The anatomy of the coracohumeral ligament and its relation to the subscapularis muscle

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Background: Only a few reports describe the extension of the coracohumeral ligament to the subscapularis muscle. The purposes of this study were to histo-anatomically examine the structure between the ligament and subscapularis and to discuss the function of the ligament.

Methods: Nineteen intact embalmed shoulders were used. In 9 shoulders, the expansion of the ligament was anatomically observed, and in 6 of these 9, the muscular tissue of the supraspinatus and subscapularis was removed to carefully examine the attachments to the tendons of these muscles. Five shoulders were frozen and sagittally sectioned into 3-mm-thick slices. After observation, histologic analysis was performed on 3 of these shoulders. In the remaining 5 shoulders, the coracoid process was harvested to investigate the ligament origin.

Results: The coracohumeral ligament originated from the horizontal limb and base of the coracoid process and enveloped the cranial part of the subscapularis muscle. The superficial layer of the ligament covered a broad area of the anterior surface of the muscle. Laterally, it protruded between the long head of the biceps tendon and subscapularis and attached to the tendinous floor, which extended from the subscapularis insertion. Histologically, the ligament consisted of irregular and sparse fibers abundant in type III collagen.

Conclusion: The coracohumeral ligament envelops the whole subscapularis muscle and insertion and seems to function as a kind of holder for the subscapularis and supraspinatus muscles. The ligament is composed of irregular and sparse fibers and contains relatively rich type III collagen, which would suggest flexibility.

Level of evidence: Basic Science, Anatomy.

Keywords: Anatomy; histology; shoulder joint; subscapularis muscle; coracohumeral ligament; collagen

This study used cadaveric specimens with full consent for study. There was no need for approval from the institutional review board or ethical committee in terms of ethical considerations.

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The coracohumeral ligament (CHL) was classically described to originate in the outer margin of the horizontal limb of the coracoid process, insert into the greater and lesser tubercles, and cover the rotator interval, which is the space between the supraspinatus and subscapularis muscles. The CHL was considered to play a key role in the function of the rotator interval. In a biomechanical study, Harryman et al. showed that the tension of the CHL has a great effect on the stability and range of motion of the glenohumeral joint. In fact, it was clinically reported that dysfunction of the CHL can lead to "frozen" shoulder or a kind of loose shoulder.

The posterior extension of the CHL from the rotator interval has become well known since the anatomic study of Clark and Harryman. Their study showed that both the superficial and deep branches of the CHL envelop the anterior part of the supraspinatus tendon; the superficial branch fans out laterally and posteriorly over the supraspinatus tendon, extending as far as the infraspinatus, and merges with the peristeum of the greater tubercle. This envelop-like structure of the CHL should act as a stabilizer of the posterosuperior side of the glenohumeral joint.

However, to date, studies focusing on the anteriorly extending fibers of the CHL are few. Recently, Yang et al. macroscopically examined the insertion of the ligament-like portion of the CHL in 26 fresh-frozen cadavers. They showed that in 3 shoulders, the ligament-like CHL bifurcated and inserted into both the supraspinatus and subscapularis tendons. Interestingly, in 1 specimen, the ligament inserted only into the subscapularis tendon. They, however, did not show the continuity between the ligament-like CHL insertion into the subscapularis and the membranous portion of the CHL in the rotator interval. Furthermore, the expansion of the CHL around the subscapularis muscle was not shown. Arai et al. reported on the soft tissue composing the CHL, which bridged over the cranial part of the subscapularis muscle, but to date, there is no clear report on the detailed structure of the anterior CHL. Considering the dynamic function of the subscapularis muscle to maintain the balanced "force couple" between the anterior and posterior rotator cuff muscles and the consistency of the function in any position of the upper limb, it would be expected that the anteriorly extending component of the CHL has an appropriate structure sufficient to hold the subscapularis, just as the posterior portion of the ligament has the configuration to hold the supraspinatus muscle.

The purposes of this study were to closely observe the anteriorly extending fibers of the CHL anatomically and histologically and to examine the role of the CHL in the stabilization of the subscapularis muscle.

Materials and methods

All of the cadavers used in this study were donated to the Department of Anatomy, Tokyo Medical and Dental University. The purposes of this study were to closely observe the anteriorly extending fibers of the CHL anatomically and histologically and to examine the role of the CHL in the stabilization of the subscapularis muscle.

Figure 1  Anatomy of CHL. A right shoulder viewed from the lateral side is shown. The scapular spine (SS) was cut, and the muscular tissue of the supraspinatus and subscapularis was carefully removed. The CHL originated from the coracoid process (C). The CHL extended over not only the rotator interval but also the cranial part of the subscapularis muscle (blue arrows). It covered a broad area of the anterior surface of the subscapularis muscle. The orange circle indicates the intramuscular tendon of the supraspinatus, and the yellow circles indicate the intramuscular tendons of the subscapularis. GT, Greater tuberosity; lhb, long head of biceps brachii tendon.

