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

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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-weighted 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 ± 2.2) compared with control group b (mean 11.1 mm, standard deviation ± 2.3) or zero-sample group c (mean 13.6 mm, standard deviation ± 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.

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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.

Preoperative diagnosis of SSC tears remains challenging. Clinical examination has only low sensitivity and tears are frequently missed even on magnetic resonance imaging (MRI). Several radiological modalities have been described to evaluate the CHD including plain radiology, fluoroscopy, computed tomography, ultrasound, and MRI. Several radiological modalities have been described to evaluate the CHD including plain radiology, fluoroscopy, computed tomography, ultrasound, and MRI.

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. Consistent with this, a small CHD is associated with SSC tears.

Several radiological modalities have been described to evaluate the CHD including plain radiology, fluoroscopy, computed tomography, ultrasound, and MRI. 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 1.

Intraoperatively, SSC tears were classified according to Fox and Romeo (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 osteoarthritis, rotator cuff arthropathy, 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-weighted 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 mm3. Power calculation for an alpha failure of 0.05, an effect size of 1, and an aimed power (1-β) of 0.74) to full SSC tears (7.4 mm, SD 0.55) 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.4,10,24

Gerber et al.4 and Patte19 were the first to further examine the coracohumeral interval in regards to shoulder pathology. Lo and Burkhart13 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.1,3,10,12,14

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,12 coracoid base angle,14 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

| 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                          |
| Affected side (r/l) | 16 female        | 31 female                       | 5 female                         |
|              | 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.
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.1 (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.2 However, in the present study, there were no significant differences in distribution of sex or age in any subgroup.5,10

Navarro-Ledesma et al16 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.

| CHD less than 9.5 mm on MRI | Yes | No | Total |
|-----------------------------|-----|----|-------|
| Intraoperative confirmed SSC tear | 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.

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References

1. Asal N, Sahan MH. Radiological Variabilities in Subcoracoid Impingement: Coracoid Morphology, Coracohumeral Distance, Coracoglenoid Angle, and Coracohumeral Angle. Med Sci Monit 2018;24:8678-84. https://doi.org/10.12659/MSM.911470.

2. Balke M, Banerjee M, Greshake O, Hoehler J, Bouillon B, Liem D. The Coracohumeral Distance in Shoulders With Traumatic and Degenerative Subscapularis Tendon Tears. Am J Sports Med 2016;44:198-201. https://doi.org/10.1177/0363546515611653.

3. Brunkhorst JP, Giphart JE, LaPrade RF, Millett PJ. Coracohumeral Distances and Correlation to Arm Rotation: An In Vivo 3-Dimensional Biplane Fluoroscopy Study. Orthop J Sport Med 2013;1:2325967113496099. https://doi.org/10.1177/2325967113496099.

4. Cetinkaya M, Ataoglu MB, Ozer M, Ayanoglu T, Kanatli U. Subscapularis Tendon Slip Number and Coracoid Overlap Are More Related Parameters for Subcoracoid Impingement in Subscapularis Tears: A Magnetic Resonance Imaging Comparison Study. Arthrosc J Arthrosc Relat Surg 2017;33:734-42. https://doi.org/10.1016/j.arthro.2016.09.003.

5. Dugarte AJ, Davis RJ, Lynch TS, Schickendantz MS, Farrow LD. Anatomic Study of Subcoracoid Morphology in 418 Shoulders: Potential Implications for Subcoracoid Impingement. Orthop J Sport Med 2017;5:2325967117731996. https://doi.org/10.1177/2325967117731996.

6. Faul F, Erdfelder E, Lang A-G, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39:175-91. https://doi.org/10.3758/BF03193146.

7. Fox J, Romeo AA. Arthroscopic subscapularis repair; Annual Meeting of the American Academy of Orthopaedic Surgeons. 2003. Lippincott Williams & Wilkins, Inc.: New Orleans, LA, USA.

