Arthroscopic anatomy of the subdeltoid space

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Abstract

From the first shoulder arthroscopy performed on a cadaver in 1931, shoulder arthroscopy has grown tremendously in its ability to diagnose and treat pathologic conditions about the shoulder. Despite improvements in arthroscopic techniques and instrumentation, it is only recently that arthroscopists have begun to explore precise anatomical structures within the subdeltoid space. By way of a thorough bursectomy of the subdeltoid region, meticulous hemostasis, and the reciprocal use of posterior and lateral viewing portals, one can identify a myriad of pertinent ligamentous, musculotendinous, osseous, and neurovascular structures. For the purposes of this review, the subdeltoid space has been compartmentalized into lateral, medial, anterior, and posterior regions. Being able to identify pertinent structures in the subdeltoid space will provide shoulder arthroscopists with the requisite foundation in core anatomy that will be required for challenging procedures such as arthroscopic subscapularis mobilization and repair, biceps tenodesis, subcoracoid decompression, suprascapular nerve decompression, quadrangular space decompression and repair of massive rotator cuff tears.

Introduction

Through the evolution in arthroscopic techniques, instrumentation, and implants, the shoulder anatomy has remained constant, but only recently have shoulder arthroscopists begun to explore precise anatomical structures within the subdeltoid space. An appreciation of the anatomy begins with proper entry and extensive bursectomy. In the present article, the authors have described the arthroscopic anatomy of the lateral, medial, anterior, and posterior regions of subdeltoid space.

Arthroscopic anatomy by location
Lateral

Greater tuberosity

The greater tuberosity is the insertion site of the supraspinatus, infraspinatus, and teres minor (Figure 1A and B). Of particular interest to the arthroscopist is the footprint of the supraspinatus insertion on the greater tuberosity. An anatomic dissection study of the supraspinatus footprint found that the mean anterior to posterior dimension of the supraspinatus tendon was 25 mm, with a mean medial to lateral thickness of the footprint of 12 mm - the mean distance from the cartilage to the supraspinatus footprint was 1.5 mm at midtendon.[1]

The greater tuberosity can be seen from either a posterior viewing portal or lateral viewing portal. It is important to perform at least a partial resection of the sub-acromial bursa to improve visualization of this structure. With the use of a mechanical shaver or electrocautery device the lateral sub-deltoid region can be visualized and the most lateral insertion of the greater tuberosity is well visualized.

Supraspinatus tendon

The supraspinatus originates from the supraspinatus fossa and the superior surface of the spine of the scapula, and runs laterally to insert on the anteromedial area of the highest impression of the greater tuberosity.[2] The anterior margin of the supraspinatus is defined by the posterior edge of the rotator interval that separates the supraspinatus from the rolled superior border of the subscapularis. The posterior margin of the supraspinatus is marked by the extension of the raphe between supraspinatus and infraspinatus around the scapular spine. The anterior portion of the supraspinatus is composed of a long and thick tendinous component whereas the posterior portion has been shown to be short and thin. The supraspinatus derives its innervation from the suprascapular nerve.

Arthroscopic evaluation of the supraspinatus tendon has been well described from the subdeltoid space. The key to its evaluation is appropriate resection of the sub-deltoid bursa. This must be accomplished with some alacrity as the bursa may become distended with arthroscopic fluid and swell, impeding visualization. Optimal viewing of the supraspinatus insertion is via 2 portals - by viewing the insertion from at least 2 vantage points the surgeon can more easily identify the anatomic insertion.

Infraspinatus tendon

The infraspinatus originates from both the infraspinatus fossa and the inferior surface of the spine of the scapula, running from this medial origin in a superior and lateral direction to insert on the middle impression of the greater tuberosity. The innervation to the infraspinatus is also derived from the suprascapular nerve. Much like the supraspinatus the infraspinatus is comprised of a thick tendinous portion and a thinner component, although the thicker portion is oriented more inferiorly.

The footprint of the infraspinatus resembles a trapezoid that is wider laterally than medially, with an average maximum length of 10.2±1.6 mm and an average width of 32.7±3.4 on the lateral margin.[2] Arthroscopically the insertion of the infraspinatus can be difficult to truly delineate, as there is often some connective tissue including the coracohumeral ligament overlying the border between the infraspinatus footprint and the footprint of the supraspinatus. By following the muscle tendon unit from its more medial aspect the arthroscopist can better appreciate the demarcation.

