10 Long Head of the Biceps Tendon Complex: Pathology and Treatment Approach

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Background

Lesions of the biceps tendon had been documented since the middle ages mostly in response to spontaneous dislocation or rupture and based upon anatomic studies. Codman [1], in his seminal text *The Shoulder*, felt the biceps were more likely a recipient of the collateral damage from associated shoulder pathologies than a primary source of shoulder pain. Shortly thereafter however, a series of authors began to express their disagreement Lippmann [2], Tarsy [3], Hitchcock et al. [4] , DePalma [5]; and a series of procedures for tenodesis of the LHBT were introduced.

The significance of the intraarticular biceps tendon was introduced when Andrews described lesions of the superior labrum and Snyder et al. [7], coined the term *SLAP tear (superior labrum anterior to posterior)* and described the relationship of the superior labrum to the LHBT [6].

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Anatomy

Many aspects of the anatomy of the biceps tendon are variable. It is generally agreed the tendon is approximately 9 cm [8, 9]; in length, 5–6 mm in diameter, and can generally be divided into an intraarticular portion, a portion within the biceps groove just lateral to the insertion of the subscapularis tendon, and a subpectoral portion.

Because the tendon has been shown to glide in the groove, it is important to understand these relationships as dynamic rather than static as the same portion of the tendon can be located in a different zone based upon arm position [10].

The LHBT is most commonly described as originating from the supraglenoid tubercle, but this origin too, is variable. In fact, Habermeyer et al. [11] described origin from the supraglenoid tubercle in only 20% of specimens versus an origin from the posterosuperior labrum in most cases (48%), or a shared origin. Additional studies have confirmed a predominant relationship with the posterior labrum and little to no microscopic origin occurring from the more anterior labrum (Fig. 10.1).

The tendon begins as a relatively flat structure until it reaches the intratubercular groove around 20 mm from its origin, at which point it becomes more tubular in the middle and distal portions [12, 13]. It is important to understand flattening as a normal feature as it is often one of the reported pathologic changes of the tendon noted at arthroscopy.

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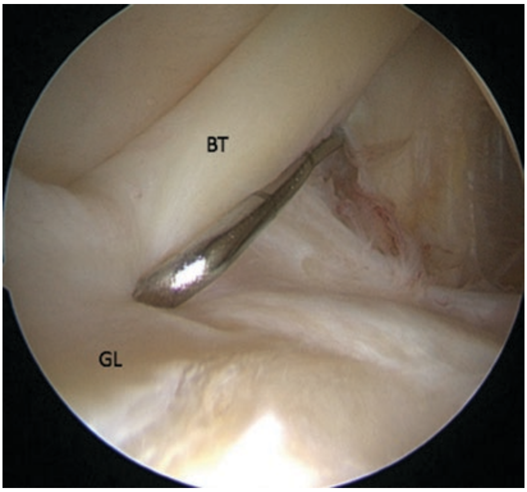

Fig. 10.1 Right shoulder, lateral decubitus position view through a standard posterior viewing portal with a 30 degree arthroscope. Probe is entering through an anterior rotator interval portal and demonstrates the normal relationship of the biceps tendon (BT) to the superior glenoid labrum (GL). Note the lack of displacement of the superior labrum and biceps anchor on the superior glenoid despite probe

Blood supply to the tendon is chiefly from the brachial artery by means of the anterior humeral circumflex artery. The portion of the tendon within the groove is supplied by a branch of the anterior humeral circumflex artery. This vessel provides perfusion to the most proximal part of the tendon in a retrograde fashion [14].

Notably, the arterial supply to the underlying supraglenoid tubercle is largely absent, particularly in the anterior superior quadrant, and no vessel from the proximal end supplies the superior labrum or biceps tendon [14, 15]. This vascular anatomy has significant biologic implications in SLAP repair where the relatively avascular tissue is secured to the poorly perfused quadrant of the glenoid bone with suture anchors (Fig. 10.2).

