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ORIGINAL PAPER

Coracohumeral index and coracoglenoid inclination as predictors for different types of degenerative subscapularis tendon tears

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Abstract

Purpose To define and compare the coracohumeral index (CHI) and coracoglenoid inclination (CGI) in patients with different types of the subscapularis tendon tears.

Methods Patients were divided into two groups: articular-sided lesion group (group A) and bursal-sided lesion group (group B). All the patients were examined using a 3.0-T magnetic resonance imaging scanner pre-operatively. The morphometric parameters of the coracoids, including the coracohumeral distance (CHD), CHI, and CGI, were measured on MRI.

Results There were 165 (70.2%) and 70 (29.8%) patients in groups A and B, respectively. There was no significant difference in the average CHD (7.98 ± 1.7 mm vs 7.82 ± 2.1 mm, respectively) and CGI (50.5° ± 16.6° vs 44.9° ± 17.4°, respectively; $P =$ 0.427) between the two groups. Conversely, there was a significant difference in the CHI between them (0.32 ± 0.08 vs 0.57 ± 0.11, respectively; $P = 0.0001$). According to the CHI and CGI, the coracoid process was divided into three types, and nearly half of the patients (46.8%) had standard coracoids with a hook tip, which are vulnerable to injury on the articular side. However, with overlapping coracoids and hook tips, the patients (16.2%) tended to experience injury on the bursal side. There was a significant difference in the incidence of articular or bursal side tear between the two groups.

Conclusions The CHI and CGI are potential valuable predictors of the types of degenerative subscapularis tendon tears. With standard hook coracoids, the lesions tend to appear on the articular side initially; otherwise, with overlapping hook coracoids, the subscapularis tendon tears are commonly seen on the bursal side.

Keywords Subscapularis · Rotator cuff · Coracoid impingement · Coracoid type · Shoulder arthroscopy

Introduction

Recent advances in arthroscopic repair of the rotator cuff have led to greater progression in degenerative subscapularis (SSc) tendon tear diagnosis. Coracoid impingement syndrome, as reported previously by many researchers, has been considered as the most common factor related to degenerative SSc tendon lesions [1–3]. The internal rotation is limited because of pain, even if the SSc tendon is fraying concomitant with a supraspinatus tendon rupture, and the SSc injury is only secondary [4–6]. Progressive degeneration was seen in worn SSc tendon fibers; however, limited studies have discussed the degenerative SSc tendon tear types and their relationship with the coracoid process.

Magnetic resonance imaging (MRI) has been widely accepted as a valuable tool for the diagnosis of rotator cuff tears and SSc impingement [7, 8]. Many anatomic and imaging studies have shown the normal coracohumeral interval range of 8.7 to 11.0 mm, and an interval of less than 6 mm was accepted as an indicator of coracoid impingement [9–11]. However, owing to the individualized baselines for different patients, it is not precise enough to apply the coracohumeral interval in the prediction of subcoracoid impingement.

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Better understanding of the relationship between the degenerative SSc tear types and coracoid process is helpful to identify the initiating factor of SSc tendon tears. Although many physicians believe that different types of the coracoid process lead to distinct impingement types [12–14], there is limited statistical evidence to prove the theory. In the present study, two novel calculated ratios, i.e., coracohumeral index (CHI) and coracoglenoid inclination (CGI), were introduced to predict the different types of degenerative SSc tendon tears. We hypothesized that the types of the coracoid process can be defined by the CHI and CGI, which could serve as potential predictors for the types of degenerative SSc tears.

Methods

Study objects

This study was based on the examination and intra-operative findings of 235 shoulder joints; the MRI scans and surgery videos of the patients were reassessed. This retrospective study protocol was approved by institutional review board (IRB), and written informed consents were obtained from all study participants. The inclusion criteria were as follows: (1) degenerative SSc tendon tear identified during arthroscopy; (2) SSc tendon tear classified under arthroscopy (Table 1); (3) pre-operative MRI scans with signs of SSc tendon degeneration; and (4) SSc tendon injury with or without other rotator cuff injury. The exclusion criteria were as follows: (1) unavailable pre-operative MRI scans; (2) deformity of the humerus and scapula (including the coracoid process); (3) acute traumatic SSc tendon tears; (4) previous shoulder surgery or systemic corticosteroid use.