Acromion

The acromion has been implicated by several authors in the pathology of rotator cuff dysfunction and injury.[3] The classic study by Aoki et al. described three types of acromial morphology.[4] A type I acromion is one with a flat undersurface, a type II Acromion is defined as

having a curved undersurface, and a Type III has a hooked undersurface that carried the highest risk of impingement.

Nicholson *et al*. reported the mean acromial dimensions in men to be length = 48.5 mm, width = 19.5 mm, and anterior thickness = 7.7 mm. The mean dimensions in women were significantly different and reported to be length = 40.6 mm, width = 18.4 mm, and thickness = 6.7 mm.[3]

The acromion serves as the attachment of the coracoacromial ligament, is the origin of the deltoid muscle, and forms the acromioclavicular joint via an articulation with the clavicle. The arthroscopist can choose to evaluate the acromion via a lateral, posterior, or anterior portal position, though the posterior and lateral portals are most common. It is important to remove the soft tissue from the undersurface to delineate the anatomy.

Coracoacromial ligament

The coracoacromial ligament (CAL) is part of the coracoacromial arch, serving as a connection between the coracoid and the acromion. Holt *et al*. described 3 main anatomic variants of the CAL: quadrangular, Y-shaped, and a broadband variant.[5] In 2008 Kesmezacar *et al*. added a V-shaped variant and multiple band variant to the existing classification.[6] They determined that the Y-shaped variant was the most common type occurring at a frequency of 41.3% while the multi-band type was least common occurring in 11.2% of specimens, with a significantly increased incidence of rotator cuff pathology in those specimens with CALs that had more than one bundle.

Flatow *et al*. reported that the CAL is an important superior stabilizer of the shoulder.[7] Lee *et al*. demonstrated that with release of the CAL increased translation was observed in the inferior and anterior directions at multiple degrees of abduction.[8] For this reason, release of this structure may lead to anterior and superior instability when the primary stabilizers (i.e. rotator cuff) of the humerus are absent.

Optimal viewing of the CAL can be achieved from a postero-lateral portal in the subacromial space (Figure 1C). By viewing from this area subtle extensions of the ligament that may contribute to an impingement-like condition can be appreciated. The CAL also serves as the anterior boundary of a triangle formed by the undersurface of the AC joint and the anterior border of the supraspinatus that is the initial interval for suprascapular nerve decompression at the suprascapular notch.

Medial

Distal clavicle/AC Joint

Distal clavicle resection was first described by Mumford in 1941.[9] Disease processes including AC joint arthritis, distal clavicle oste-

olysis, and fractures of the distal end of the clavicle have all been treated arthroscopically.[10]

This anatomy is also of particular interest in the arthroscopically assisted reconstruction of the coraco-coracoid ligaments. Rios *et al*. determined the mean distances from the lateral clavicle to the conoid tuberosity (Male: 47.2 mm, Female: 42.8 mm) and the distance from the lateral edge of the clavicle to the center of the trapezoid tuberosity (M: 25.4 mm, F: 22.9 mm).[11]

For simple evaluation of the AC joint a lateral or posterior viewing portal is sufficient in the subacromial space (Figure 2A). The AC joint can be arthroscopically excised via the indirect subacromial approach through a lateral viewing portal with the working portal being anterior, or via direct superior approach with the arthroscope placed posterior to the AC joint and directed intra-articularly.[10,12]

Rotator interval

First described by Neer in 1970, the RI defines the anterosuperior space in the rotator cuff between the supraspinatus and subscapularis tendons.[13] This triangular space, whose base is located medially at the coracoid process and whose apex is lateral at the intertubercular groove, contains the long head of the biceps tendon, the superior glenohumeral ligament (SGHL), the glenohumeral joint capsule and coracohumeral ligament (CHL).[14,15] While debate still remains in the orthopaedic surgery literature as to its exact function, recent studies have demonstrated that the rotator interval plays a role in the stability of the glenohumeral joint.[16-21] The interval and its structures can be visualized from a lateral viewing portal or from an anterior viewing portal.