Neurologically, Alpantaki et al. [16] demonstrated a rich plexus of sympathetic fibers supplying the biceps anchor and a relatively less innervated pattern more distally. The presence of sympathetic fibers in pathologic conditions was confirmed with immunohistochemical studies [17]. These findings

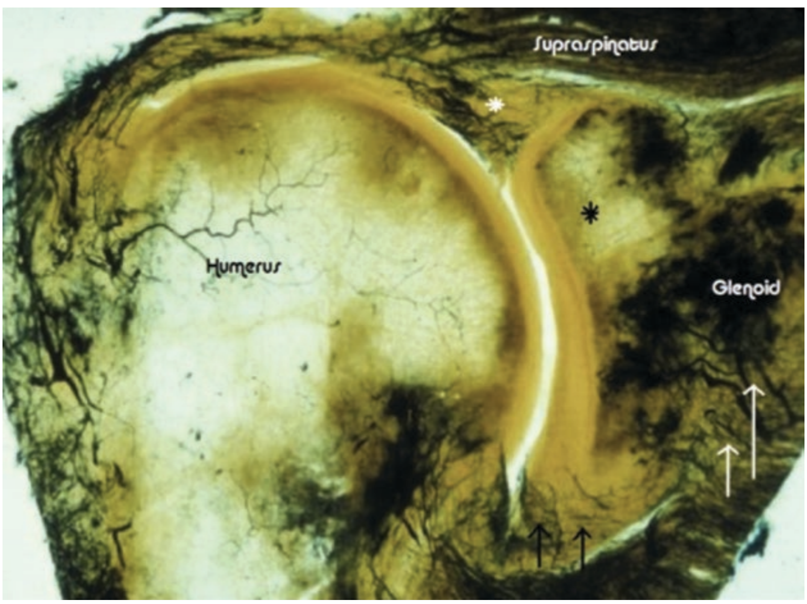

Fig. 10.2 Mid coronal section of the glenohumeral joint demonstrating the avascular area of superior glenoid bone (black asterisk) and superior glenoid labrum (white asterisk) compared to the inferior glenoid bone and labrum (white and black arrows respectively). Note that the cartilage extends superiorly beyond the articulating glenoid surface preventing communication of vessels in this region and contributing to the generally poor vascularity. (Photo courtesy of Dr. S. Arnoczky, DVM)

support the role of the biceps tendon as a potential pain generator in the shoulder.

Surprisingly, the presence of proprioceptive fibers has not been confirmed [18]. The presence of pain fibers in the absence of proprioception may explain the vague nature of the pain often described by patients with LHBT pathology and their difficulty in localizing the source of discomfort accurately.

Soft tissue restraint of the LHBT in the glenohumeral joint is provided by the biceps sling, or pulley, which is composed of tissue surrounding the rotator interval. This structure is relevant to surgical treatment of the LHBT as it is the primary restraint to medial dislocation of the tendon [19]. This pulley structure is composed of fibers of the superior glenohumeral ligament (SGHL), the coracohumeral ligament (CHL), and parts of the subscapularis tendon. It is intimately related to both the subscapularis and supraspinatus tendons as well as the superior capsule [20] (Fig. 10.3).

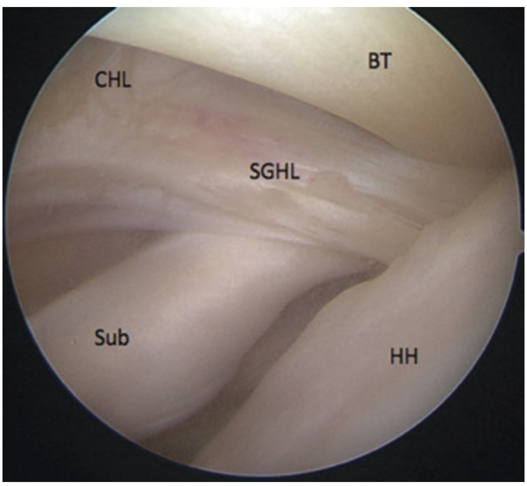

Fig. 10.3 Right shoulder, beach chair position view through a standard posterior viewing portal with a 30 degree arthroscope. The anatomy of the biceps pulley sling is demonstrated. The coracohumeral ligament (CHL) and the (SGHL) ligament provide resistance to displacement of the intraarticular biceps tendon (BT). The subscapularis tendon (Sub) is seen inserting on the lesser tuberosity. The humeral head (HH) is visualized. More laterally the supraspinatus tendon (not illustrated in this image) prevents posterior and lateral displacement of the tendon

More distally the biceps groove is covered by a transverse ligament which provides a secondary role in stabilization of the tendon; however, dislocation of the biceps tendon has been noted in specimens where the transverse ligament is intact. Conversely, complete transection of the transverse ligament does not lead to biceps dislocation in the setting of an intact rotator cuff.