Arthroscopic evaluation

The procedures were performed under interscalene block and general anesthesia, and the conventional portals were used (posterior, anterior, and lateral) to evaluate the physical structures. With the patients' arm in internal rotation, the SSc tendon and particularly its footprint on the lesser tuberosity were observed via a posterior viewing portal. To evaluate the bursal side of the SSc tendon, an anterosuperolateral view portal was necessary, and a 70° arthroscope was applied. To visualize the lesion on the articular side of the SSc tendon, the arthroscope was placed via the routine posterior portal to complete the assessment [15]. The indications for biceps tenodesis included as follows [16, 17]: degeneration involving 50% of the thickness of the tendon or biceps tendon instability; inflammatory infiltration in 360° around the LBT; and injury involving pulley structures [4, 18, 19] (including full-thickness tear of the upper one third of the SSc tendon or anterior one third of the supraspinatus).

Table 1 Arthroscopic evaluation of the impingement lesions

Articular side		Bursal side	
A0	Normal	B0	Normal
A1	Minor Scuffing	B1	Minor scuffing
A2	Marked damage	B2	Partial thickness tear
A3	Bare Bone Areas	B3	Full thickness tear
		B4	Massive cuff tear

Note: There are four degrees (including A0 to A3) with articular-sided subscapularis tendon injury and five degrees (including B0 to B4) with bursal-sided tendon injury

Gerber et al. defined the subcoracoid space as the interval between the tip of the coracoid and the humeral head [12]. For the patients who underwent arthroscopic SSc repair, the size of the subcoracoid space was estimated by introducing an instrument of a known size (5.0-mm Resector; Stryker Endoscopy, Santa Clara, CA) via the anterosuperolateral portal [15]. Dynamical evaluation of coracoid impingement was performed under arthroscopic view by rotating the arm into external and internal rotations in adductive and anteflexed positions [19]. If signs of coracoid impingement were observed arthroscopically, coracoplasty was performed (Video 1).

Based on the arthroscopy findings of the impingement lesion, the SSc tendon lesions were identified and recorded [20]. Moreover, particular attention was paid to the location of the SSc tendon, with the marks "B" on the bursal side and "A" on the articular side. If the SSc lesions were found both on the articular and bursal sides, the prominent side was recorded (Table 1). Finally, all patients were divided into the articular-sided lesion group (group A) and bursal-sided lesion group (group B) based on the intra-operative findings.

MRI measurement

The pre-operative MRI scans of the affected shoulders from all patients were collected. All MRIs were performed using a 3.0-T unit (GE Excite Scanner, GE Healthcare Technologies, Waukesha, Wis). To guarantee the accuracy of the measured parameters, every patient was instructed to assume a standard neutral position for the MRI scan. Using axial MRI scan, the distance between the posterior cortex of the coracoid process and the anterior humeral head/minor tubercle was measured as the coracohumeral distance (CHD), following the criteria established by previous studies [9, 21]. With the different degrees of external or internal rotation of the humerus, the CHD would change within a certain range, and a neutral measurement has been accepted as a baseline.

Similar with the acromion clavicular joint, the type of the coracoid process was also divided into several types as described previously by many researchers [13, 22]. In the

Table 2 Demographic data

	Number of patients	Mean age (year) ± SD (range)	Gender male/female (%)	Affected dominant side (%)	Limited internal rotation (%)	Specific physical test positive* (%)
Total	235	57.5 ± 8.7 (36–78)	98 (41.7%)/137(58.3%)	166 (71%)	204 (86.8%)	135 (57.4%)
Group A	165 (70.2%)	54.6 ± 7.2 (42–78)	64 (38.8%)/101(61.2%)	107 (64.8%)	143 (86.7%)	97 (58.8%)
Group B	70 (29.8%)	55.3 ± 8.2 (36–73)	34 (48.6%)/36(51.4%)	59 (84.3%)	61 (87.1%)	38 (54.3%)

Note: *Specific physical tests, including the Lift-off test and Napoleon test

present study, we introduced two novel concepts to help define the type of the coracoid process, i.e., CHI and CGI.