Coracohumeral ligament

Neer who implicated shortening and thickening of the CHL in the pathology of adhesive capsulitis, particularly loss of external rotation.[22] Yang *et al*. dissected 26 fresh frozen shoulders, and identified that the CHL is shaped like an irregular trapezoid.[23] The CHL lies below the subacromial bursa and above the subcoracoid bursa. The origin of this structure is constant, taking rise from the lateral aspect of the coracoid. The insertion is more variable, with the termination seen on the supraspinatus, rotator interval, or subscapularis.[23]

This structure can be visualized from the lateral portal when the rotator interval is opened or has been injured (Figure 2B). Alternatively the anterior portal can be used to optimize the visualization of the CHL.

Coracoid

Several procedures, including arthroscopic transfer of the coracoid and conjoint tendon, and release of the transverse scapular ligament (TSL) require visualization of the coracoid as a landmark.[24,25] The coracoid serves as

the origin of the short head of the biceps and coracobrachialis tendons as well as the insertion of the pectoralis minor, coracoacromial, coracohumeral, coraco-clavicular ligaments. From the subdeltoid space the coracoid can be located reliably by dissecting initially with a blunt instrument into the triangle formed by the undersurface of the AC joint, the anterior border of the supraspinatus, and the edge of the CA ligament. By viewing from a lateral portal the arthroscopist can look over the top of the supraspinatus and follow the conoid ligament to find the base of the coracoid (Figure 2C). The TSL extends laterally from the coracoid base (Figure 2D).
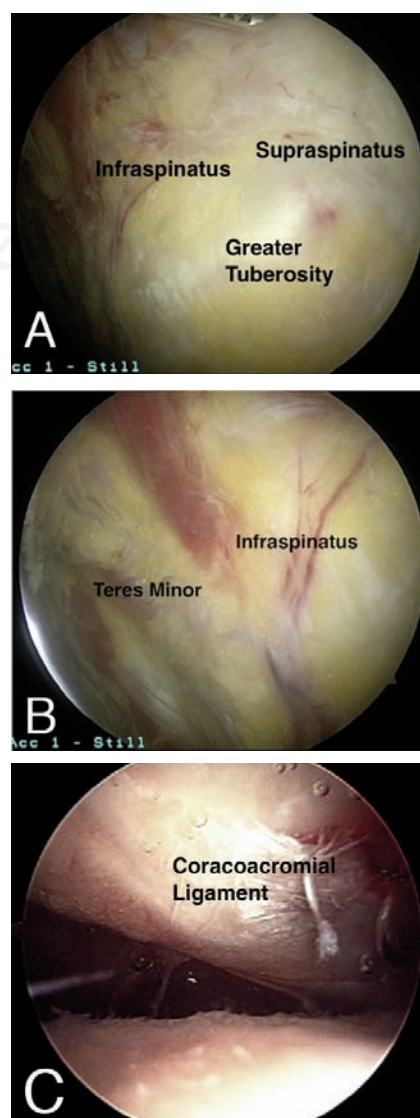

Figure 1. A) Insertion of the supraspinatus and Infraspinatus tendons is visualized on the rotator cuff fooprint on the greater tuberosity (lateral viewing portal). B) Insertion of the Infraspinatus and teres minor is visualized (lateral viewing portal). C) Visualization of the coracoacromial ligament from posterolateral viewing portal.

Sub-coracoid space

The area between the lesser tuberosity and the coracoid process has recently been implicated by some authors as a potential location for impingement of the subscapularis.26-30 There have been several studies that have determined the normal coracohumeral distance with measurements ranging between 8.7-11 mm.[29,31] In a study by Nove-Josserand *et al*. using CT-arthrograms performed in patients with full thickness rotator cuff tears, patients with tears involving the subscapularis had a significantly decreased coracohumeral distance, with 26% having less than 6 mm of space.[32]

The coracohumeral space can be seen by viewing from either a standard posterior viewing portal or from a lateral portal. An arthroscopic probe can be used to measure the distance between the subscapularis tendon and the coracoid.

Coracoclavicular ligaments

The CCLs are two distinct structures connecting the clavicle to the coracoid, with the primary function of providing stability of the clavicle in the superior and inferior plane. The more medial of the two is the conoid ligament and is seen to originate on average 47 mm from the lateral edge of the clavicle in males and 42.8 mm from the lateral edge in females.

The more lateral structure is the trapezoid ligament, with an average distance from the lateral clavicle to the footprint of the trapezoid of 25.4 mm in men and 22.9 mm in women.[11] The conoid footprint (25.3 mm) on the clavicle is more than 2 times the size of the trapezoid origin (11.8).

