Variation of the subscapularis tendon at the fetal glenohumeral joint

By

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Summary: We examined the topohistology of the subscapularis tendon at the glenohumeral joint in 10 mid-term (15–16 weeks of gestation) and 10 late-stage (27–32 weeks) human fetuses. At both stages, there were two patterns of terminal course of the subscapularis tendon: 1) the tendon was tightly attached to the medial part of the joint capsule and extended anterosuperiorly along the capsule to the lesser tubercle (7/10 mid-term fetuses; 5/10 late-stage fetuses); 2) the tendon passed superiorly through the joint cavity for a long distance in combination with the subcoracoid bursa opening widely to the joint cavity (3/10 mid-term fetuses; 5/10 late-stage fetuses). The lower glenoid labrum tended to be well developed in the former pattern because the subscapularis tendon did not interfere with the superior extension of the labrum. With only one exception (late stage), the capsule-attaching tendon was seen in fetuses in which the coracoid process was located on the superior side of the lesser tubercle, whereas the intra-articular tendon accompanied the coracoid process at the same supero-inferior level of the tubercle. Thus, the topographical relationship between the coracoid process and lesser tubercle in fetuses seemed to determine the courses of the subscapularis tendon at the glenohumeral joint. The present variation in the subscapularis tendon was likely connected with the adult morphologies of the middle and inferior glenohumeral ligaments or folds, whose variations are well known.

Introduction

The middle glenohumeral ligament provides anterior stability at 45–60 degrees of abduction, whereas the inferior glenohumeral ligament is the most important stabilizer against anteroinferior shoulder dislocation [1]. There are many reports of individual variations of the middle and inferior glenohumeral ligaments in the adult shoulder [2-6]. Touheti et al. [4] considered that the morphology of the inferior glenohumeral ligament was determined by the attachment site of the biceps tendon. When the anterior-superior labrum is absent and replaced by a cord-like middle glenohumeral ligament, the morphology is known as the “Buford complex” [7]. According to a review by O’Brien et al. [2], the subcoracoid bursa usually (54.4%) opens to the joint cavity at a site between the superior and middle glenohumeral ligaments or at two sites among the superior and middle ligaments and the anterior band of the inferior glenohumeral ligament. However, if absence or poor development of the anterior band is also taken into account, six types of topographical relationships can be seen. Another critical point for classifying the morphology of the middle glenohumeral ligament is whether the sublabral foramen is present or absent [5].

Is the sublabral foramen evident in the fetal shoulder? Previously, our group histologically examined the rotator interval region in mid-term fetuses, but we did not find such a tissue loss [8]. The rotator interval is defined as a triangular structure, in which the coracoid process forms the base, the anterior margin of the supraspinatus forms the upper border, and the superior margin of the subscapularis muscle-tendon unit forms the lower border [9]. Cole et al. [10] classified the fetal rotator interval region into two types: an area covered by a contiguous capsular layer (type I, 9/37) and an area with a capsular defect (type II, 28/37). However, the window of the joint capsule they described might simply have corresponded to a large opening of the subcoracoid bursa, as they observed shoulder speci-
mens after removal of any structures outside the capsule. Overall, in fetuses, there is little information to connect with adult variations of the middle and inferior glenohumeral ligaments. Abe et al. [8] considered that the variations seen in adults correspond to postnatal mechanical demands from the subscapularis and biceps tendons. To provide a developmental basis for better understanding of the adult shoulder, the aim of the present study was to describe fetal morphology, especially that of the subscapularis tendon, at the glenohumeral joint.

Materials and Methods

This study was performed in accordance with the provisions of the Declaration of Helsinki 1995 (as revised in Edinburgh 2000). We examined the paraffin-embedded histology of 20 mid-term and late-stage fetuses (unilaterally in each of 20 fetuses; 11 left and 9 right shoulders). The gestational ages were 15–16 weeks (10 fetuses) and 27–32 weeks (10 fetuses) according to the clinical history. The paraffin blocks employed contained the shoulder and part of the thoracic wall. All specimens were part of the large collection kept at the Embryology Institute, Universidad Complutense, Madrid, and were products of miscarriages and ectopic pregnancies managed at the Department of Obstetrics at the university. Approval for the study was granted by the university ethics committee (B-08/374).