The CHI, which was measured on axial fat-suppressed T2-weighted images, refers to the relative ratio of the coracoid length and humeral head diameter. In general, the slice showed longest length of coracoid was chosen as measurement slice. Coracoid length was measured in the chosen slice and humeral head diameter was measured in the same slice. The A tangent line running through the anterior and posterior rims of the glenoid was considered the baseline, indicating the direction of the glenoid surface. The relative length of the humeral head was measured by the line running through the outer cortex of the greater tuberosity and perpendicular to the baseline. Similarly, the relative length of the coracoid was measured by the line running through the tip of the coracoid and perpendicular to the baseline. Finally, the CHI was calculated by the relative length of the coracoid divided by the relative diameter of the humeral head (Fig. 3).

To assess the morphologic characteristics of the coracoid tip, the CGI was introduced. The tangent line running through the glenoid surface was also considered the baseline in the measurement, and a perpendicular line was created on the baseline. Thereafter, a parallel line of the vertical line through the inner cortex of the coracoid tip (line A) was drawn. Another line was drawn from the point of tangency running through the tip of the coracoid process (line B). The angle between lines A and B was measured as the CGI, indicating the morphologic feature of the coracoid tip (Fig. 3).

Statistical analysis

Two-way chi-square test and Student's t test were used for categorical variables and continuous variables, respectively. All calculations were performed using two-tailed tests, and $p < 0.05$ was assumed as statistically significant. The SPSS 17.0 for Mac was used for the statistical analysis. Further, box-blot graphs were drawn for the two index and inclination groups.

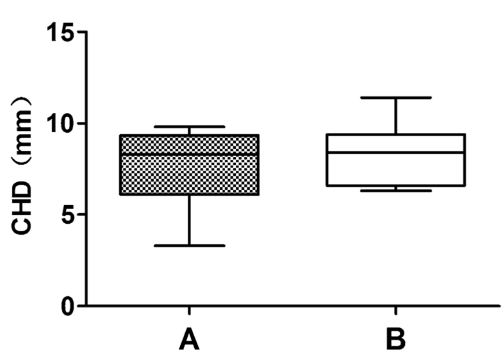


Fig. 1 Coracohumeral Distance (CHD) in the patients with articular-sided lesion (group A) and bursal-sided lesion (group B). Calculated using Student's t test. There was no significant difference between the two groups

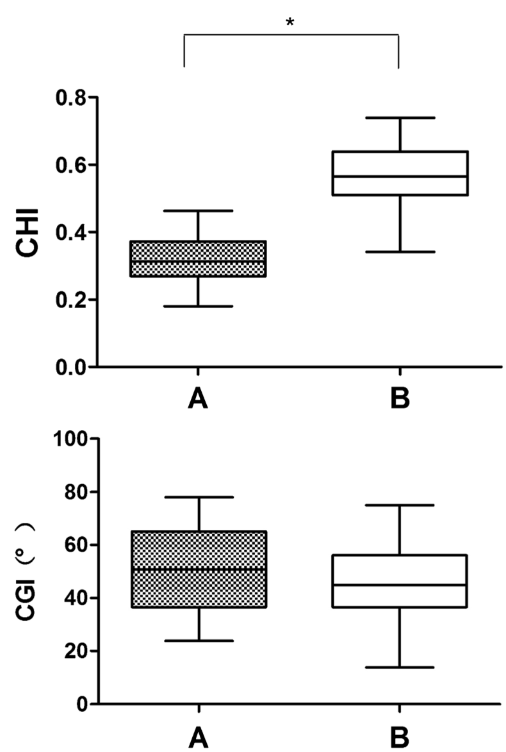


Fig. 2 1: Coracohumeral index (CHI) in the patients with articular-sided Lesion (group A) and bursal-sided lesion (group B). *Calculated using Student's t test. There was a significant difference between the two groups. 2: Coracoglenoid inclination (CGI) in the patients with articular-sided lesion (group A) and bursal-sided lesion (group B). *Calculated using Student's t test. There was a significant difference between the two groups

Table 3 Distribution of the coracoid types and comparison between the two groups

		Group A	Group B	*P* value
Too short		5 (2.1%)	6 (2.6%)	0.212
Standard	Flat	40 (17%)	9 (3.8%)	0.025
	Hook	110 (46.8%)	6 (2.6%)	0.001*
Overlapping	Flat	4 (1.7%)	14 (6%)	0.001*
	Hook	3 (1.3%)	38 (16.2%)	0.001*

Note: Numbers in parentheses denote percentages of all the patients

**P* values less than 0.001 indicate an extremely significant difference between the two groups

Results

Demographic characteristics

From April 2016 to April 2017, 583 shoulder arthroscopies were performed at the Sports Medicine Center by the senior author. Based on the inclusion and exclusion criteria, a total of 235 patients were enrolled in this study. Based on the intra-operative findings under arthroscopy, 165 (70.2%) patients were included in group A and 70 (29.8%) patients in group B. The demographic characteristics of all patients are presented in Table 2.