Relevant osseous anatomy includes the bony groove itself which has a higher medial ridge formed by the lesser tuberosity and a lower lateral ridge formed by the anterior border of the greater tuberosity. The relationship of the groove to the humeral epicondylar axis is a consistent 45° and can be used as a landmark in establishing version in the setting of a proximal humerus fracture treated with arthroplasty. The groove has an opening angle of 30–40° into the glenohumeral joint which is consistent with reports regarding the course of the biceps tendon in the setting of an intact biceps pulley [21]. The medial wall angle (meaning the angle formed by the bottom of the groove and the top of the medial wall) is constant in apes but varies in a human which probably represents a varying degree of physiologic adaptation to throwing [4]. This angle has been inversely correlated to likelihood of biceps dislocation.

Function

The shoulder joint is one of the most morphologically labile structures in the fossil record following the evolution of our species. In a clear case of form following function the steady shift from brachiating hominids to bipedal hominids to modern homosapiens is marked by a steady change in shoulder anatomy [22].

In quadruped species the biceps tendon is still attached at the labrum and supraglenoid tubercle but takes a direct course into the groove and down the axis of the forelimb such that it is an effective elevator of the arm in the forward plane. In primates, the course of the tendon is progressively more oblique with humans developing the most oblique course [4]. This angle has been inversely correlated to likelihood of biceps dislocation. This adaptive position subjects the tendon to stress and creates potential for impingement and degenerative change of the tendon as it changes course before entering the intertubercular groove.

The biceps tendon is theorized to have been a source of storage of potential energy in the shoulder. This adaptation allowed forceful throwing motion which in turn allowed hunting and incorporation of animal proteins into the hominid diet. This expanded the range of early hominids and may have facilitated the diaspora from Africa – or so the theory goes [23].

Multiple older biomechanical studies have suggested a role of the long head of the biceps tendon as a depressor of the humeral head, and this has long been propagated as fact [24, 25]. However, in vivo studies using radiographs have failed to reproduce these findings [26, 27]. Electromyography studies by Sakurai et al. [28] have shown no activation of the biceps tendon when the elbow is immobilized. Thus, the direct function of the biceps tendon in humans remains uncertain. As discussed later, the loss of biceps tendon function due to either traumatic rupture or through iatrogenic means seems to leave little functional impairment in most patients calling further into question the purpose of the LHBT in the native anatomic state.

Clinical Presentation and Diagnosis of LHBT Lesions

History

Biceps tendon pain most commonly presents as exertional anterior shoulder pain. There is often no specific history of trauma. Because the pain can radiate to the deltoid origin it can be difficult to distinguish from rotator cuff tendonitis or glenohumeral pain from an intraarticular source such as a labral tear, subtle glenohumeral instability, or degenerative joint disease. In cases of biceps tendon subluxation or rupture there may be a history of a discrete pop which is heard or felt. Both subluxation and rupture are commonly associated with traumatic or degenerative changes of the rotator cuff, particularly the anterior aspect of the supraspinatus and the upper portion of the subscapularis.

In the case of SLAP lesions, a history of repetitive overhead activities is common and may be associated with vague posterior shoulder pain over the area of the posterior deltoid and rotator cuff which is exacerbated with activity and improved with rest. Patients often complain of being unable to sleep on that shoulder, unable to reach behind i.e. into the backseat of a car, unable to perform military press during weight-lifting.

Physical Examination

As is the case with the history, the examination of the biceps is confounded by the associated structures in close proximity.

Direct palpation of the biceps tendon is best performed with the arm in slight internal rotation and by placing the examiners fingers just lateral to the coracoid process and the palpable divot formed by the glenohumeral joint. Because of the relationship of the biceps tendon to the humeral shaft this same position should become less tender with larger angles of internal and external rotation. It is worth noting that tenderness to direct palpation is more specific to pathology of the extraarticular biceps tendon and may not be present in the setting of SLAP tear or lesions of the biceps anchor.

Provocative tests for biceps tendonitis have been shown to be of generally low sensitivity and specificity, Hegedus et al. [29]; and the same is true for SLAP tears [30]. Regardless, the most common tests for the distal biceps are Speed's test and Yergason's sign; for SLAP tears O'Brien's test is the most frequently described.

Speed's test can be performed with the patient seated with the arm in 90° of forward elevation, the elbow extended, and the arm fully supinated. The examiner provides downward pressure on the hand while the patient resists. The reported sensitivity for this test has been described as 90% but with a specificity of only 13% [31].