The CC ligaments can be identified from either a lateral or posterior viewing portal, but we prefer a lateral viewing position in the sub-acromial space. A triangle defined by the undersurface of the AC joint, the medial edge of the CAL and the anterior border of the supraspinatus muscle belly is the first interval that must be developed when attempting to define these structures (Figure 2C). A Wissenger rod may be helpful to retract the anterior border of the supraspinatus to better define these structures as described by Ghodadra *et al*.[25] The posterior aspect of both ligaments can be seen from this approach and by following the conoid ligament distally the arthroscopist can easily and reproducibly identify the coracoid (Figure 2D and E).

Suprascapular notch/transverse scapular ligament

The TSL serves as the roof of the suprascapular notch (Figure 2F), and has been classified by Rengachary *et al*. into 6 different types.[33] The suprascapular artery passes over the TSL and the suprascapular nerve passes beneath it. There are many reports of suprascapular nerve entrapment occurring at this site and recently arthroscopic techniques of TSL release have been described.[25]

With the patient in the beach chair position the surgeon can place the arthroscope in the lateral portal for viewing while working initially from an anterior portal. Again the triangle formed by the supraspinatus anterior border, the posterior aspect of the CAL ligament, and the undersurface of the AC joint is developed by blunt dissection (Figure 2C). The CC ligaments are identified and followed to the base of the coracoid. The TSL inserts here on the base of the coracoid and can be more clearly defined by blunt dissection. Once identified the ligament can be released with an arthroscopic device.

Anterior

Lesser tuberosity

The lesser tuberosity is the insertion site for the subscapularis tendon. The biceps groove is located directly lateral to the lesser tuberosity, with the articular cartilage of the humeral head being medial. The insertion of the subscapularis muscle was described by Curtis *et al*. to take place in a comma-shaped pattern from 7 to 11 o'clock around the tuberosity (with the right shoulder used as a point of reference).[34] In this cadaveric study, the average maximum length of the tendon insertion was 40 mm (range: 35-55 mm), and the average maximum width was 20 mm (range: 15-25 mm), with the superior portion of the footprint the widest part of the subscapularis insertion. The mean width at the most superior aspect of the insertion site was 1.8 cm (range: 1.5 to 2.6 cm). The most inferior aspect of the footprint was much narrower with a mean width of 0.3 cm (range: 0.1 to 0.7 cm).

Subscapularis tendon

The subscapularis muscle is the largest and most powerful rotator cuff muscle, arising from the anterior surface of the scapula. This muscle is innervated by the upper and lower subscapular nerves, and Its major role is internal rotation of the humerus. The subscapularis has between four and six tendon slips that arise from deep within the muscle and converge superiorly and laterally to form the main tendon that inserts along the superior aspect of the lesser tuberosity.[17]

At the upper aspect of the subscapularis tendon, the fibers interdigitate with the anterior fibers of the supraspinatus to contribute to the structure of the rotator cuff interval as well as the transverse humeral ligament. Glenohumeral arthroscopy can be used to visualize the subscapularis tendon by positioning the arthroscope in the posterior portal and then elevating the shoulder to greater than 45
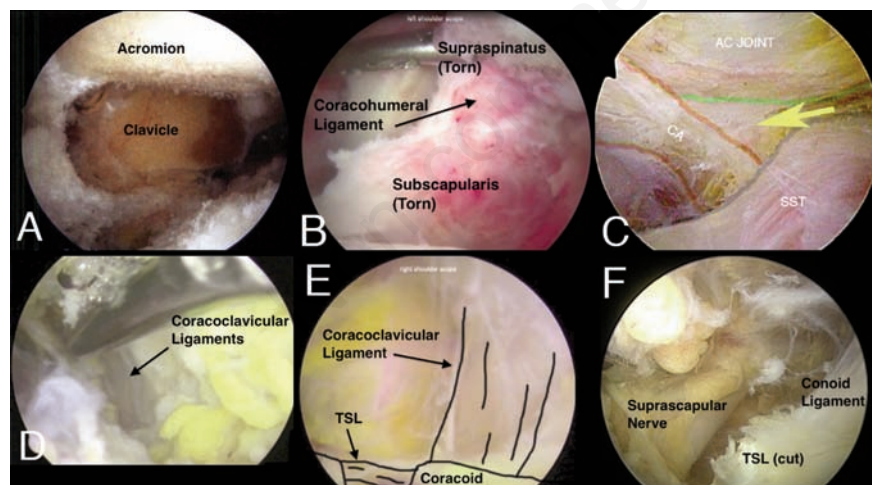