Arthroscopic examination

All 235 patients had SSc tendon tears with and without other rotator cuff tears. Among them, 17 patients (7.2%) had an isolated SSc tendon tears, and 165 patients with SSc tendon tears (70.2%) had concurrent LBT subluxation. Arthroscopic suture repairs were performed in 135 patients (57.4%), LBT tenodesis in 150 patients (10 patients underwent LBT myotenotomy without tenodesis), and coracoplasty in 206 patients (87.7%) owing to the arthroscopic evidence of coracoid impingement.

Among the patients in group A, 83 patients (35.3%) had minor scuffing (A1 grade); 58 patients (24.7%) had marked damage (A2 grade); and 24 patients (10.2%) had bare bone areas. Among the patients in group B, 14 patients (6%) had minor scuffing (B1 grade); 39 patients (16.6%) had partial tears (B2 grade); and 17 patients (7.2%) had full-thickness or massive tears (B3 and B4 grade). More than two thirds of the patients (70.2%) had SSc tendon fraying on the articular side, and most of them (35.3%) only had minor scuffing. There were significant differences between the articular-sided lesions and bursal-sided lesions.

MRI measurement

The CHD has been widely accepted as a critical standard parameter to predict underlying coracoid impingement syndrome. The CHD of all patients, as the baseline, was shown in this study. The CHDs of all 235 patients ranged from 3.3 to 9.8 mm, with an average CHD of 7.95 mm. In group A, the average CHD of the 165 patients was 7.98 ± 1.7 mm; meanwhile, the average CHD of the 70 patients in group B was 7.82 ± 2.1 mm. There was no significant difference in the average CHD between the two groups (Fig. 1).

To identify the morphologic features of the coracoid process precisely, the CHI and CGI were introduced. The CHI ranged from 0.18 to 0.63 (mean ± SD = 0.35 ± 0.21), and the CGI ranged from 0° to 71° (mean ± SD = $41.4 \pm 17.4°$) for all the enrolled patients. There was no significant difference between the men and women. There was a significant difference in the CHI (0.32 ± 0.08 vs 0.57 ± 0.11, respectively; $P < 0.001$) between the two groups; however, there was no significant difference in the CGI ($50.5° \pm 16.6°$ vs $44.9° \pm 17.4°$, respectively; $P = 0.427$). To evaluate the influence of the CHI and CGI on the SSc lesion, the box-blot graphs are presented in Fig. 2.

According to the CHI and CGI, the coracoid process was divided into three types: too short (CHI less than 0.2); standard (CHI from 0.2 to 0.5); and overlapping (CHI higher than 0.5). Further, the coracoid tip was divided into two types: flat (CGI from 0° to 30°) and hook (CGI larger than 30°). Theoretically, there were six configurations; however, we found only five types in clinical practice, as the too short coracoid process seemed to have a flat tip most of the time. Among the 235 patients enrolled in this study, 11 patients (4.7%) were classified into the too short group, 165 patients (70.2%) into the standard group (including 49 patients (20.8%) with flat tips and 116 patients (49.4%) with hook tips), and 59 patients (25.1%) into the overlapping group (including 18 patients (7.7%) with flat tips and 41 patients (17.4%) with hook tips). The distribution of the coracoid types and comparison between the two groups are demonstrated in Table 3.

Discussion

The biomechanical and functional importance of the SSc tendon has become more evident in recent years. Gerber et al. reported the relationship between the coracoid process and soft tissue impingement in the 1980s [12]. Lo and Burkhart thought that subcoracoid stenosis and subcoracoid impingement, which cause a "roller-wringer effect," are the most prominent causes [19]. Many researchers reported the relationship between SSc tendon tears and the coracohumeral interval [2, 11, 21]. However, few studies have reported the correlations between the coracoid and the types of degenerative SSc tendon tears.

