Original article

The relationship of the anterior articular capsule to the adjacent subscapularis: An anatomic and histological study


© 2017 Elsevier Masson SAS. All rights reserved.

1. Introduction

The anterior articular capsule of the glenohumeral joint is a thin fibrous structure between the subscapularis and the joint cavity [1]. It is firmly attached to the deep surface of the subscapularis near the tendinous insertion at the lesser tubercle. The attachment might functionally complement the insertion of the subscapularis tendon and facilitate maintenance and endurance of the subscapularis footprint [2,3]. However, no studies to date have delineated the anatomic nature of the articular capsule and its relationship to the adjacent subscapularis.

Although numerous reports in literature have described in detail the anatomy of the subscapularis footprint [4–10], most of the studies have not dissected the subscapularis tendon from the articular capsule, thus the width of subscapularis footprint may have been overestimated. Knowledge of the overall dimension of the footprint...
of the subscapularis and the attachment of the articular capsule may allow more accurate assessment of the extent of subscapularis tears and make the surgical restoration of the normal anatomic footprint more reproducible.

In addition, operative procedures addressing the anterior capsulolabral reconstruction or shoulder arthroplasty require meticulous dissection of the subscapularis from the underlying articular capsule by splitting the subscapularis or dissecting the subscapularis off of the underlying capsule [11,12]. Moreover, some orthopaedic surgeons have recently proposed the lateral “subscapularis-sparing” approach, which calls for separation of the lower subscapularis from the underlying capsule to avoid detachment of the subscapularis in order to expose and repair the humeral avulsion of glenohumeral ligament (HAGL) lesion [13,14]. However, separating the subscapularis and the articular capsule can be very challenging in the clinical setting. Thus, knowledge of the anatomical relationship between the subscapularis and the underlying articular capsule is important in facilitating our surgical treatment.

Due to the thin and minor structure, the presence of the articular capsule attachment on the lesser tubercle is negligible in the past [5–7,9]. The purpose of this study was to delineate the macroscopic and microscopic anatomical relationship between the anterior articular capsule and the adjacent subscapularis by measuring the dimensions of the anterior articular capsule attachment, and the subscapularis footprint on the humerus and also investigating the interface between the two structures at the tendinous and muscular insertions of the subscapularis. We hypothesized that the anterior articular capsule attachment would occupy a larger area of the proximal humerus than previously documented which would complement the footprint of the subscapularis; furthermore, there would be an identifiable interface between the articular capsule and the subscapularis.

2. Materials and methods

Thirteen fresh-frozen human cadaveric shoulder specimens (9 unpaired and 2 paired) from 8 men and 5 women were available for this study (6 right and 7 left shoulders). The mean age of the deceased was 63.7 years (range: 52–70 years). Each shoulder specimen included the entire scapula, the proximal third of the humerus and the full clavicle with the attached soft tissues. All specimens were free of subscapularis tears; biceps tendon tear or osteophytes near the intertubercular sulcus, since lesions near the tuberosities would make measurement of the insertion inaccurate. Ten specimens underwent macroscopic assessments, the other three underwent histological analysis.

2.1. Histological assessment

Three shoulder specimens (1 man and 2 women; mean age, 64 years) underwent histological analysis. Cross-sections through the subscapularis and the attached articular capsule (subscapularis-capsule complex) at the tendinous and muscular insertion of the subscapularis were harvested sequentially from superior to inferior in 5 mm intervals. The orientation of the section was orthogonal to the plane of the subscapularis. The harvested pieces were cut into segments of approximately 5 mm in width and 25 mm in length. The segments were embedded in paraffin and sectioned sequentially at a thickness of five micrometers in the longitudinal plane. The sequential slides from each block were stained with hematoxylin and eosin (H&E) and Masson trichrome stain for morphological evaluation and evaluation of muscle and connective tissue, respectively (Fig. 1). The histological sections were examined with light microscopy at 4 ×, 10 ×, 20 × and 40 × objectives lens with the 10 × magnification factor by the eyepiece (CX31; Olympus, Tokyo, Japan). Orientation of the collagen fibers was documented. Particular attention was paid to the interface between the articular capsule and the attached subscapularis, and relevant areas were digitally photographed with QIClick™ CCD Camera (QImagingInc, Surrey, Canada) and QCapture Pro 7 software (QImagingInc, Surrey, Canada).