All of the donors voluntarily expressed their will, before death, that their remains be used as materials for education and study. This voluntary donor system of cadavers is widespread throughout Japan, and our study completely complied with the current laws of Japan. A history of any shoulder problem was not available.

All cadavers were fixed in 8% formalin and preserved in 30% ethanol. First, 8 cadavers (4 males and 4 females; mean age, 78.0 years) were randomly selected for this anatomic study. Among these specimens, 2 left shoulders of 2 male cadavers with torn tendons with or without severe degenerative changes were excluded from this study. We used 9 specimens (from 3 male and 2 female cadavers; mean age, 82.0 years) for the morphologic examination (group 1) and 5 specimens (from 1 male and 2 female cadavers; mean age, 71.3 years) for the sectioning study, including frozen section with a diamond saw or histologic staining (group 2).

In the 9 shoulders in group 1, the clavicle and humerus were cut at the proximal portion and the muscles of the shoulder girdle were removed. After the acromion was resected, the fat tissue on the CHL was carefully removed. The specimens were observed with special attention given to the extent of the CHL. In 6 shoulders, the muscular portion of the supraspinatus and subscapularis was gently unraveled in water and removed from the myotendinous units, and the tendons were left attached to the humerus. After the muscle removal, the humerus could be displaced slightly inferiorly so that the extent of the CHL was more clearly observed. The results were recorded with digital photographs (Fig. 1).

In group 2 shoulders, 5 specimens were frozen at −80°C and serially sectioned (3-mm thickness) with a band saw (WN-25-3; Nakajima Seisakusho, Osaka, Japan) in parallel to the glenoid surface for observations of anteroinferior expansion of the CHL.
Coracohumeral ligament and subscapularis muscle

Figure 2  Macroscopic sagittal sections of shoulder joint. (A) Section at coracoid process (C) near its base. From the rotator interval, the CHL extended below the supraspinatus muscle (ssp) and ran from the anterior to posterior side of the subscapularis muscle. (B) Section at lesser tuberosity (LT). The subscapularis tendon was located on the lesser tubercle and extended as a tendinous slip to the top of the intertubercular groove (yellow asterisk). The long head of the biceps tendon accompanied the gentle slope of the subscapularis tendon. The CHL covered the anterior surface of the subscapularis and made a fold to enter below the long head of the biceps brachii tendon (lhb); it then attached to the tendinous slip of the subscapularis. The CHL enveloped the anterior portion of the supraspinatus (ssp). A, Acromion; ct, conjoined tendon; d, deltoid muscle; HH, humeral head; isp, infraspinatus muscle; ssc, subscapularis muscle/tendon; tm, teres minor muscle.

Afterward, a section series of 3 of 5 shoulders (2 male and 1 female; mean age, 75.0 years) were randomly selected, and histologic analyses were performed. The anterosuperior part of the gleno-humeral joint, including the long head of the biceps tendon, and the supraspinatus, subscapularis, coracoid process, and humerus were cut out in every slice between the glenoid and humerus. The portion below the lesser tuberosity was discarded. The constructs of the 3 shoulders were decalcified for 1 week in a solution containing aluminum chloride, hydrochloric acid, and formic acid, as described by Plank and Rychlo.20 After dehydration, the specimens were embedded in paraffin. The blocks were serially sectioned (5-μm thickness) vertically to the most superior intramuscular tendon of the subscapularis. One hundred sections were taken to make sets of each 500-μm span. Three sets were stained: one set with Masson trichrome, one set with anti-human type I collagen antibody (F-56; Daiichi Fine Chemical, Toyama, Japan), and one set with anti-human type III collagen antibody (F-58; Daiichi Fine Chemical). Combined antibodies were stained by diaminobenzidine (Histostain-SP kit; Life Technologies, Carlsbad, CA, USA).

In addition, we created group 3, comprising 5 shoulders, to closely measure the dimensions of the CHL on the coracoid process (both sides of 58- and 96-year-old male cadavers and the left side of a 92-year-old female cadaver). The right side of the female specimen was discarded because of a large rotator cuff tear. The coracoid process was harvested at the level of the upper margin of the glenoid and the medial margin of the supraspinatus notch with the CHL attached to the process. To observe the attachment area of the CHL, the ligament was meticulously detached with a scalpel from the inferior surface of the horizontal limb and base of the coracoid process. The attachment area of the CHL was marked, and the dimensions were measured with a standard caliper.