Yergason's sign is present when pain is reproduced in the anterior shoulder with resisted supination of the elbow with the arm at the side and the elbow at 90°.

These tests were reviewed by Holtby and Razmjou [32] in a level one diagnostic study who found while both had reasonable specificity, they did not generate a large change in the posttest probability and therefore were useful in preoperative diagnosis and decision making.

O'Brien's test is performed with the patient seated with the arm in slight adduction, forward elevation to 90°, and full pronation of the forearm with the elbow extended. Again, the examiner provides downward force while the patient resists. The arm is then fully supinated and the test is repeated. The test is positive when the pain is recreated in pronation and relieved in supination. Since the development of this classic test a variety of new tests have been described in an effort to improve diagnostic accuracy. Unfortunately, no single test has demonstrated a consistent diagnostic reliability [33] (Fig. 10.4).

Often a combination of tests, provide the most reliable method of diagnosis. It is helpful to first test the opposite arm for comparison. Do not allow the patient to torque their body or scapula to compensate or lean on something with their other arm during testing of the affected limb.

Imaging

In the absence of reliable history and physical exam findings, diagnostic imaging can play a significant role. Unfortunately, most studies have demonstrated limitations of common imaging modalities.

X-Ray Plain radiographs are normal in the setting of SLAP tears and biceps tendinopathy. Specialized views have been described to visualize the biceps groove, but the relevance of groove morphology to pathologic conditions of the tendon remains unclear [34, 35]. A standard screening series of plain radiographs including anteroposterior in external rotation (AP), Grashey AP (oblique with internal rotation), scapular Y, and axillary lateral are still useful as a screening tool to identify other sources of shoulder pain.

Ultrasound More recently, ultrasonography has emerged as a common tool for diagnosis of biceps tendon pathology. The advantages are the study can be performed in the office, performed dynamically with patient cooperation, is non-invasive, and is less expensive than MRI. Armstrong et al. [36] confirmed the utility of ultrasound for diagnosis of lesions of the LHBT in the groove including subluxation, rupture, or dislocation, but noted its inability to diagnose intraarticular partial thickness tears and SLAP tears.

Fig. 10.4 Physical Examination for Biceps Tendon Pathology (**a**) O'Briens Test- arm is in 90 degrees of forward elevation and 10 degrees of adduction with the elbow extended and forearm pronated. Examiner applies downward pressure. (**b**) O'Briens Test continued-maintain position of the shoulder and supinate the forearm. Examiner again applies downward pressure. Improvement in pain with supination suggests SLAP tear or lesion of the biceps anchor. (**c**) 'Speed's' test – Arm is positioned in 90 degrees of forward elevation, 30 degrees of abduction, and full supination. Examiner applies downward pressure. Pain in the shoulder anteriorly suggests biceps tendon pathology without specificity towards the biceps anchor or groove

Ultrasound is highly user dependent and a learning curve exists for achieving competency. Studies on rotator cuff tears have suggested that with experience, surgeons can achieve a high degree of diagnostic accuracy comparable to magnetic resonance arthrography (MRA); however, studies specific to biceps tendon pathology are lacking [37, 38].

Magnetic Resonance Imaging (MRI) MRI has evolved to become the advanced imaging modality of choice for the diagnosis of a multitude of musculoskeletal pathologies. Advances in medical technology have improved the quality of imaging and specific sequences have been developed to increase diagnostic accuracy. The addition of contrast, MRA, has increased the clinician's ability to detect SLAP lesions [39].

Unfortunately, in multiple comparisons of MRI to arthroscopy, MRI has been shown to incompletely evaluate the LHBT for pathology. Malavolta et al. [40] demonstrated a sensitivity of MRI of only 67% for complete tears [41]. The ability to identify more subtle lesions such as fraying, partial tearing, or degeneration is probably even more limited. The correlation between LHBT lesions and rotator cuff tears has been well established, and MRI is very useful for diagnosis of associated pathology. Thus, MRI is a useful but incomplete screening tool for both SLAP lesions and lesions of the LHBT itself (Fig. 10.5).