The purpose of this study was to explore potential correlations between the coracoid and the types of degenerative SSc

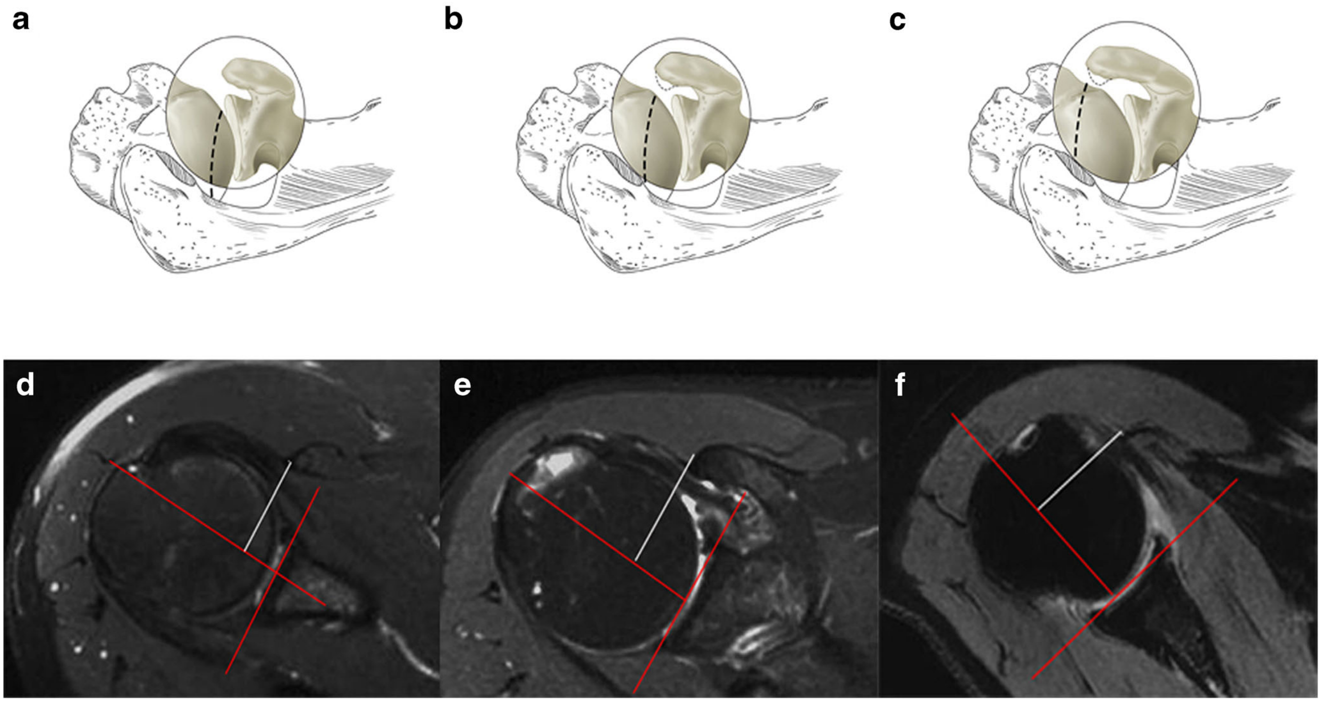
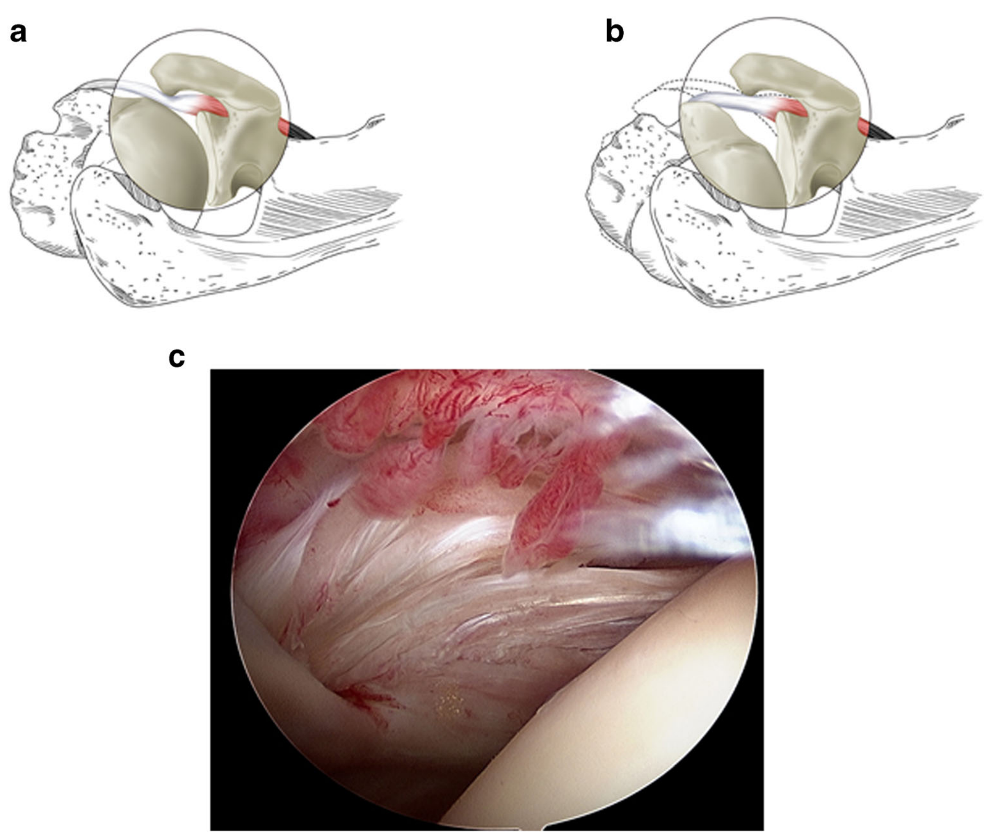