Results

The CHL originated at the horizontal limb and base of the coracoid process. The CHL could be divided into two parts: one part spread fibers over the rotator interval to the posterior portion of the greater tubercle, and the other part extended fibers to envelop the cranial part of the subscapularis muscle. Moreover, the superficial layer of the latter seamlessly continued to the subscapularis fascia and tightly covered a broad area of the anterior surface of the subscapularis muscle (Fig. 1). By macroscopic analysis of the sagittal sections, the relationship between the subscapularis muscle and CHL mentioned earlier could be confirmed. In addition, at the lateral portion, the subscapularis tendon was located on the lesser tubercle. The tendon of this portion further extended as a tendinous slip, making a gentle slope, and continued to the top of the intertubercular groove. This portion had no cartilage but, rather, had a tendinous floor of the subscapularis slip. The long head of the biceps tendon was situated above this portion. The CHL made a fold to enter the narrow space between the long head of the biceps tendon and subscapularis slope and then attached to the tendinous floor. Consequently, the CHL enveloped the whole subscapularis insertion including the tendinous slip (Fig. 2).

When viewed from the inferior side, the CHL attachment was composed of a narrow anteromedial part and a broad lateral part. The anteromedial part of the CHL attached to the anterior edge of the inferior surface of the coracoid process. The lateral part attached to the lateral one-third area of the inferior surface of the horizontal limb of the process (Fig. 3). The mean size of the coracoid process and the dimensions of the CHL are listed in Table I.

During the histologic investigation, the CHL was identified at the rotator interval and it was found to encircle the subscapularis muscle. The ligament consisted of irregular and sparse fibers and did not show the typical ligamentous structure of parallel bundles as described in a previous article.10 The portion around the long head of the biceps
tendon near the humerus contained relatively dense fibers, but the border between the CHL and the superior glenohumeral ligament was not distinct even by histologic analysis. Immunohistologically, the CHL stained more densely for type III collagen than the subscapularis or the long head of the biceps tendon (Fig. 4).

Discussion

Several previous reports have indicated that the CHL attaches to the subscapularis muscle. Harryman et al.13 described that the CHL divides into two major bands, one of which inserts into the tendinous anterior edge of the supraspinatus and the other of which inserts into the superior border of the subscapularis. Yang et al.24 macroscopically showed that the ligament-like portion of the CHL was split and inserted into both the supraspinatus and subscapularis tendons in 3 of 26 fresh-frozen cadavers and that the ligament-like portion inserted into only the subscapularis tendon in 1 specimen. Arai et al.1 reported on the soft tissue composing the CHL, which bridges over the cranial part of the subscapularis muscle. In our study, anteriorly extending fibers of the CHL enveloped the cranial part of the subscapularis muscle. In our study, anteriorly extending fibers of the CHL enveloped the cranial part of the subscapularis muscle, and moreover, the superficial layer of the CHL seamlessly continued to the subscapularis fascia and tightly covered a broad area of the anterior surface of the subscapularis muscle. It is reasonable that the CHL would continue to the subscapularis fascia seamlessly because both of them are composed of loose connective tissue.10,24 On the basis of the enveloping structure and broad coverage of the subscapularis, the CHL would function as a kind of holder for the subscapularis muscle in the same way in which the ligament works for the supraspinatus muscle.

As shown on a lateral slice of the macroscopic sagittal sections, the subscapularis tendon continued as a tendinous slip from the upper surface of the lesser tubercle to a cartilage-lacking portion of the superior intertubercular groove, which corresponded to the fovea capitis of the humerus, and formed a tendinous floor. The CHL was noted to enter below the long head of the biceps tendon and to attach to the tendinous floor. Regarding the tendinous slip of the subscapularis, our finding is supported by previous anatomic studies, and for the tissue that attaches to the tendinous slip, these previous articles claimed that it was the superior glenohumeral ligament.1,2 In contrast, we did not find the connection of the superior glenohumeral ligament; rather, we found a direct connection of the CHL to the tendinous slip, although according to our histologic results, the portion of relatively dense fibers around the long head of the biceps tendon seemed to correspond to the superior glenohumeral ligament. This difference might appear paradoxical.

To resolve the inconsistency of the results between previous studies and our study, we must first confirm some premises. Classically, the superior glenohumeral ligament was thought to have 3 basic types of origin: (1) the middle glenohumeral ligament, long head of the biceps tendon, and superior labrum; (2) the long head of the biceps tendon and superior labrum; and (3) the long head of the biceps tendon only.8 At the lateral rotator interval, the superior glenohumeral ligament was classically thought to be in close contact with the CHL because some articles insisted that they were tightly united.17,22 Recently, both the superior glenohumeral ligament and the CHL were thought to be components of the same loose connective tissue rather than the unity of 2 independent structures.1 In addition, Pouliart et al.21 proposed the concept of these ligaments as 1 ligamentous structure with variable parts, and furthermore, our histologic study did not find any clear border for the superior glenohumeral ligament in the CHL. These newer studies and our histologic results suggest that the superior glenohumeral ligament may simply be a limited portion of the CHL, which attaches to the tendinous slip of the subscapularis.