It is not uncommon for an MRI and even an MRA report stating "Normal Labrum and Biceps" demonstrate clear pathologic changes during diagnostic arthroscopy. The shoulder surgeon needs to have an index of suspicion based on the history and physical exam and explain to the patient a dynamic arthroscopic examination is still the gold standard to diagnose lesions of the LHBT and SLAP tears. When preoperative diagnostic studies are unclear, it is encouraged to initiate non-surgical treatment with rest, modification of activity, physical therapy, medication etc. If pain persists, it can be useful to apply a Single Assessment Numeric Evaluation (SANE) rating. Even in the face of a normal MRI, if the patient states the affected shoulder is 50 or below out of 100, after reasonable non-operative treatment, surgery is a rational option.

Arthroscopy Direct arthroscopy is typically the gold standard used in studies comparing other

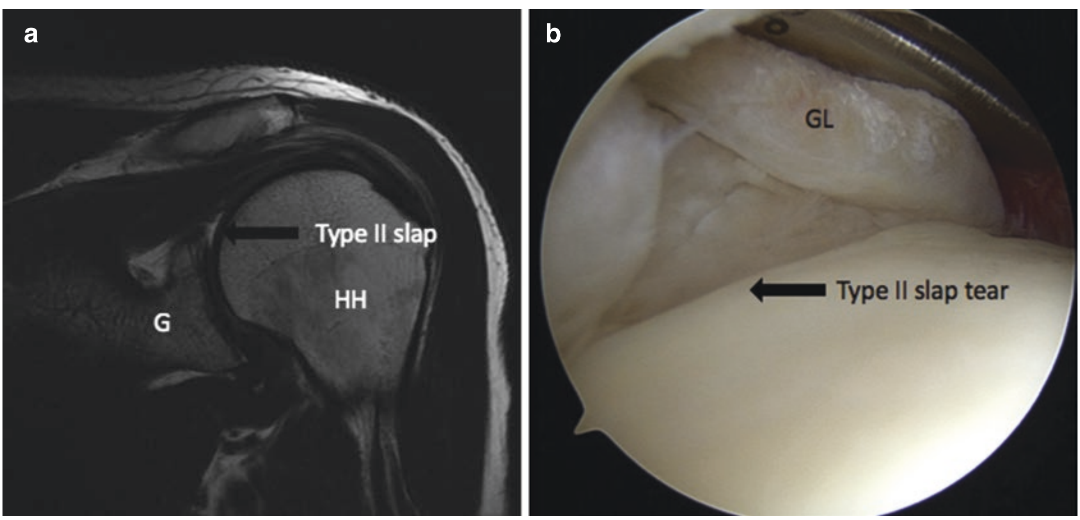

Fig. 10.5 (**a**) Coronal T2 MRI arthrogram image of a type II SLAP lesion (black arrow). Note the contrast medium extending between the superior aspect of the glenoid labrum and the superior labrum. Glenoid (G) and humeral head (HH). (**b**) Corresponding arthroscopic image of type II SLAP lesion in the same patient. Left shoulder, lateral decubitus position view with a 30 degree arthroscope in a standard posterior viewing portal demonstrates clear displacement of the superior glenoid labrum (GL) and biceps anchor by probe

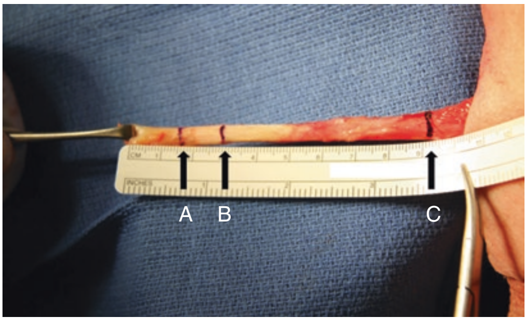

Fig. 10.6 In vivo gross examination of right shoulder biceps tendon after arthroscopic tenotomy in preparation for open subpectoral biceps tenodesis. The proximal tendon end is held in the Alice clamp in the lefthand portion of the image. (**a**) Indicates portion of tendon visualized arthroscopically. (**b**) Indicates portion of tendon visualized arthroscopically with assistance of arthroscopic grasper. (**c**) Myotendinous junction

modalities. Our group, Gilmer et al. [8], evaluated arthroscopy in evaluation of LHBT lesions in patients undergoing biceps tenodesis. We identified that only approximately only 32% of the biceps tendon is evaluated arthroscopically even with use of an arthroscopic probe. Furthermore, arthroscopy only identified 67% of pathology that was identified by open examination during tenodesis (Fig. 10.6).

In summary, no single diagnostic tool has clearly been identified for definitive diagnosis of all lesions of the LHBT. A combination of history, physical exam, advanced imaging, and even arthroscopy is necessary to fully evaluate the LHBT anchor and distal tendon.