After routine procedures for paraffin-embedded histology, sections were cut horizontally (15–16 weeks) or transversely along the humerus (25–30 weeks) with a thickness of 5 or 10 μm, at intervals of 20 μm (15–16 weeks) or 0.5 mm (25–30 weeks). Such horizontal or tilted horizontal sections show the longitudinal course of the subscapularis tendon in human fetuses [1]. There were around 100 sections for each shoulder, all of which were stained with hematoxylin and eosin (HE). Although we observed the left or right shoulder in each of 20 fetuses (see above), all figures are prepared according to the same orientation, i.e., the coracoid process (a medial structure of the shoulder) is located in the right-hand side of the figure.

Results

In all specimens, the thorax enclosed by muscles was almost round in shape in the horizontal plane, and the width/thickness ratio corresponded to 4/3 or even almost 4/4. The scapular plate extended inferoposteriorly on the lateral side of the thorax. Thus, the subscapularis muscle-tendon unit as well as the infraspinatus originated from a site inferoposterior to the glenohumeral joint and the terminal part of the tendon extended anteriorly to the humerus. The muscular insertion of the subscapularis to the lesser tubercle was identified in the mid-term fetuses (Fig. 1), but was not clear in the late-stage fetuses because muscle fiber bundles were embedded in the collagenous structure (Figs. 2 and 3). The coracoid process originated from the superomedial part of the glenoid and extended anteromedially and inferiorly. From the inferior part of the process, near the subscapularis, the coracobrachialis and the short head of the biceps extended inferiorly. Between the deltoideus and the coracoid process, a thick ligament or fascia extended anterosuperiorly toward the acromion. The humerus extended almost along the supero-inferior axis of the body and the head of the humerus was located on the anterior side of the glenoid of the scapula. The lesser tubercle of the humerus was lower than, or located at the same level of the coracoids process: the topographical relationship varied between specimens (see the next paragraph). Spotty ossification was seen in the humeral head as well as the scapula. The subcoracoid bursa was unclear in mid-term fetuses because of the very thin lining (Fig. 1C), but it was large with a synovial lining in the late-stage fetuses (Figs. 2BC and 3H). From the opening, the bursa extended inferiorly for more than 10 mm along the subscapularis muscle-tendon unit.

In mid-term fetuses (Fig. 1) as well as in late-stage fetuses (Fig. 2), we found two patterns of terminal course of the subscapularis tendon: 1) the tendon was tightly attached to the medial part of the joint capsule (outer aspect of the capsule) and extended anterosuperiorly along it (7/10 mid-term fetuses; 5/10 late-stage fetuses); 2) the tendon passed superiorly through the joint cavity for a long distance toward the lesser tubercle in combination with the subcoracoid bursa opening widely to the joint cavity (3/10 mid-term fetuses; 5/10 late-stage fetuses). In specimens with the former pattern or capsule-attaching tendon, the lower glenoid labrum tended to be well developed because the subscapularis tendon did not interfere with the superior extension of the labrum. In specimens with the latter pattern, the large opening of the subcoracoid bursa appeared to make the long intra-articular course possible. Thus, in most sections including the intra-articular tendon, the distal part of the tendon was attached to the coracoid process by synovial tissue (Fig. 1AB). Notably, with only one exception (late stage; Fig. 3), the capsule-attaching tendon (Figs. 1CD and 2CD) was seen in fetuses in which the coracoid process was located on the superior side of the lesser tubercle (major parts of the coracoid process was located out side or superior side of these photos). In contrast, the intra-articular tendon of the subscapularis (Figs. 1AB and 2AB) consistently accompanied the coracoid process at the same supero-inferior level of the lesser tubercle.

Figure 3 demonstrates a limited specimen in which the capsule-attaching tendon was seen at a level including the major parts of the coracoid process. In the limited case, the superior end of the coracoid process was located at the level of the lesser tubercle (Fig. 3A). The subscapularis tendon contained several clusters of muscle fiber bundles (Fig. 3B-F). The opening of the subcoracoid bursa was
Variation of the subscapularis tendon