<table>
<thead>
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<th>Table I Dimensions of coracoid process and attachment area of CHL</th>
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<td>Location of measurement</td>
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<tr>
<td>Coracoid process</td>
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<td>Anterior length (L1)</td>
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<tr>
<td>Posterior length (L2)</td>
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<td>Anteroposterior width of lateral part (W2)</td>
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The locations of the specific measurements are shown in Fig. 3.
This complexity among the subscapularis tendinous slip, the CHL, and the superior glenohumeral ligament at the most lateral rotator interval has drawn attention historically as the “reflection pulley.” The main function of the reflection pulley has been considered to be the maintenance of the position of the long head of the biceps tendon, and the superior glenohumeral ligament (a limited portion of the CHL according to our study) has been thought to be an important sustainer of the biceps tendon. On the basis of the macroscopic sagittal sections in this study, the CHL envelops the whole subscapularis insertion including the tendinous slip, and consequently, the CHL would likely function as a holder of the subscapularis insertion. Therefore, the CHL can be considered to spread into the narrow space between the biceps tendon and subscapularis insertion to function as both the sustainer of the biceps tendon and the holder of the subscapularis insertion.

The function of the CHL as suggested in our study as a holder of the subscapularis muscle and insertion would be very important from the clinical viewpoint. Even in the resting neutral position, the subscapularis tendon is pressed against the spherical surface of the anterior anatomic neck and bent vertically along the lesser tubercle because it inserts into the upper margin as well as the anterior aspect of the lesser tubercle. Especially in the abducted and externally rotated position, the upper border of the subscapularis is coiled around the coracoid process and the humeral head becomes anteriorly prominent and pushes the subscapularis muscle forward and upward. To maintain the whole subscapularis during such extreme morphologic changes, the enveloping structure of the CHL must be both strong and flexible.

On the basis of our findings, we should consider these expected unique characteristics of the CHL: (1) As the CHL fibers converge to the coracoid process, the CHL can be thought to have sufficient stiffness to stabilize the subscapularis muscle, and the coracoid process functions as an important anchor of the CHL. (2) The histologic analysis showed that the CHL consisted of irregular and sparse fibers and that the proportion of type III collagen in the CHL was higher than that in the long head of the biceps tendon or in the intramuscular tendons of the subscapularis muscle. Because, in general, type III collagen is more pliable than type I collagen and the proportion of type III to total collagen is roughly parallel to the extensibility of the tissue, this finding means that the CHL consists of loose connective tissue and that it should be relatively flexible; therefore, the CHL can envelop the subscapularis muscle while maintaining the position of the insertion pressed against the humeral head.

From the clinical viewpoint, many surgeons suggest that the CHL should be cut and removed to release and mobilize the subscapularis tendon when performing subscapularis tendon repairs. In such a pathologic situation,
inflammation around the torn subscapularis tendon might occur, and loose connective tissue composing the CHL can proliferate, leading to scar tissue formation. Adhesion to the surrounding structure may also occur. As a result, the CHL will lose its flexibility and may consequently hold the subscapularis muscle too tightly. This might be the reason patients benefit from removal of the CHL to allow the subscapularis muscle to slide correctly in subscapularis repair.

Macroscopically, the CHL was observed to be divided into two parts: one part spread fibers over the rotator interval to the posterior portion of the greater tuberosity, and the other part enveloped the superior portion of the subscapularis muscle. The anterior CHL holds the subscapularis muscle and anchors the muscle to the coracoid process in a manner similar to that of the posterior CHL enveloping the supraspinatus (ssp) and infraspinatus (isp). The CHL is also a likely chief element in the reflection pulley and functions as a sustainer of the long head of the biceps tendon (lhb). HH, Humeral head.

Consequently, the CHL may be affected by degeneration due to aging in a similar way to the rotator cuff. We, however, excluded 2 specimens with rotator cuff tears; therefore, we investigated morphologically intact shoulders only, and the structural characteristics should be maintained even in elderly specimens.

Although Edelson et al already discussed that the CHL is a central element for suspending the humeral head because of its flexible strength and “strategic” position, further study will be needed for a comprehensive understanding of the mechanism by which the CHL holds the rotator cuff and maintains the global glenohumeral joint.

**Conclusion**

The CHL envelops the whole subscapularis muscle and insertion, and consequently, the ligament would function as a kind of holder for the subscapularis in the same way in which the ligament works for the supraspinatus muscle. The CHL is composed of irregular and sparse fibers and contains relatively rich type III collagen, which would suggest the flexibility of the ligament.

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