeo grade 1 to grade 4, $P = .154$-.890), but mean CHD decreased from partial (8.7 mm, SD 0.74) to full SSC tears (7.4 mm, SD 0.55).

The receiver operating characteristic curve for variable CHD cutoff value between group A and all other groups (group b and c) (Fig. 3) or between group A and group C (Fig. 4) promoted a cutoff of CHD<9.5 mm. A threshold value of CHD<9.5 mm had a pooled sensitivity of 83.6% and a specificity of 84.5% to predict SSC tears (Table II).

Discussion

The present study revealed significant differences in CHD between patients with or without SSC tears. This finding is consistent with other authors that reported a correlation between lower CHD and SSC tears.[2,12,21]

Gerber et al[9] and Patte[19] were the first to further examine the coracohumeral interval in regards to shoulder pathology. Lo and Burkhart[13] attributed a subcoracoid stenosis with its resulting "roller-wringer effect" as an additional etiologic factor for SSC tendon degeneration and tearing next to intrinsic tendon degeneration.

The CHD was the first parameter to quantify this subcoracoid stenosis and its resultant impingement. In multiple studies, the reliability of CHD measurement by fluoroscopy, computed tomography, MRI, and ultrasound was proven.[3,7,10,16]

Recently, there have been attempts to find more robust correlations between SSC lesions and the coracoid morphology by using multiple quantifiable parameters such as coracoid index and coracoglenoid inclination,[26] coracoid overlap,[4,12] coracoid base angle,[4,24] coracohumeral angle,[1] and even measurements of angle and distance in a sagittal plane.[20,24] Some of these parameters exhibit the advantage of being uninfluenced by arm rotation, but well-accepted cutoff values are still missing and no consensus exists, which parameters are most reliable. For clinical practice, however, a more feasible and reliable parameter to predict SSC tears must be chosen. We believe CHD is suitable to fit these demands.

Table I
Patient demographics.

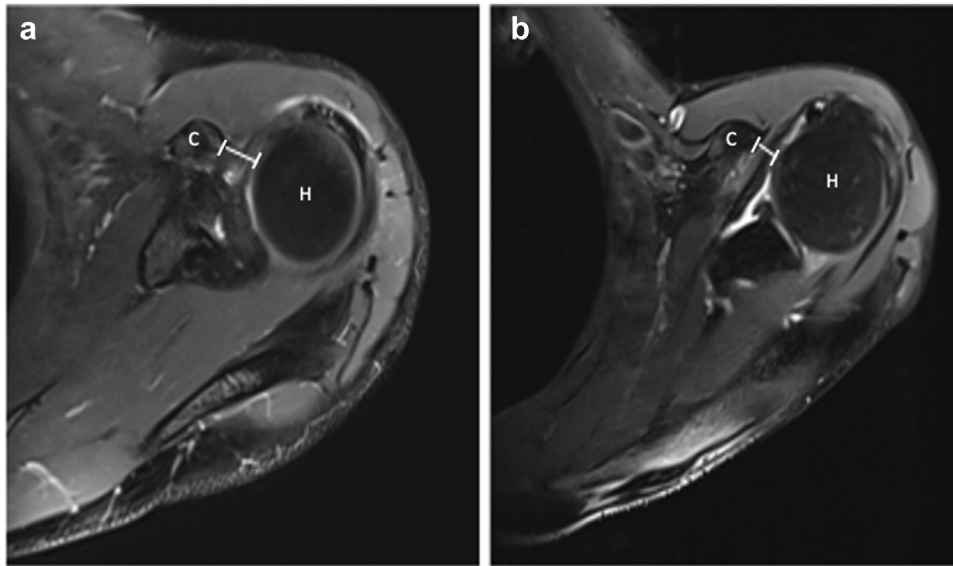| Demographics	Group A (SSC tear)	Group B (RCT other than SSC tear)	Group C (glenohumeral instability)
No. of patients	62	71	39
Mean age, standard deviation	62.4 ± 1.7	60.2 ± 1.2	28.7 ± 1.4
Gender (m/f)	46 male	40 male	34 male
	16 female	31 female	5 female
Affected side (r/l)	39 right	43 right	21 right
	23 left	28 left	18 left

SSC, subscapularis.