8. Friedman RJ, Bonutti PM, Geneb B. Cine magnetic resonance imaging of the subcoracoid region. Orthopedics 1998;21:545-8.
9. Gerber C, Terrier F, Zehnder R, Ganz R. The subcoracoid space. An anatomic study. Clin Orthop Relat Res 1987:132-8.
10. Giaroli EI, Major NM, Lemley DE, Lee J. Coracohumeral Interval Imaging in Subcoracoid Impingement Syndrome on MRI. Am J Roentgenol 2006;186:242-6. https://doi.org/10.2214/AJR.04.0830.
11. Hatta T, Yamamoto N, Sano H, Omori Y, Sugimoto K, Suzuki K, et al. Three-dimensional morphometric analysis of the coracohumeral distance using magnetic resonance imaging. Orthop Rev (Pavia) 2017;9:6999. https://doi.org/10.4081/or.2017.6999.
12. Leite MJ, Lopes MJ, Matos RM, Sousa AN, Torres JM. Coracohumeral distance and coracoid overlap as predictors of subscapularis and long head of the biceps injuries. J Shoulder Elbow Surg 2019;28:1723-7. https://doi.org/10.1016/j.jse.2019.01.012.
13. Lo IKY, Burkhart SS. The Etiology and Assessment of Subscapularis Tendon Tears: A Case for Subcoracoid Impingement, the Roller-Wringer Effect, and TUFF Lesions of the Subscapularis. Arthrosc J Arthrosc Relat Surg 2003;19:1142-50. https://doi.org/10.1016/j.arthro.2003.10.024.
14. Lo IK, Parten PM, Burkhart SS. Combined subcoracoid and subacromial impingement in association with anterosuperior rotator cuff tears: an arthroscopic approach. Arthrosc J Arthrosc Relat Surg 2003;19:1068-78. https://doi.org/10.1016/j.arthro.2003.10.016.
15. Malavolta EA, Assunção JH, Gracitelli MEC, Yen TK, Bordalo-Rodrigues M, Ferreira Neto AA. Accuracy of magnetic resonance imaging (MRI) for subscapularis tear: a systematic review and meta-analysis of diagnostic studies. Arch Orthop Trauma Surg 2019;139:659-67. https://doi.org/10.1007/s00207-018-3955-6.
16. Navarro-Ledesma S, Struyf F, Labajos-Manzanares MT, Fernandez-Sanchez M, Luque-Suarez A. Is coracohumeral distance associated with pain-function, and shoulder range of movement, in chronic anterior shoulder pain? BMC Musculoskelet Disord 2017;18:136. https://doi.org/10.1186/s12891-017-1498-0.
17. Oh JH, Song BW, Choi J-A, Lee GY, Kim SH, Kim D-H. Measurement of Coracohumeral Distance in 3 Shoulder Positions Using Dynamic Ultrasonography: Correlation With Subscapularis Tear. Arthrosc J Arthrosc Relat Surg 2016;32:1502-8. https://doi.org/10.1016/j.arthro.2016.01.029.
18. Ono Y, Sakai T, Carroll MJ, Lo IKY. Tears of the Subscapularis Tendon. JBJS Rev 2017;5:1. https://doi.org/10.2106/JBJS.RVW.16.00054.
19. Patte D. The subcoracoid impingement. Clin Orthop Relat Res 1990;55-9.
20. Porter NA, Singh J, Tins BJ, Lalani RK, Tyrell PNM, Cassar-Pullicino VN. A new method for measurement of subcoracoid outlet and its relationship to rotator cuff pathology at MR arthrography. Skeletal Radiol 2015;44:1309-16. https://doi.org/10.1007/s00256-015-2166-9.
21. Richards DP, Burkhart SS, Campbell SE. Relation Between Narrowed Coracohumeral Distance and Subscapularis Tears. Arthrosc J Arthrosc Relat Surg 2005;21:1223-8. https://doi.org/10.1016/j.arthro.2005.06.015.
22. Schiefer M, Júnior YAC-S, Silva SM, Fontenelle C, Dias Carvalho MG, de Faria FG, et al. Clinical diagnosis of subscapularis tendon tear using the bear hug semilogical maneuver. Rev Bras Ortop 2012;47:588-92. https://doi.org/10.1016/S2255-4971(15)30008-2.
23. Tan V, Moore RS, Omarini I, Kneeland JB, Williams GR, Iannotti JP. Magnetic resonance imaging analysis of coracoid morphology and its relation to rotator cuff tears. Am J Orthop (Belle Mead Nj) 2002;31:329-33.
24. Watson AC, Jamieson RP, Martin AC, Page RS. Magnetic resonance imaging based coracoid morphology and its associations with subscapularis tears: a new index. Shoulder Elbow 2019;11:52-8. https://doi.org/10.1177/1758521717744170.
25. Yoon JP, Chung SW, Kim SH, Oh JH. Diagnostic value of four clinical tests for the evaluation of subscapularis integrity. J Shoulder Elb Surg 2013;22:1186-92. https://doi.org/10.1016/j.jse.2012.12.002.
26. Zhang H, Zhang Q, Li ZL. Coracohumeral index and coracoglenoid inclination as predictors for different types of degenerative subscapularis tendon tears. Int Orthop 2019;43:1909-16. https://doi.org/10.1007/s00264-018-4678-5.