Figure 2. A) Undersurface of the acromion and resected distal clavicle as viewed from a lateral portal. **B)** The coracohumeral ligament is identified in an anterosuperior rotator cuff tear (lateral viewing portal). Notice how it attaches to both the leading rolled border of the subscapularis and the leading edge of the supraspinatus. **C)** The triangular interval formed by the anterior border of the supraspinatus, the medial border of the coracoacromial (CA) ligament, and the undersurface of the acromioclavicular (AC) joint is entered (from lateral viewing portal) to gain access to the coracoclavicular ligaments. **D)** The posterior aspect of the coracoclavicular ligaments is identified from a posterior viewing portal anterior to the supraspinatus plane. **E)** With the arthroscope advanced more medial compared with figure 2d, the posterior aspect of the coracoacromial ligaments is identified from a lateral viewing portal anterior to the supraspinatus plane. The schematic on the right demonstrates the conoid ligament, the transverse scapular ligament (TSL) and the base of the coracoid. **F)** The resected transverse scapular ligament (TSL) along with the decompressed suprascapular nerves are identified from a lateral viewing portal.

degrees while providing internal rotation.[35] This position also allows visualization of the biceps tendon, coracohumeral, and superior glenohumeral ligaments.

A study by Pearsall *et al*.[36] found that the intra-articular portion of the subscapularis constituted approximately 25% of the entire cephalocaudal dimension of the subscapularis tendon. Burkhart and Tehrany were the first to report on arthroscopic repair of the subscapularis tendon.[37] An extra-articular view of the subscapularis tendon can also be achieved by use of a lateral viewing portal (Figure 3A).

Pectoralis major tendon

The pectoralis major muscle is a powerful internal rotator, flexor, and adductor of the arm. This muscle has a superior half, which forms the clavicular head, and an inferior half, which forms the sternal head. The lateral pectoral nerve is responsible for innervating the clavicular head and the medial portion of the sternal head. The medial pectoral nerve innervates the lateral portion of the sternal head.

The pectoralis tendon is approximately 5 cm wide, 1 cm long on the anterior surface, and 2.5 cm long on the posterior surface.[38,39] The tendon has been described as having three laminae.[40] The investing fascia of the pectoralis muscle is continuous with the fascia of the brachium as well as the medial antebrachial septum, making it challenging to visual the true tendon arthroscopically. However, the deep and superior surface of the pectoralis major can be visualized during an arthroscopic suprapectoral biceps tenodesis (Figure 3B).

Long head of biceps tendon

The LHB is normally found within the glenohumeral joint, within a synovial sheath. It passes anterior and superior to the humeral head, emerging from the joint in the bicipital groove. In the bicipital groove the tendon is bound by the subscapularis, supraspinatus, the transverse humeral ligament, and an extension from pectoralis major.[41] The long head of biceps tendon has been described as originating at the supraglenoid tubercle, however several studies have demonstrated significant anatomic variance. Pal *et al*. found in 70% of shoulder the posterior-superior glenoid labrum was deficient and the long head of the biceps replaced it, resulting in only a small portion of the tendon attaching to the supraglenoid tubercle.[42] Similarly, Vangsness *et al*. studied 105 cadaveric shoulders and found only 40-60% of LHB tendons originated at the supraglenoid tubercle, with the rest originating at the superior glenoid labrum.[43]

The bicipital groove is located between the greater and lesser tubercles at the proximal extremity of the humerus and extends inferiorly. A recent study by Wafae *et al*. found the average length of the groove to be 8.1 cm, with a width of 10.1 mm, and an average depth of 4 mm.[44] Direct arthroscopy of the bicipital groove can be performed, by placing a 4.5 mm cannula through a superior-medial (Neviaser) portal and into the glenohumeral joint.[45] The arm is then positioned in abduction, external rotation, and forward flexion, to align the groove with the arthroscope, allowing direct visualization.