Figure 1 Images showing a normal CHD of 12 mm (*Left*, **a**) and a narrowed CHD of 7 mm (*Right*, **b**) with arthroscopically confirmed SSC lesion; *C*, coracoid; *H*, humeral head; *CHD*, coracohumeral distance; *SSC*, subscapularis.
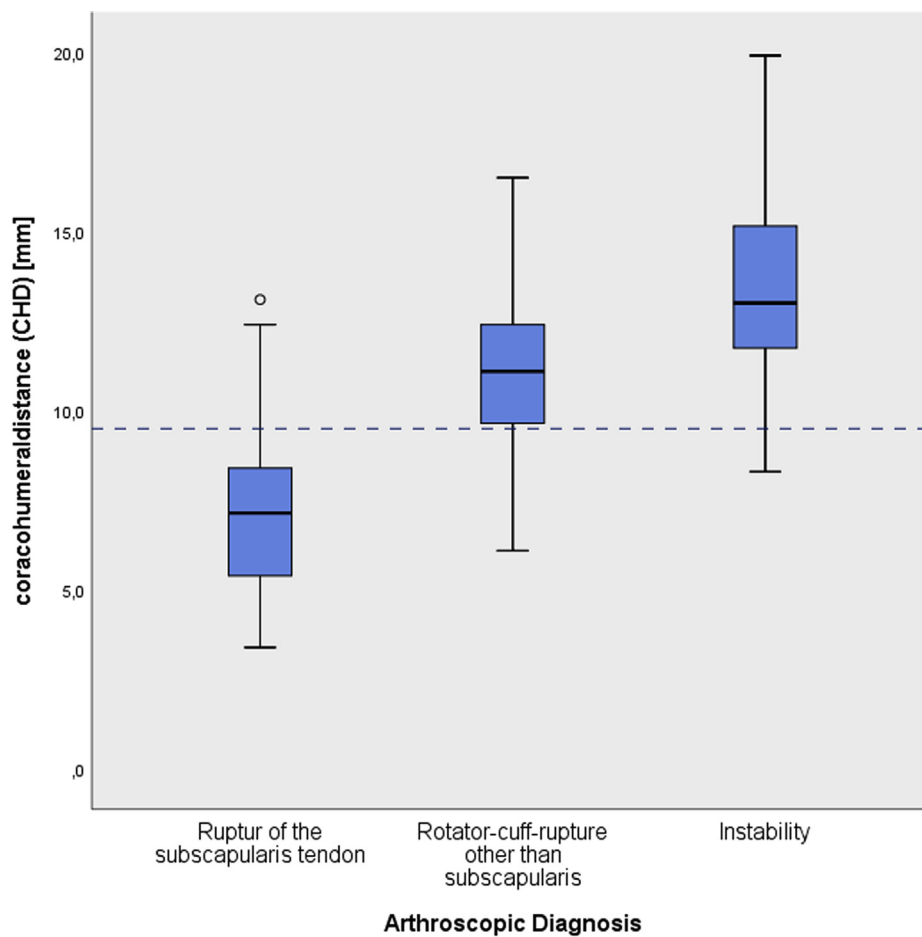

