Identification of Diagnostic Magnetic Resonance Imaging Findings in 47 Shoulders with Subcoracoid Impingement Syndrome by Comparison with 100 Normal Shoulders

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Conflict of interest:  
None declared

Background:  
The aim of this study was to identify the diagnostic magnetic resonance imaging (MRI) findings in 47 shoulders with subcoracoid impingement syndrome by comparison with 100 normal shoulders.

Material/Methods:  
The subcoracoid impingement syndrome group consisted of 47 shoulders with subcoracoid impingement syndrome and the normal group consisted of 100 normal shoulders. The MRI parameters – coracoids-humeral distance (CHD), coracoid index (CI), height of the lesser tuberosity (HLT), coracoid obliquity (CO), coracoglenoid angle (CGA), coracohumeral angle (CHA), width of the subscapular tendon (WST), and contact distance between subscapular tendon and coracoid process (CD) – were compared between the subcoracoid impingement syndrome group and the normal group. The areas under the curves (AUCs) from the receiver operating characteristic (ROC) for single MRI parameters were recorded, in which the MRI parameters with AUC exceeding 0.70 were included in the analysis of combined parameters. Comparisons of ROC were made among single parameters and combined parameters.

Results:  
For diagnosing subcoracoid impingement syndrome by using single MRI parameters (CHD, CI, HLT, CGA, CHA, WST, and CD), the AUCs were 0.963, 0.806, 0.745, 0.691, 0.613, 0.685, and 0.614, respectively, of which CHD had the largest AUC. CHD, CI, and HLT (AUC exceeding 0.70) were included in the study of the combined parameters. The AUC of combined CHD and HLT showed a significantly larger AUC than that of CHD (0.986 vs 0.963, P=0.036), and showed no significant difference compared with that of combined CHD, CI, and HLT (0.986 vs 0.987, P=0.882).

Conclusions:  
Measurement of the coracoid–humeral distance and height of the lesser tuberosity were key MRI diagnostic findings for subcoracoid impingement syndrome.

Keywords:  
Magnetic Resonance Imaging • Shoulder Impingement Syndrome • Coracoid Process

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Background

Subcoracoid impingement syndrome is defined as impingement of the anterior soft tissues of the shoulder between the coracoid process and the lesser tuberosity, which causes fiber failure and damage, then partial or complete tearing of the subscapularis tendon, resulting in anterior shoulder pain [1-10].

There were some studies discussing the imaging index for diagnosing subcoracoid impingement syndrome. Some studies have shown that the coracohumeral distance (CHD) is the predictor for subcoracoid impingement syndrome on plain film, CT, and MRI [11-14], and the excessive extension of the coracoid process and variants in the lesser tuberosity anatomy are associated with subcoracoid impingement syndrome [4,11,15]. Other authors report that an increase in overall size of the tendon and disproportionate contact of the rotator cuff with surrounding structures were also associated with subcoracoid impingement syndrome [16-18]. Additionally, some angles, such as the coracoglenoid angle and coracohumeral angle, have been found to be indices for subcoracoid impingement syndrome [3,19,20].

However, other studies have shown different results. Radas and Pieper [21] found no correlation between the coracohumeral interval and subscapularis injury. Bergin et al [17] reported no significant relationship between the measured subcoracoid interval and severity of subscapularis tendon abnormalities. Some studies showed no correlation between subscapularis injury and MRI parameters [22,23].

We know that impingement syndrome is related to the position of anatomical structures in three-dimensional space; these studies with a single parameter are limited because subcoracoid impingement syndrome arises from a three-dimensional pathology [14]. We speculate that the diagnostic value of combining multiple parameters of MRI is better than that of a single parameter. Therefore, the purpose of this study was mainly to identify the diagnostic magnetic resonance imaging (MRI) findings in 47 shoulders with subcoracoid impingement syndrome by comparison with 100 normal shoulders.