Fig. 1. Subscapularis tendon at the glenohumeral joint cavity of two mid-term fetuses (16 weeks). Panels A and B display the intra-articular tendon, while panels C and D exhibit the capsule-attaching tendon. The upper side of the figure corresponds to the anterior side of the body. Panels A and B display the subscapularis tendon (SST) passing through the joint cavity for a long distance toward the lesser tubercle in combination with the subcoracoid bursa opening widely to the joint cavity. Panels C and D show the tendon tightly attached to the joint capsule and extending superoposteriorly along it. Panel A or C is located 0.6 mm above panel B or D, respectively. SS* indicates a muscle attachment of the subscapularis to the lesser tubercle. Note that panels A and B contain the coracoid process (CP), in contrast to its absence in panels C and D. The coracoid process is located 1.0–1.5 mm higher than panel C. Arrows in panels A and B indicate the joint capsule lined by a thick fascia or ligament extending between the coracoid and acromion. All panels are prepared at the same magnification (scale bar in panel A). BT, biceps tendon; CB, coracobrachialis and the short head of the biceps; L, glenoid labrum. Scale bar = 1 mm.
Fig. 2. Subscapularis tendon at the glenohumeral joint cavity of two late-stage fetuses (27 weeks). Panels A and B display the intra-articular tendon, while panels C and D exhibit the capsule-attaching tendon. The upper side of the figure corresponds to the anterior side of the body. Panels A and B display the subscapularis tendon (SST) passing through the joint cavity for a long distance toward the lesser tubercle in combination with the subcoracoid bursa opening widely to the joint cavity. Panels C and D show the tendon attached to the joint capsule and extending superoposteriorly along it. Panel A or C is located 3 mm above panel B or D, respectively. The subcoracoid bursa (bursa) is enclosed by synovial tissue in panels B and D. Note that panels A and B contain major parts of the coracoid process (CP), in contrast to the inferior end seen in panel D. Candidates for the glenoid labrum (L) in panel C may correspond to the inferior glenohumeral ligament. Arrows in panels C and D indicate a thick fascia or ligament extending between the coracoid and the acromion. All panels are prepared at the same magnification (scale bar in panel A). BT, biceps tendon; CB, coracobrachialis and the short head of the biceps; L, glenoid labrum; SS, muscular part of the subscapularis. Scale bar = 1 mm.
During postnatal development, the intra-articular tendon 
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to cover the intra-articular course. The capsule-attaching 
complicated configuration of the glenohumeral ligaments 
intra-articular tendon seemed to require a wide, thick and/or 
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Thus, in contrast to the capsule-attaching tendon of the 
capsule or become separated by the synovial membrane 
tendon of the subscapularis would move outside the joint. 
course of the biceps tendon was formed at the late 
stage fetuses (Fig. 2AB). In addition, the lower glenoid 
labrum, at the medial edge, formed a valve-like protrusion 
along the lateral margin of the subscapularis tendon (Figs. 
1D, 2AC and 3A).

Discussion

The present study demonstrated individual variations of 
the subscapularis tendon at the fetal glenohumeral joint. 
The capsule-attaching tendon of the subscapularis (inci-
dence, 12/20) was seen in fetuses in which the coracoid 
process was located on the superior side of the lesser 
tubercle, whereas the intra-articular tendon (8/20) accom-
panied the coracoid process at the same supero-inferior 
level as the lesser tubercle. We found a limited exception 
to this rule: one specimen with the capsule-attaching tendon 
at the level of the coracoid process. If we had examined a 
greater number of specimens, we may have seen multiple 
exceptions or intermediate morphologies between two 
patterns of tendon courses, i.e., the capsule-attaching or 
intra-articular tendon. Likewise, the incidence of each 
pattern may have changed slightly depending on the size 
of the population examined. This was one limitation of 
the study. Nevertheless, the topographical relationship 
between the coracoid process and lesser tubercle in fetuses 
appeared highly likely to determine the courses of the 
subscapularis tendon at the glenohumeral joint. Such a 
slight difference in the topographical relation is unlikely to 
be determined by a basic body plan for positioning of the 
shoulder alongside the trunk.

Abe et al. [8] considered that the so-called intra-articular 
course of the biceps tendon was formed at the late stage. 
In contrast to the biceps tendon, even in mid-term fetuses, 
the fetal subscapularis tendon often took an intra-articular 
course. During postnatal development, the intra-articular 
tendon of the subscapularis would move outside the joint 
capsule or become separated by the synovial membrane 
and its associated ligaments. Even in cases of Buford 
complex, the tendon is covered by synovial tissue [7]. 
Thus, in contrast to the capsule-attaching tendon of the 
subscapularis (i.e., a tendon outside of the capsule), the 
intra-articular tendon seemed to require a wide, thick and/or 
complicated configuration of the glenohumeral ligaments 
to cover the intra-articular course. The capsule-attaching 
tendon of the subscapularis may provide O'Brien’s type 1 
or 5 ligament configuration, i.e., the upper opening of the 
subcoracoid bursa above the middle ligament [2], whereas 
the intra-articular tendon is likely to provide any type. 
During postnatal development, the intra-articular tendon 
seems to require a thick and complex configuration of the 
glenohumeral ligaments to cover the intra-articular course. 
Therefore, the various adult morphologies of the middle 
and inferior glenohumeral ligaments are, to a greater or 
lesser degree, determined during early fetal development 
(earlier than 15 weeks) rather than through postnatal modi-
fication or restructuring as a result of mechanical demands 
from the subscapularis tendon itself.