Figure 2 Box plots of CHD measurements with mean and standard deviation. The mean CHD for group A = rupture of the SSC tendon (*Left*, 7.3 mm, SD 2.2) was highly significantly ($P < .001$) less compared with group C = instability (*Right*, 13.6 mm, SD 2.9) or group B = other RC rupture (*Middle*, 11.1 mm, SD 2.3). *CHD*, coracohumeral distance; *SSC*, subscapularis.
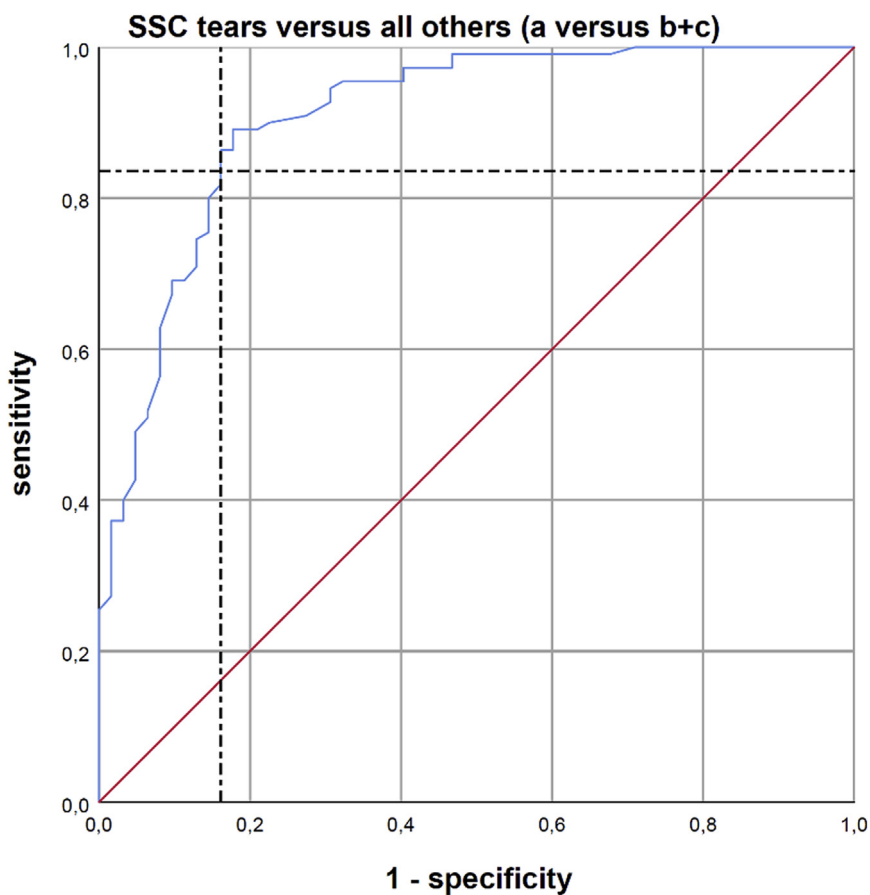
Figure 3 ROC curve for different CHD values to predict an SSC tear and (group A vs. group B and group C). Optimal cutoff of 9.5 mm leads to a sensitivity of 83.6% and specificity of 83.9%. *CHD*, coracohumeral distance; *SSC*, subscapularis.

The present study provides a large sample of 172 cases with 2 control groups to find a cutoff for CHD value to predict SSC tears by measuring the CHD.

The mean CHD for our patients with glenohumeral instability or RCTs with intact SSC tendon was significantly larger than in the group with SSC pathology. The CHD value of our control group b was similar to that recently published results thereby confirming a range from 8.1 mm to 13.4 mm as the spectrum of regular shoulder anatomy.[2,8,9,12]

In our sample, a CHD lower than 9.5 mm was a good predictor of a SSC lesion, consistent with other authors that proposed a CHD cutoff between 6 and 9 mm to predict SSC pathology.[2,12,14,21]

In the present study, a cutoff value of 9.5 mm had a sensitivity of 83.6% and a specificity of 84.5% to predict SSC tears. This value slightly differs from results published by Leite et al who propose a cutoff of 7.6 mm for a sensitivity of 84.4% and a specificity of 88.6%.[10] If we used this value of 7.6 mm, we got a sensitivity of 92.5% and a specificity of 81.1%. With our data, this was not the optimal value in receiver operating characteristics curve analysis.

This difference might be related to a different control group with different concomitant pathology. Our CHD cutoff is based on patients without rotator cuff lesions, whereas only 9.6% of the control group reported in the study by Leite et al had an intact rotator cuff.[10] This control group without concomitant degenerative tendon pathology is a major strength of our study in contrast to previous reports.

The present study has the following limitations: (1) The control group used in the present study was operated on for shoulder instability. CHD might differ in a healthy population. (2) The present study does not differentiate between full-thickness or partial tears of the SSC. (3) Arm positioning during MRI can influence CHD to a certain level.[3] (4) Variation in sequences (ie, proton density FS, T1) can slightly impair CHD measurement. (5) Even careful arthroscopic examination can miss minor SSC lesions. (6) CHD seems to be less in women.[10] Furthermore, coracoid morphology can vary with age.[5] However, in the present study, there were no significant differences in distribution of sex or age in any subgroup.[5,10]

Navarro-Ledesma et al[16] reported poor correlation of a small CHD and shoulder function or pain in asymptomatic individuals. CHD can be influenced by gender, age, and arm position during MRI. Therefore, CHD can only provide an important hint to diagnose SSC tears. It cannot supersede careful clinical examination and assessment of the SSC tendon in MRI or ultrasound.