2.2. Gross dissection and macroscopic assessment

After thawing each specimen at room temperature (22°C) for 24 hours, a deltopectoral incision was used to approach the anterior aspect of each shoulder. All soft tissues surrounding the rotator cuff were removed. The supraspinatus, rotator interval and subscapularis insertion onto the proximal humerus were inspected. The subscapularis, supraspinatus, infraspinatus and teres minor were peeled away from their origins on the scapula toward their insertions on the tubercles of the humerus. Next, the muscles were carefully dissected from the underlying capsule, without damaging the latter. Subsequently, the articular capsule was detached along the glenoid rim. Prior to cutting the remnants of the supraspinatus, infraspinatus and teres minor with their attached capsule along their humeral insertion, separation of the articular capsule from the overlying subscapularis muscle and tendon was carefully done. At the time of these determinations, we put the interface under tension to straighten the line of pull of the musculature, thus facilitating identification of the plane between the articular capsule and the subscapularis. The articular capsule and subscapularis were detached sharply from the humerus until 1 mm height of the remnants were left attached to the footprint. The attachment of the articular capsule on the humerus was then exposed and delineate with gentian violet. The tendinous and muscular footprint of the subscapularis were likewise demarcated with gentian violet. The width of the articular capsule attachment and the subscapularis footprint were measured at sequential locations (Fig. 1). A digital camera (EOS 6D, EF 100 mm, 1:2.8, Canon, Japan) was utilized to capture the image while positioned perpendicularly to the articular capsule attachment and the subscapularis footprint alongside a calibration sale. The dimension of the articular capsule attachment and the subscapularis footprint were measured and calibrated by image analysis software (SigmaScan Pro 5.0, SPSS, Chicago, IL), in which 3 consecutive measurements of each dimension were taken independently by 2 investigators; the intraclass and interclass correlation coefficients were 0.91–0.96. The mean of their measurements for each dimension in each specimen was recorded (Fig. 2).

3. Results

3.1. Histological assessment

In our histological analysis, the section of the subscapularis-capsule complex obtained at the tendinous insertion of the subscapularis, demonstrated that the subscapularis muscle tissue gradually intermingled with bundles of collagen fibers and forms a tendon tissue. The articular capsule has thin and loosely arranged collagen fibers with many interspersing fibroblast nuclei (Fig. 1C). The outer layer of the articular capsule blends into a layer of more loosely spaced and less organized collagen fibers, which is distinct from the overlying subscapularis, specifically at the region medial to the tendon tissue of the subscapularis (Fig. 1F).

In the section at the muscular insertion of the lower subscapularis, there is a clear demarcation between the subscapularis and the underlying articular capsule. This interface is filled with more loosely spaced and less organized collagen fibers (Fig. 1B).
3.2. Humeral footprint of the subscapularis

The footprint of the subscapularis on the proximal humerus consisted of both a tendinous as well as a muscular portion. The tendinous footprint (SSCtf) was on the lesser tubercle, and the muscular footprint (SSCm) was on the inferior aspect of the lesser tubercle and the anterior aspect of the humeral metaphysis, not involving the crest of lesser tubercle. The tendinous footprint had a broad and wide attachment with the insertion tapering inferiorly to form a muscular footprint (Fig. 2).

3.3. Humeral attachment of the articular capsule

The articular capsule initiated from an average distance of 4.9 mm (standard deviation [SD], 2.1 mm) distal to the superior margin of the subscapularis. The attachment of the articular capsule was broadest in the middle zone of the articular capsule, which was located at a distance of 5 mm distal to the end of the tendinous footprint (A4B4 in Fig. 1), and the ends of the attachment tapered proximally and distally.

3.4. Measurement of the articular capsule attachment and the subscapularis footprint

The average width of the articular capsule attachment and that of the corresponding subscapularis footprint were summarized in Table 1. The average height of the SSCtf and the SSCm was 25.5 mm (SD, 4.0 mm) and 16.9 mm (SD, 2.9 mm), respectively.