Neurovascular structures

The main neurovascular structures in the anterior aspect of the subdeltoid space are the axillary nerve and the musculocutaneous nerve. The axillary nerve runs obliquely across the inferolateral border of the subscapularis, crossing 3 to 5 mm from its musculotendinous junction (Figure 3C and D). Bryan and colleagues found that it averaged 0.32 cm inferior to the capsule of the shoulder.[46] Eakin *et al*. delineated a safe zone for the placement of casulolabral sutures, finding that as long as the sutures entered the capsule 1 cm from the glenoid, all were farther than 7 mm from the axillary nerve at any position around the capsule.[47,48] The musculocutaneous nerve can be predictable found as it courses through the conjoined tendon about 1 to 5 cm distal to the coracoid process - by following the conjoined tendon inferiorly from the coracoid, it can be visualized arthroscopically.

Posterior

Posterior interval

The posterior rotator interval lies between the supraspinatus and the infraspinatus in the space created by the separation of these muscles by the scapular spine (Figure 4A). Miller *et al*. defined the interval to be an average of 49.4 mm (scapular spine to the confluence of the tendons) which is devoid of any muscle or tendon.[49] The interval is technically triangular, and the histologic makeup of the interval is fibroadipose tissue with a synovial lining analogous to the shoulder capsule.
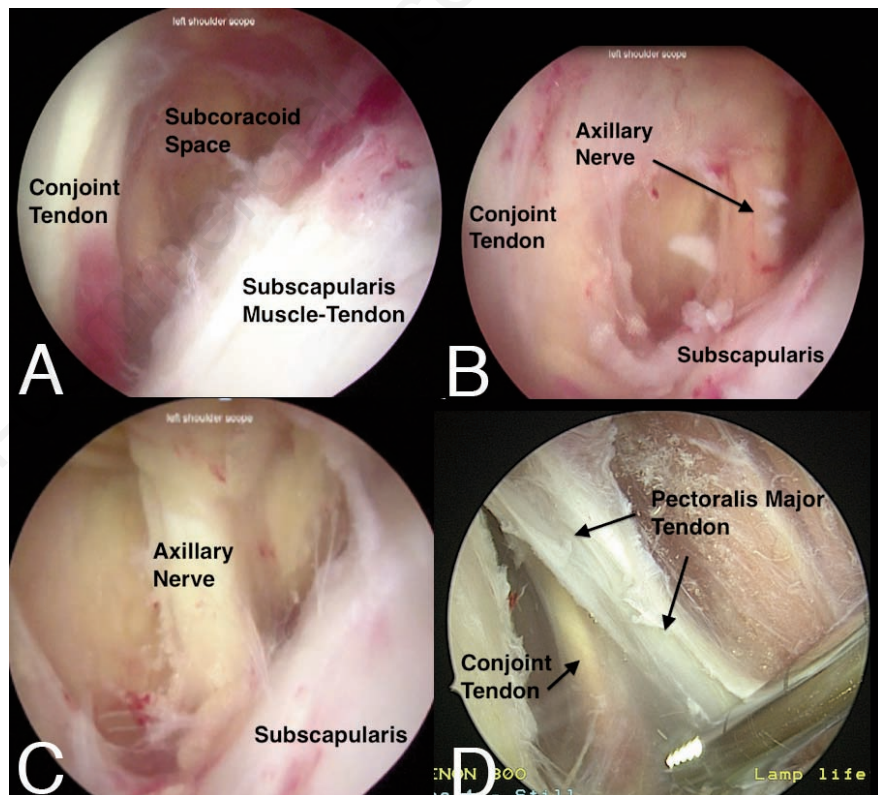

Figure 3. A) The conjoint tendon and the subscapularis muscle tendon units define the anterior and posterior boundaries of the subcoracoid space, respectively, and can be visualized from a lateral viewing portal. B) With the arthroscope advanced more medially compared with Figure 3a, the deep aspect of the conjoint tendon and medial subscapularis muscle tendon unit can be seen. After a careful bursectomy in this area, the axillary nerve can also been seen along the lower border of the subscapularis. C) The axillary nerve visualized in the subcoracoid space from a lateral viewing portal. D) The conjoint tendon and the deep portion of the pectoralis major tendon can be visualized during the dissection required for an arthroscopic biceps tenodesis. This view is appreciated from a lateral viewing portal at the junction of the anterior and middle thirds of the acromion with the arm in a forward flexed and slightly abducted position.