Fig. 3 Classification of the coracoid process according to the CHI and CGI and measurement on Axial MRI. Note: Diagrammatic sketch and MRI for the different types of the coracoid process. A and D, too short; B and E, standard with or without hook; C and F, overlapping with or without hook

tendon tears. A total of 235 patients with degenerative SSc tendon tears were divided into two groups based on the pathologic findings. Two novel parameters were introduced and measured on MRI: CHI and CGI. In the present study, we investigated the effects of the CHI and CGI on MRI in patients with articular-sided or bursal-sided tears of the SSc tendon.

Fig. 4 Injury mechanism of the subscapularis tendon for the standard coracoid process and the pathologic findings under arthroscopy. Note: Mechanism of coracoid impingement for the standard type. A and B, fraying on the articular side during humeral head internal rotation. C, arthroscopic view. SSc, Subscapularis; H, humeral head



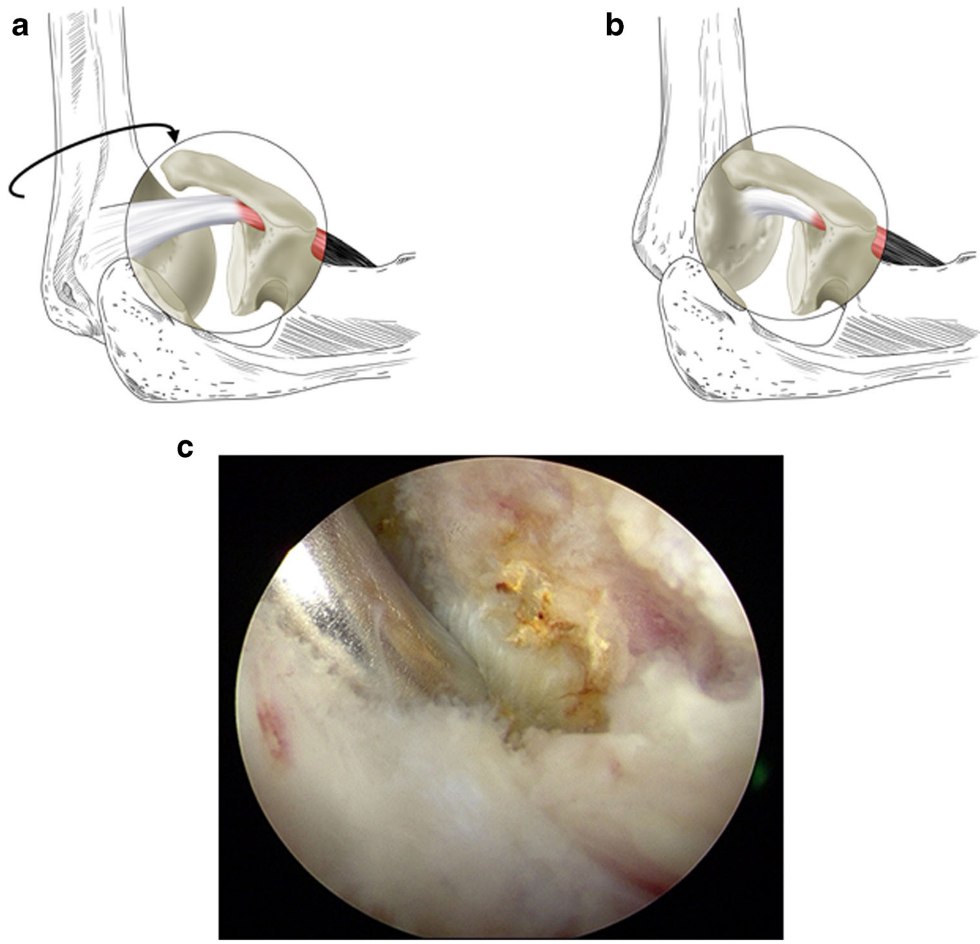


Fig. 5 Injury mechanism of the subscapularis tendon for the overlapping coracoid process and the pathologic findings under arthroscopy. Note: Mechanism of coracoid impingement for the overlapping type. A and B, fraying on the bursal side during humeral head internal rotation with forward flexion. C, arthroscopic view. SSc, Subscapularis; Co, coracoid process

The interval between the coracoid and humeral head, defined as the CHD by Gerber et al. in the 1980s, has been widely accepted as a standard parameter in clinical practice [10, 12, 23]. Friedman et al. evaluated the coracohumeral interval using a kinematic technique. They reported a normal coracohumeral interval of 11 mm and a cut-off CHD of 5.5 mm [21]. Our results showed that the CHD of all 235 patients ranged from 3.3 mm to 9.8 mm, with an average CHD of 7.95 mm. We presumed that the CHD could not describe the characteristics of the coracoid process precisely owing to the scapular dynamic rotation and individual differences. As shown in Fig. 1, there was no significant difference in the CHD between group A and group B.

In this study, we introduced the CHI and CGI to describe the morphologic features of the coracoid process individually (Fig. 3). The results suggest that standard hook coracoids are vulnerable to scuffing on the articular side; otherwise, overlapping hook coracoids are vulnerable to tears on the bursal side. In the CHI, there was a significant difference between groups A and B ($P < 0.05$). Nevertheless, there was no significant difference in the CGI. This indicates that the hook tip is the primary cause of impingement injury. Among the patients with a CHI of less than 0.2 (too short group), only 11 had SSc tendon injuries.