4. Discussion

The results of the present study demonstrate that the attachment of the articular capsule occupies a larger area on the lesser tubercle and the metaphysis of the humerus than previously documented, which verified our hypothesis. The histological study demonstrates that the articular capsule has thin and loosely arranged collagen fibers which are features distinct from the overlying subscapularis; the histological demarcation was best appreciated at the region medial to the tendon tissue of the subscapularis and at the muscular insertion of the subscapularis.

The footprint of the subscapularis has been defined in several human cadaver studies. Reported differences in its dimensions were most likely due to variations in techniques of measurement or
Based on this study, the articular capsule is shown to attach to the lesser tubercle with a wider attachment than previously thought. The thinnest portion of the articular capsule attachment was located at a point 4.9 mm distal to the superior margin of the subscapularis along the articular cartilage border. Above this point, the superior portion of the subscapularis insertion was unaccompanied by an articular capsule attachment. Given that the articular capsule could functionally reinforce the rotator cuff tendon, the thinnest point of the articular capsule attachment and lack of capsule attachment at the superior edge of the subscapularis might provide explanation for why tears have been found to initiate at the articular surface of the upper portion of the subscapularis tendon [10,17–19].

During an anterior approach to the glenohumeral joint for an anterior capsuloligamentous reconstruction or shoulder arthroplasty, the subscapularis and underlying articular capsule may require mobilization as a tissue for repair or a shift to reinforce attenuated structures [11,12]. In tendon-elevating or splitting procedures on the subscapularis, separation of the subscapularis from the underlying capsule attachment is a difficult maneuver, since the articular capsule is firmly attached to the deep layer of the subscapularis especially near the tendinous insertion on the lesser tubercle. Therefore, blunt dissection starting medial to the tendinous insertion may often facilitate identification of the plane between the subscapularis and the underlying articular capsule [2,3]. The current study addresses this point by histologically documenting that the outer layer of the articular capsule blends into a layer of loose areolar tissue, which is distinct from the overlying tissue specifically at the region medial to the tendinous insertion of the subscapularis. Therefore, our histological finding of the loose connective tissue layer does support intraoperative observations made while detaching the subscapularis from the underlying articular capsule from an anterior approach to the glenohumeral joint.

Most procedures have described the mobilization near the tendinous insertion of the subscapularis but few have commented on the presence of the muscular insertion of the lower subscapularis. We found that the muscular insertion was adherent to the capsule but not as intimately as the densely adherent tendinous

in definition of the footprint (i.e., tendinous only versus tendinous and muscular) [4–6,8–10,15,16]. In this study, the mean maximum width of the tendinous footprint was 15.8 mm, which was less than that of the previous reports that accounted for the entire footprint including the articular capsule attachment and the subscapularis attachment [5–7,9]. Other studies did not dissect the subscapularis tendon from the articular capsule, thus the measurements might have included the mixed construct of the tendon and capsule as the footprint of the subscapularis. These findings could also be explained by the belief that the articular capsule is a thin and minor structure, which blends with the tendinous portion of the subscapularis, and therefore, the presence of the articular capsule attachment on the lesser tubercle is negligible before.

in definition of the footprint (i.e., tendinous only versus tendinous and muscular) [4–6,8–10,15,16]. In this study, the mean maximum width of the tendinous footprint was 15.8 mm, which was less than that of the previous reports that accounted for the entire footprint including the articular capsule attachment and the subscapularis attachment [5–7,9]. Other studies did not dissect the subscapularis tendon from the articular capsule, thus the measurements might have included the mixed construct of the tendon and capsule as the footprint of the subscapularis. These findings could also be explained by the belief that the articular capsule is a thin and minor structure, which blends with the tendinous portion of the subscapularis, and therefore, the presence of the articular capsule attachment on the lesser tubercle is negligible before.