Material and Methods

Patients

This study included 100 normal shoulders and 47 shoulders with subcoracoid impingement syndrome. The diagnostic criteria of subcoracoid impingement syndrome are as follows: (1) MRI findings include narrowed subcoracoid space, increased signal and fraying of the subscapularis tendon; (2) tenderness of the soft tissue around the coracoid process or between the coracoid process and lesser tuberosity; (3) shoulder apprehension test can induce anterior shoulder pain, and the pain is relieved after retesting; (4) coracoid impingement test or modified Kennedy-Hawkins impingement sign was positive, and turned negative after subcoracoid infiltration of local anesthetics [15,24]. A total of 47 patients diagnosed with subcoracoid impingement syndrome (19 males and 28 females) undergoing shoulder MRI, with mean age of (47.19±10.08) and age range from 34 to 70 years, were included in this study. All of them had single shoulder disease, including 24 cases of right shoulder and 23 cases of left shoulder.

The range of the course on subcoracoid impingement syndrome was from 1 month to 1 year. All patients underwent a comprehensive shoulder physical examination before MRI. The normal group consisted of 100 volunteers. The inclusion criteria of normal group are as follows: no history of chronic shoulder pain, with normal shoulder function, no history of shoulder trauma and surgery, no obvious MRI features of subcoracoid impingement syndrome. The normal group included 51 males and 49 females, aged 24-76 years, with an average age of (48.74±12.14). MRI Technique and Measurements

All MRI examination were performed using the 1.5 Tesla MRI system (Avanto 1.5T, Siemens, Berlin, Germany). All subjects lay in supine position with a loop coil around the shoulder. MRI was performed with the arm in neutral position. The scanning parameters are shown in Supplementary Table 1.

The coracoid-humeral distance (CHD) is defined as the minimal distance between the coracoid process and lesser tuberosity on an axial image [3,11]. The coracoid index (CI) is defined as the distance between coracoid process and glenoid process on an axial image [25]. The height of the lesser tuberosity (HLT) was defined as the length of the line through the highest point inside and outside the intertubercular sulcus and the parallel line through the bottom of the intertubercular sulcus. The coracoid obliquity (CO) was defined as the angle between the axis of the coracoid process and a horizontal line on the coronal image. The coracoid-glenoid angle (CGA) was measured as the angle between a line along the plane of the glenoid face and the apex of the coracoid on the axial image [3]. The coracoid-humeral angle (CHA) was measured as the included angle between the internal and external tangent lines of the humeral head through the tip of the coracoid process on the axial image [3]. The width of the subscapular tendon (WST) is the...
Subcoracoid impingement

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Test statistics

Women. The normal group included 48 left and 52 right shoulders, and the subcoracoid impingement syndrome group included 23 left and 24 right shoulders. There was no significant difference between the normal group and subcoracoid impingement syndrome group in age (t=1.017, P=0.136), sex, or left-and-right side (χ²=1.433, P=0.231; χ²=0.011, P=0.916) (Table 1).

The CHD, CI, HLT, CO, CGA, CHA, WST, and CD of the normal group were 7.7±1.5 mm, 16.0±3.3 mm, 5.5±1.0 mm, 8.9±2.9°, 132.6±8.5°, 106.7±9.5°, 5.4±1.3 mm, and 8.9±2.3 mm, respectively. The CHD, CI, HLT, CO, CGA, CHA, WST, and CD of subcoracoid impingement syndrome group were 4.7±1.2 mm, 20.1±3.3 mm, 6.6±1.4 mm, 9.3±1.0°, 126.8±9.6°, 110.2±10.5°, 6.4±1.8 mm, and 10.5±3.8 mm, respectively. The CHD, CI, HLT, CGA, CHA, WST, and CD between subcoracoid impingement syndrome group and normal group showed significant differences (Z=-9.043, P<0.001; Z=5.981, P<0.001; Z=4.787, P<0.001; Z=-3.731, P<0.001; Z=2.205, P=0.027; Z=3.623, P<0.001; Z=2.233, P=0.026) (Table 2; Figures 1-3).

Using a single parameter for diagnosing subcoracoid impingement syndrome, the area under the curve (AUC) of CHD, CI, HLT, CGA, CHA, WST, and CD were 0.963, 0.806, 0.745, 0.691, 0.613, 0.685, and 0.614, respectively (Figure 4), in which CHD showed the largest AUC.