Our study demonstrated that the articular-sided lesion of the SSc tendon was more common in degenerative SSc tendon tears, which is consistent with the findings of previous studies [19, 24–26]. In this situation, we presume that when patients are set in the internal rotation position, posterior rolling tends to exit in the humeral head. Coracoid stenosis serves as a fulcrum in the process of internal rotation, deteriorating the degeneration of the SSc tendon by adding the tensile undersurface loads on the articular side of the tendon (Fig. 4). When the coracoid process is too long (overlapping with or without hook tips), the direct impingement between the SSc tendon and coracoid appeared to be in the position of internal rotation (Fig. 5). This scenario correlates with the impingement lesions located on the bursal side of the SSc tendon. The classification of SSc tendon tear is helpful for the surgeons in the clinic decision and preoperation plan making. Meanwhile, the exploration of SSc tear mechanism would help us in a better understanding of shoulder diseases.

There were also many limitations in our study. We collected the preoperative MRI scans with the patients in the neutral position, rather than in the previously reported maximal internal rotation position. Second, only few patients with too short coracoids were observed in our study; thus, we supposed that the too short coracoid process does not cause impingement syndrome; however, this needs to be confirmed by an epidemiological investigation. In addition, there was an inherent selection bias in our retrospective study process. The injury mechanism and the relationship with coracoid morphometry still need to be investigated further.

Conclusion

In conclusion, the CHI and CGI are potential valuable predictors of the types of degenerative SSc tendon tears. Patients with standard coracoids and overlapping coracoids with hook tips (CHI, 0.2–0.5 and > 0.5, respectively; CGI larger than 30°) are vulnerable to SSc injury. With standard hook coracoids, the lesions tend to appear on the articular side initially; otherwise, the SSc tendon tear on the bursal side is commonly seen in patients with overlapping hook coracoids.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent This retrospective study protocol was approved by institutional review board (IRB) of General Hospital of People's Liberation Army, and written informed consents were obtained from all study participants.

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