### Table 1

<table>
<thead>
<tr>
<th>Locations of the measurements</th>
<th>Average width ± standard deviation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articular capsule</td>
<td>Subscapularis</td>
</tr>
<tr>
<td>Superior margin of the articular capsule</td>
<td>A1B1: 4.2 ± 2.2 B1C1: 10.1 ± 4.9</td>
</tr>
<tr>
<td>Maximum width of the subscapularis</td>
<td>A2B2: 5.2 ± 1.8 B2C2: 15.8 ± 2.9</td>
</tr>
<tr>
<td>End of the SSCmf and beginning of the SSCmf</td>
<td>A3B3: 9.0 ± 6.4 B3C3: 10.9 ± 3.8</td>
</tr>
<tr>
<td>Maximum width of the articular capsule</td>
<td>A4B4: 11.1 ± 3.7 B4C4: 9.7 ± 3.0</td>
</tr>
<tr>
<td>Distance of 10 mm distal to the third line</td>
<td>A5B5: 10.4 ± 2.8 B5C5: 7.5 ± 2.8</td>
</tr>
<tr>
<td>Distance of 15 mm distal to the third line</td>
<td>A6B6: 10.9 ± 3.0 B6C6: 6.4 ± 2.1</td>
</tr>
<tr>
<td>Distance of 20 mm distal to the third line</td>
<td>A7B7: 10.1 ± 4.1</td>
</tr>
<tr>
<td>Distance of 25 mm distal to the third line</td>
<td>A8B8: 7.6 ± 5.1</td>
</tr>
<tr>
<td>Distance of 30 mm distal to the third line</td>
<td>A9B9: 3.2 ± 1.8</td>
</tr>
</tbody>
</table>

Locations of measurements are demonstrated in Fig. 2. SSCmf: muscular footprint of subscapularis; SSCmf: muscular footprint of subscapularis.

in definition of the footprint (i.e., tendinous only versus tendinous and muscular) [4–6,8–10,15,16]. In this study, the mean maximum width of the tendinous footprint was 15.8 mm, which was less than that of the previous reports that accounted for the entire footprint including the articular capsule attachment and the subscapularis attachment [5–7,9]. Other studies did not dissect the subscapularis tendon from the articular capsule, thus the measurements might have included the mixed construct of the tendon and capsule as the footprint of the subscapularis. These findings could also be explained by the belief that the articular capsule is a thin and minor structure, which blends with the tendinous portion of the subscapularis, and therefore, the presence of the articular capsule attachment on the lesser tubercle is negligible before.
insertion. Recently, some orthopaedic surgeons have proposed the lateral “subscapularis-sparing” approach to expose and repair the HAGL lesion.[13,14] The lateral “subscapularis-sparing” window provides access to the anteroinferior humeral neck and articular capsule for repair of the HAGL lesion by separating the lateral aspect of the lower subscapularis muscle gradually from the underlying capsule to avoid detachment or splitting of the subscapularis. The ease of passing through the muscle-capsular plane between the inferior border of the subscapularis muscle and the underlying articular capsule corresponds with our histological findings of the loose areolar tissue layer.

Our study has several limitations. First, although the number of shoulders in the study was relatively higher than in most related publications, more data are needed to decrease variability. Second, we did not have access to height and weight data for our specimens. These parameters may have independently influenced the size of the articular capsule attachment and the subscapularis footprint. Third, the method of determining the subscapularis-capsule interface by visual inspection and sharp dissection, which was similar to techniques of most other anatomic studies in the literature, contains possibility of observer-related bias.[7,19,20] Finally, we did not trace the various elements of the subscapularis-capsule complex in serial histological sections from the muscle belly to the tendinous insertion in a medial to lateral fashion. In our study, we focused on the histological evaluation at the tendinous and muscular insertion of the subscapularis.

In conclusion, our results suggest that the anterior articular capsule attachment of the glenohumeral joint complements the footprint of the subscapularis and occupies a larger area of the lesser tubercle and metaphysis of the humerus than previously documented. The histological study confirms the presence of a demarcation between the subscapularis and articular capsule, specifically more significant at the region medial to the tendon insertion and at the muscular insertion of the subscapularis.

Disclosure of interest

The authors declare that they have no competing interest.

References