observations, the subscapularis tendon merges with the 
middle glenohumeral ligament at a right angle. However, 
such a specific band-like structure is difficult to identify 
in horizontal and tilted horizontal sections in which the 
subscapularis tendon has been cut longitudinally. A syno-
vial tissue, we found around the tendon, might be corre-
spend to the primitive morphology. The cord-like middle 
glenohumeral ligament seems to develop postnatally to 
cover the large opening of the subcoracoid bursa and to 
assist the “intra-articular” tendon of the subscapularis. In 
a macroscopic dissection of a 14-week-fetus, Fealy et al. 
[12] demonstrated the inferior glenohumeral ligament. 
However, from the photo, our impression was that the 
structure was difficult to discriminate from the developing 
glenoid labrum. In a dissection study using 16-week and 
20-week fetuses, Aboul-Mahasen et al. [13] successfully 
demonstrated the middle and inferior glenohumeral liga-
ments. Thus, in the present late-stage specimens, the liga-
ments should have been present. In fact, we found that the 
lower glenoid labrum, at the medial edge, formed a valve-
like protrusion along the lateral margin of the subscapu-
laris tendon (Figs. 1D, 2AC and 3A). These structures may 
correspond to the inferior or middle glenohumeral liga-
ment in adults. However, strict identification would seem 
to be meaningless because of the difference in topograph-
ical anatomy between fetuses and adults.

Arai et al. [14] divided the insertion areas of the adult 
subscapularis into 4 parts: therein, the subscapularis 
muscle-tendon unit approaches the humerus from the 
medio-inferior side. In contrast, in fetuses, the muscle 
approaches the lesser tubercle from the posterior side. 
Moreover, the muscle insertion to the lesser tubercle (the 
lowest part of the insertion in adults) was not identified 
in late-stage fetuses. Rearrangement between the muscle 
fibers and connective tissue seems to occur during post-
natal development under mechanical demands as well as 
as a result of the posterior shift of the scapular plate with 
flattening of the thorax. Finally, as Touheti et al. [4] have 
suggested in adults, the fetal topographical anatomy of 
the biceps tendon is also likely to determine the postnatal 
development of the middle and inferior glenohumeral liga-
ment.

Conclusions

The topographical relationship between the coracoid
Fig. 3. Subscapularis tendon attached to the glenohumeral joint capsule in a 32-week-fetus. The upper side of the figure corresponds to the anterior side of the body. Panel A (Panel H) is the most superior (inferior) side of the figure. Panel B is a higher-magnification view of the central part of panel A. Intervals between panels are 5 mm (A–C), 1 mm (C–D), 2 mm (D–E), 5 mm (E–F), 6 mm (F–G) and 8 mm (G–H), respectively. Although most parts of the coracoid process are included in the figure, the subscapularis tendon (SST) is attached to the joint capsule and extends superoposteriorly along it (panels A–E). The tendon contains muscle fiber bundles (stars in panels B–F). The subcoracoid bursa (bursa) opens to the joint cavity in panel G and extends inferiorly along the subscapularis tendon to a level almost 10 mm away from the joint (panel H). Candidates for the glenoid labrum (L) in panel A (or panel F) may correspond to the inferior (or middle) glenohumeral ligament. BT, biceps tendon; CB, coracobrachialis and the short head of the biceps; SS, muscular part of the subscapularis; supinatus T, infraspinatus tendon. Scale bars = 1 mm (A–H).
process and the lesser tubercle in fetuses earlier than 15 weeks appears most likely to determine the morphologies of the subscapularis tendon at the glenohumeral joint, i.e., the intra-articular tendon or the capsule-attaching tendon. The various adult morphologies of the glenohumeral ligaments are, to a greater or lesser degree, determined during early fetal development.

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References