Further studies on larger samples should be performed to evaluate and improve cutoff values for complete and partial tears in respect to age and gender. Other morphologic factors of coracoid or glenoid morphology should also be investigated in this regard.

Conclusion

CHD is a reliable measurement on axial MRI scans. It is significantly less in presence of an SSC tear. Based on the present study, a CHD of less than 9.5 mm predicts SSC tears with high specificity.
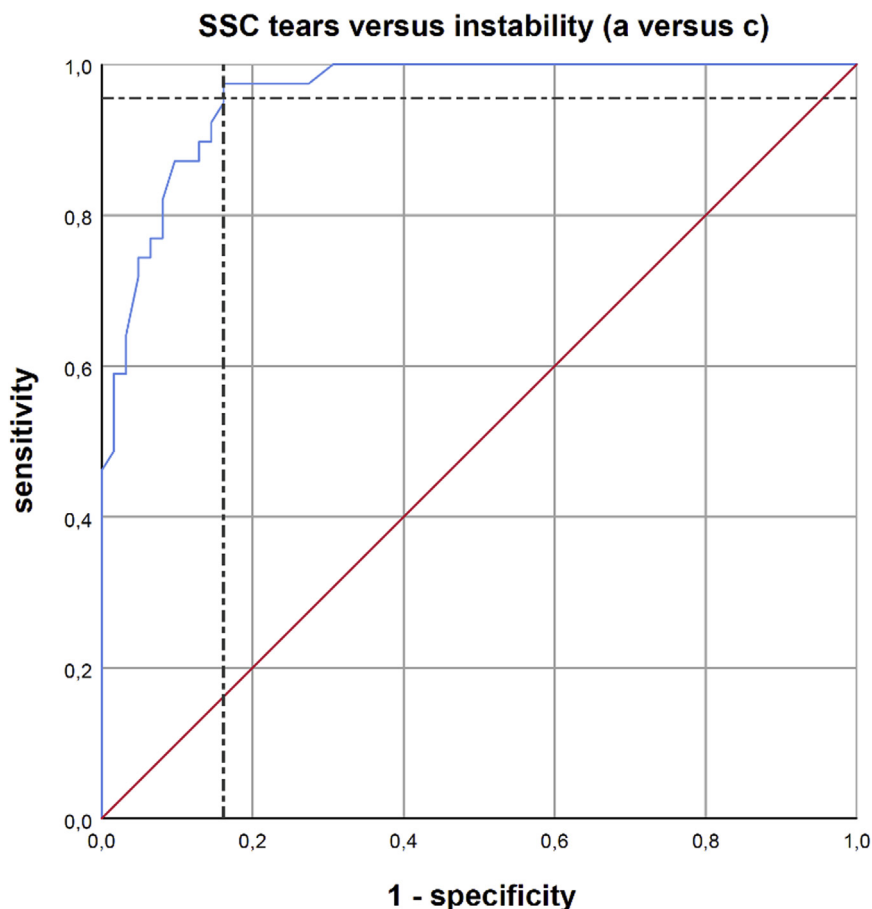
Figure 4 ROC curve for different CHD to predict SSC tear (group A vs. group C). Without other RC tears, the cut-off of 9.5 mm leads to a sensitivity of 94.9% with a specificity of 83.9%. *CHD*, coracohumeral distance; *SSC*, subscapularis.

Table II
Contingency table for CHD less than 9.5 mm.

Intraoperative confirmed SSC tear				
CHD less than 9.5 mm on MRI		Yes	No	Total
	Yes	52 (83.9%)	17 (15.5%)	69 (40.1%)
	No	10 (16.1%)	93 (84.5%)	103 (59.9%)
	Total	62	110	172

CHD, coracohumeral distance; *MRI*, magnetic resonance imaging; *SSC*, subscapularis.

Disclaimers:

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