The parameters (CHD, CI, HLT) with AUC exceeding 0.70 were included in the study of the combined parameters. When the cut-off values were 5.9 mm, 16.5 mm, 5.5 mm for CHD, CI and HLT, respectively, the sensitivity and specificity were 89.4% and 92.0%, 85.1% and 61%, 83% and 57%, respectively. Compared with the AUC using a single CHD for diagnosing subcoracoid impingement syndrome, the combined CHD and CI did not have a significantly different AUC (0.966 vs 0.963, P=0.645), the combined CHD and HLT had a significantly larger AUC (0.986 vs 0.963, P=0.036), and the combined CHD, CI, and HLT also had a significantly larger AUC using the combined parameters.
AUC (0.987 vs 0.963, P=0.022). The AUC of combined CHD and HLT showed no significant difference compared with that of combined CHD, CI, and HLT (0.986 vs 0.987, P=0.882) (Figure 5).

**Discussion**

In summary, CHD, CI, HLT can be used as the efficient quantitative diagnostic indexes of MRI on CIS. Moreover, CHD combined with HLT shows higher efficiency and clinical utility.

Among the parameters in our study, 3 parameters (CHD, CI, HLT) reached the standard of combined parameters analysis, which had AUC exceeding 0.70. The AUC of CHD for diagnosing subcoracoid impingement syndrome in our study was 0.963, which was the largest AUC among all single parameters. Our result on CHD was consistent with some previous studies, which all reported the CHD is the most important index [11,13,24-30]. In our study, CHD was significantly narrower than that of the normal group (4.7 mm vs 7.7 mm), and the cut-off value based on the ROC curve was 5.9 mm. Some studies showed results similar to those of the present study [24-29], although

### Table 2. Comparison of CHD, CI, HLT, CO, CGA, CHA, WST, and CD between normal and subcoracoid impingement syndrome group.

|                | Normal group | Subcoracoid impingement syndrome group | Z value | P value |
|----------------|--------------|---------------------------------------|---------|---------|
| CHD (mm)       | 7.7±1.5      | 4.7±1.2                               | Z=-9.043| P<0.001|
| CI (mm)        | 16.0±3.3     | 20.1±3.3                              | Z=5.981 | P<0.001|
| HLT (mm)       | 5.5±1.0      | 6.6±1.4                               | Z=4.787 | P<0.001|
| CO (°)         | 8.9±2.9      | 9.3±3.0                               | Z=0.572 | P=0.567|
| CGA (°)        | 132.6±8.5    | 126.8±9.6                             | Z=-3.731| P<0.001|
| CHA (°)        | 106.7±9.5    | 110.2±10.5                            | Z=2.205 | P=0.027|
| WST (mm)       | 5.4±1.3      | 6.4±1.8                               | Z=3.623 | P<0.001|
| CD (mm)        | 8.9±2.3      | 10.5±3.8                              | Z=2.233 | P=0.026|

The results are expressed as mean±standard deviation (SD); CHD – coracoid-humeral distance; CI – coracoid index; HLT – height of lesser tuberosity; CO – coracoid obliquity; CGA – coracoglenoid angle; CHA – coracohumeral angle; WST – width of the subscapular tendon; CD – contact distance between subscapular tendon and coracoid process.
our study showed a larger AUC than the AUC (0.882) reported in a previous study [31].

In our study, the CI also reached the standard of combined parameters analysis, with an AUC of 0.806. There are many anatomic variations in the coracoid process, such as excessive lengthening of the coracoid process, that is, the increase of CI, which is also an important cause of subcoracoid impingement syndrome [3,23,32,33]. The cut-off value in our study was 16.5 mm, which agrees with a past study reporting 16.6 mm as the cut-off value [25].

The HLT was the third parameter included in combined parameters analysis in our study. As some studies reported, variation of small tuberosity anatomy, such as a prominent tuberosity, was one of the causes of impingement [11,15,19,31].