Treatment of the LHBT Lesions

The treatment of LHBT pathology lies along a spectrum ranging from simple debridement to tenotomy, to one of the multitude of procedures developed for tenodesis. The decision to perform a tenodesis versus primary SLAP repair has evolved over recent years as the rate of SLAP repair has declined in response to disappointing outcomes in some patient populations. The location of tenodesis remains a topic of controversy as does the debate between arthroscopic versus open techniques.

Tenotomy One of the simplest techniques described for treatment of LHBT is simple arthroscopic tenotomy.

The patient is in the beachchair or lateral position. After the patient is prepped and draped, a standard posterior viewing portal is placed. As the arthroscope is placed into the glenohumeral joint, identification of a lesion of LHBT is confirmed. A spinal needle is used to identify the anterior portal and then an incision made in the skin. A switching stick is used to enter the glenohumeral joint in the superior anterior portion. Dilators are used and an arthroscopic scissor is introduced. The LHBT is then cut at the origin of the biceps anchor cutting the LHBT but leaving the labral attachment intact. This is a biceps tenotomy and can be done very quickly from an arthroscopic standpoint.

Some authors have advocated simple debridement of the LHBT. The procedure is performed as above but an arthroscopic shaver is introduced through the anterior portal and the lesion is debrided to a stable base (Fig. 10.7).

Arthroscopic SLAP Repair A SLAP repair can be done in the beachchair or lateral position. After the patient is prepped and draped in sterile fashion a posterior viewing portal is placed into the glenohumeral joint. The arthroscope visualizes the superior labrum and identifies a SLAP tear. This typically involves a lesion of the labrum including the biceps anchor, occurring more commonly posterior to the biceps anchor versus anterior. An anterior portal is made at the level of the biceps tendon. A cannula is placed with a minimum of a 7 mm diameter. A shaver is introduced and the labrum is debrided and the bone of the superior glenoid is also carefully debrided and prepared for repair.

The senior author's preference is to use a percutaneous technique for repair of the superior labrum. A percutaneous insertion kit will include a long spinal needle that allows an obturator to be placed and then a dilator followed by a cannula which has a minimum of 4.7 mm inner diameter, and a 5.4 mm outer diameter. This is placed at the anterior superior to posterior portion of the lateral aspect of the acromion (depending on the posterior extent of the lesion). Once the cannula

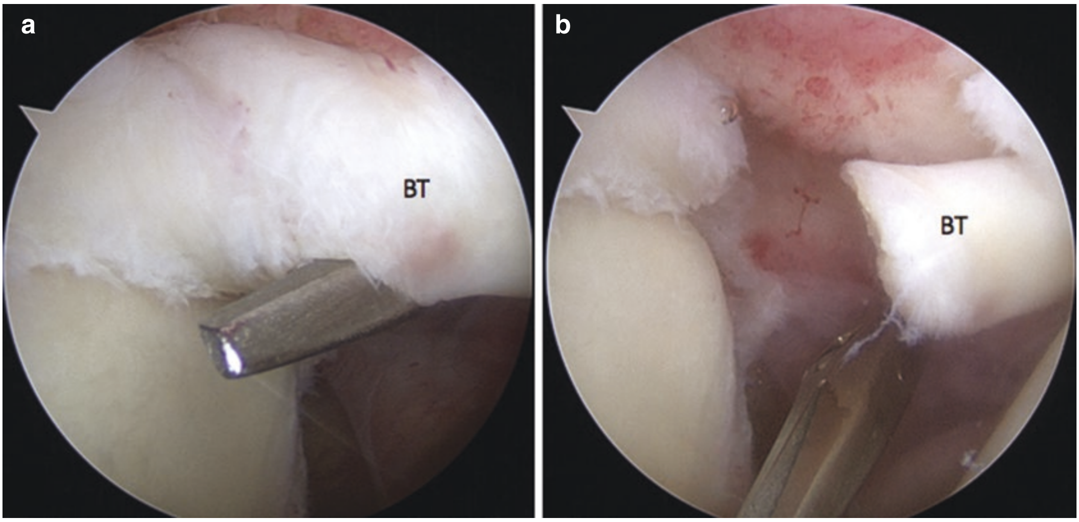

Fig. 10.7 Arthroscopic image demonstrating technique for biceps tenotomy. Right shoulder, beach chair position view through a posterior viewing portal with a 30 degree arthroscope. (**a**) An arthroscopic scissor is visualized entering through a standard anterior rotator interval portal. The biceps tendon (BT) is surrounded just distal to its origin from the superior labrum. (**b**) The biceps tendon (BT) has been truncated and released completely by the arthroscopic scissor