Scapular spine

The scapular spine serves as a boundary between the supraspinatus and Infraspinatus (Figure 4B). Tubbs *et al*. described that the length of the spine ranged from 7 to 15 cm (mean 11.5 cm), and that the mean thickness was 1 cm at the most medial segment (1 cm), 2.2 cm at the segment adjacent to the spinoglenoid notch, and 2.5 cm near the acromion (2.5 cm).[50]

Spinoglenoid notch

The reported prevalence of the spinoglenoid ligament varies between 3-80%, however a recent study by Plancher *et al*. demonstrated 100% prevalence of the spinoglenoid ligament in a cadaveric study of fifty-eight shoulders.[51]

Arthroscopic decompression of the spinoglenoid notch has been described in the literature and may be done via the glenohumeral or subacromial space. Our preferred method is to use an anterior high rotator interval portal for viewing, and a create a posterior working portal 3 cm inferior to and in line with the posterolateral acromion.[25] Any labral pathology is addressed. The posterior-superior capsule is released with a mechanical shaver between the 9-o'clock and 12-o'clock positions, preserving the posterior band of the inferior glenohumeral ligament complex. The raphe between the supraspinatus and infraspinatus is identified and followed medially (Figure 4A). If a cyst is present it can be seen directly on the scapula and decompressed with a shaver.

If inspection of the glenohumeral joint does not show a capsule or labral tear, the spinoglenoid notch cyst can be decompressed from the subacromial space, using a posterior and lateral portal. All soft tissue is removed from the undersurface of the acromion and the bursal surface of the rotator cuff. The arthroscope is directed posteriorly and medially to identify the separate muscle bellies of the supraspinatus and the infraspinatus, and to visualize the scapular spine. A probe can be used to palpate the posterior aspect of the glenoid, which defines the anterior boundary, and the cyst can sometimes be localized between the scapular spine and the posterior glenoid. The mechanical shaver is used to debride the soft tissue and further expose the spinoglenoid notch cyst is carefully advanced from anterior to posterior, to avoid injury to the SSN. The SSN is located at the base of the scapular spine, and therefore the mechanical shaver should not be used near the spine. If the cyst is not palpable, the mechanical shaver can be carefully advanced until cyst fluid is visible.

Quadrangular space

The quadrangular space is created by the teres minor superiorly, the surgical neck of the humerus laterally, the long head of triceps medially, and the upper border of teres major inferiorly. It contains the axillary nerve and the posterior circumflex humeral artery (Figure 4B). Fibrous bands of tissue can result in compression of the quadrangular space and the axillay nerve, necessitating arthroscopic evaluation and decompression.

Discussion and Conclusions

Through a thorough bursectomy of the subdeltoid space, meticulous hemostasis, and the reciprocal use of posterior and lateral viewing portals, one can identify a myriad of pertinent ligamentous, musculotendinous, osseous, and neurovascular structures. Being able to identify pertinent structures in the subdeltoid space will provide shoulder arthroscopists with the requisite foundation in core anatomy that will be required for challenging procedures such as arthroscopic subscapularis mobilization and repair, biceps tenodesis, subcoracoid decompression, suprascapular nerve decompression, quadrangular space decompression and repair of massive rotator cuff tears.

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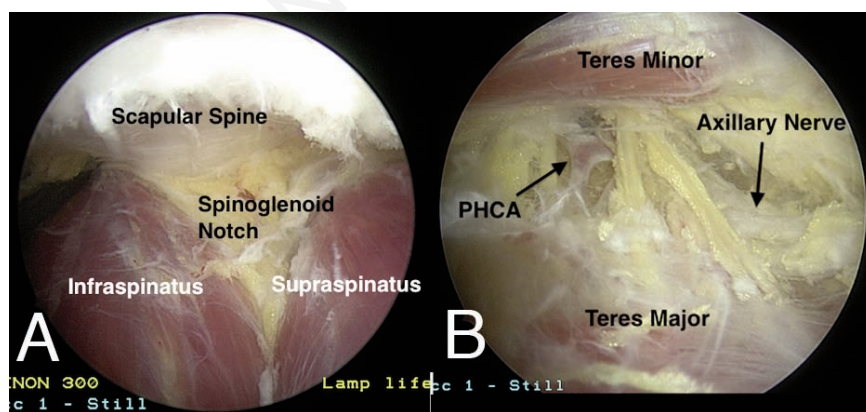
Figure 4. A) The scapular spine (as viewed from a lateral portal) can be used to delineate the border between the supraspinatus and Infraspinatus. By following the scapular spine medially, dissection to the spinoglenoid notch can also be performed. **B)** Identification of the axillary nerve and posterior humeral circumflex artery (PHCA) in the quadrangular space from a posterior viewing portal.

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