Our study is the first to report that the combined MRI parameters had a better diagnostic effect than a single MRI parameter for diagnosing subcoracoid impingement syndrome. In our study, the combined CHD, CI, and HLT, as well as the combined CHD and HLT, showed significant larger AUCs comparing with CHD alone for diagnosing subcoracoid impingement syndrome. Our study

**Figure 2.** The CI (22.17 mm) of subcoracoid impingement syndrome (A) was longer than that of the normal shoulder (15.52 mm) (B). (Avanto 1.5T, Siemens; Neusoft PACS software, version 5.5.0.19075, Neusoft). CI – coracoid index.

**Figure 3.** The HLT (7.88 mm) of subcoracoid impingement syndrome (A) was higher than that of normal shoulder (5.74 mm) (B). (Avanto 1.5T, Siemens; Neusoft PACS software, version 5.5.0.19075, Neusoft). HLT – height of lesser tuberosity.
also found the AUC of combined CHD and HLT showed no significant difference compared with that of combined CHD, CI, and HLT. Using as few parameters as possible, the combined CHD and HLT had better clinical utility than combined CHD, CI, and HLT.

**Limitations of This Study Are As Follows**

First, the sample size of subcoracoid impingement syndrome in this study was not large enough, and future studies should include more cases for detailed analysis. Second, dynamic MRI may have better value for diagnosing subcoracoid impingement syndrome. Third, in this study, the clinical application scanning parameters were used. Although the scanning thickness was slightly thicker, the conclusions of our study can directly guide clinical work.

**Conclusions**

Measurement of the coracoids-humeral distance and height of the lesser tuberosity were key MRI diagnostic findings for subcoracoid impingement syndrome.

**Declaration of Figures’ Authenticity**

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.
Supplementary Material

Supplementary Table 1. The MRI sequences and parameters for shoulder.

| Sequence                                               | TR (ms) | TE (ms) | Matrix       | Slice thickness (mm) | Section gap (mm) |
|--------------------------------------------------------|---------|---------|--------------|----------------------|------------------|
| Oblique coronal T1-weighted imaging                    | 687     | 9.40    | 384×384      | 3                    | 0.6              |
| Oblique coronal proton-weighted with fat saturation imaging | 4060    | 37      | 320×320      | 3                    | 0.6              |
| Axial proton-weighted with fat saturation imaging      | 4340    | 27      | 290×320      | 3.5                  | 0.8              |
| Axial T1-weighted imaging                               | 420     | 11      | 384×384      | 3.5                  | 0.7              |
| Oblique sagittal T2-weighted with fat saturation imaging | 2790    | 63      | 256×256      | 3                    | 0.6              |

MRI – magnetic resonance imaging; TR – repetition time; TE – echo time.

Supplementary Figure 1. (A) The coracoid-humeral distance (CHD) is defined as the minimal distance between the coracoid process and lesser tuberosity as the double arrow shown on an axial T1-weighted image. (B) The coracoid index (CI) is defined as the distance between coracoid process and glenoid as the double arrow shown on an axial T1-weighted image. (C) The4height of lesser tuberosity (HLT) was defined as distance between the line through the highest point inside and outside the intertubercular sulcus and the parallel line through the bottom of the intertubercular sulcus as the double arrow shown. (D) The coracoid obliquity (CO) was defined as the angle between axis of coracoid process and horizontal line through the apex of coracoid on coronal T1-weighted image. (E) The coracoid-glenoid angle (CGA) was measured as an angle between a line along the plane of the glenoid face and the apex of the coracoid on the axial image. (F) The coracoid-humeral angle (CHA) was measured as the included angle between the internal and external tangent lines of the humeral head through the tip of the coracoid process on the axial image. (G) The width of the subscapular tendon (WST) is the width of the subscapular tendon measured at the layer with the minimum CHD as the double arrow shown. (H) The contact distance between subscapular tendon and coracoid process (CD) was defined as the distance between superior edge of subscapular tendon and lower edge of coracoid process as the double arrow shown. (Neusoft PACS software, version 5.5.0.19075).
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