is placed using a percutaneous technique, a 45° curved lasso-type device is used through the anterior cannula, to pass suture around the posterior aspect of the labrum superiorly and posterior to the biceps anchor. In a right shoulder the 45° curved lasso suture passing instrument is curved to the left and vice versa. A suture can be passed that can be either cinched or a tape could be passed around the labrum either in a simple fashion or in a mattress fashion with a second pass using the lasso-type device. This suture having been passed through the labrum is then docked in the anterior portal. A drill is then used through the percutaneous cannula to drill into the glenoid superiorly at approximately the 11 o'clock position. The drill is then removed. The suture and/or tape is then brought out through the percutaneous placed cannula, it is loaded onto a 2.9 mm push lock anchor. In a knotless technique, the anchor is impacted into the previously drilled hole at approximately the 11 o'clock position and the first anchor/suture repair of the SLAP repair is completed. A second identical repair can be placed at approximately the 10 o'clock position and if needed, anterior to the biceps anchor. It is important to not strangulate the biceps anchor and tendon. The knotless technique is preferred because some surgeons have reported the knots from SLAP repairs can cause cartilage or rotator cuff damage (Fig. 10.8).

Sub-Pectoral Biceps Tenodesis For a sub-pectoral biceps tenodesis, the LHBT is first tenotomized arthroscopically. The correct location for the incision is identified by abducting the arm which makes the inferior border of the pectoralis major tendon easily palpable. The incision is made just lateral to the axilla extending from the inferior border of the pectoralis major distally approximately 2 cm. An incision is made through the skin then subcutaneous tissue. The pectoralis major is identified and retracted superiorly. The biceps groove is palpated and the fascia is carefully released. The LHBT is identified, having been previously released at its origin, is pulled carefully out of the incision. It is critical to protect the neurovascular structures and avoid dissection medially. Starting at the musculotendinous junction of the LHBT, a looped suture with a straight needle is used to whipstitch the tendon. Approximately

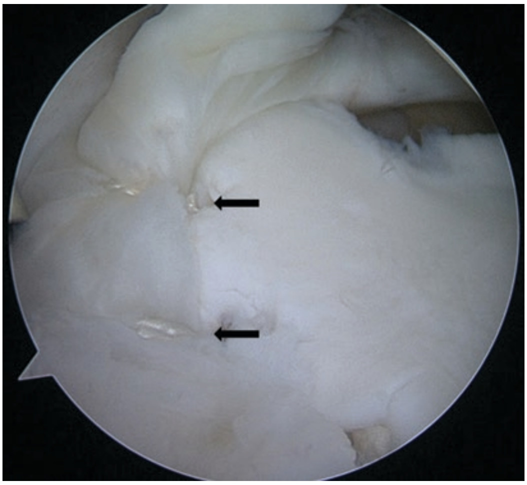

Fig. 10.8 Arthroscopic image demonstrating final construct after SLAP repair using a knotless technique. Right shoulder, lateral decubitus position view through a posterior viewing portal with a 30 degree arthroscope. Note placement of two anchors (black arrows) posterior to the biceps anchor. Note the absence of anchors or capsular imbrication anterior to the biceps tendon in the anterosuperior quadrant. Fixation in this location can lead to postoperative stiffness and pain

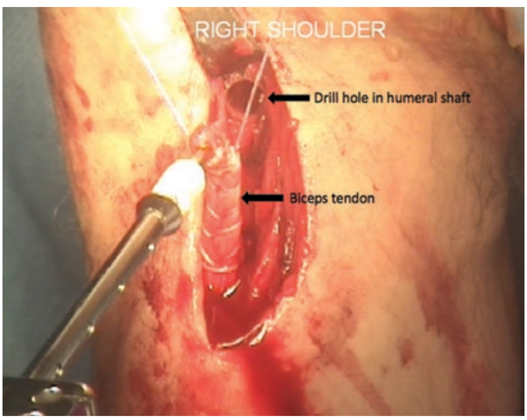

Fig. 10.9 Open view, right shoulder in preparation for subpectoral biceps tenodesis with interference screw. The biceps tendon has been whip-stitched along its course and a unicortical hole has been drilled in the humeral shaft in the subpectoral location corresponding to the anatomic location of the musculotendinous junction

five throws are placed with the second to last throw being a locking stitch. The remaining portion of the tendon may be excised. A method of fixation is then selected (Fig. 10.9).

Sub-Pectoral Biceps Tenodesis: Biotenodesis Screw Technique The screw technique involves cutting the wire from the straight needle and keeping the loop on the whip-stitched suture. Approximately 1.5–2 cm of the proximal portion of the long head of the biceps tendon is removed which allows return of the correct length tension relationship.

By marking the musculotendinous junction at the sub-pectoral region on the humerus prior to pulling the tendon from it's position in the groove allows the surgeon to plan where to cut the tendon after whip-stitching to restore the correct length tension relationship. Using a screw assumes approximately 1.5 cm of tendon will be placed into the humerus along with the screw in an interference technique.

Retractors are used to expose the bicipital groove just inferior to the pectoralis major. Once identifying the correct location, a drill is placed into the proximal humerus in the area of intertubercular groove at the sub-pectorally unicortically. Once a unicortical drill has engaged the humerus, a reamer is used to enlarge the hole depending on the size of the screw; commonly an 8 × 23 screw is used. Measurement of the length of the screw can be confirmed using another guide pin after the unicortical first pin has been placed. A wire is then used to place the looped suture through the cannulated tenodesis screw. Then using a biotenodesis screw technique with a screw handle and paddle, the screw with the tendon is placed into the proximal humerus to complete the tenodesis of the LHBT. If there is any laxity noted or if additional reinforcement is desired, a limb of one suture can be placed using a free needle back through the tendon to adjust for tension and strength. Arthroscopic knot tying technique is employed to complete the repair and then subcutaneous closure and skin closure are completed.

Sub-Pectoral Biceps Tenodesis: Unicortical Button Technique For the unicortical button technique, a tenodesis button 8.5 mm long is used which has angled edges to promote a toggle effect when the button contacts the humeral far cortex allowing it to flip unicortically.

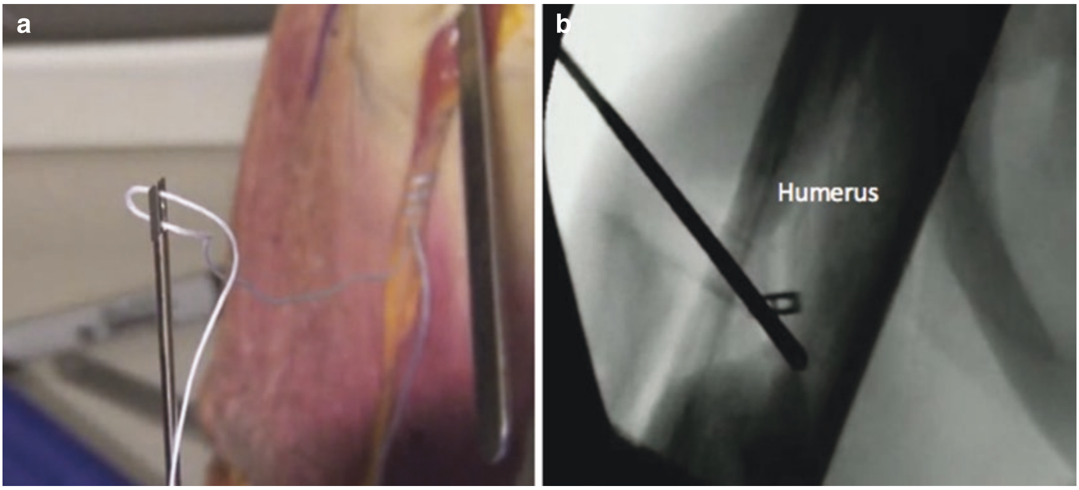

Fig. 10.10 Open view, right shoulder in preparation for subpectoral biceps tenodesis with unicortical button. (**a**) Suture from the previously prepared biceps tendon is passed through the button. (**b**) Intraoperative fluoroscopic image confirming intramedullary placement of the button

After whip-stitching the suture the proximal LHBT is then cut as described above. Using a button assumes the tendon will be placed onto the humerus, and therefore more tendon is excised in this technique than the interference screw technique. Having marked the humerus prior to displacing the tendon again allows for restoration of the correct length tension relationship.

The two ends of the suture are looped through the button. One limb is placed proximally and distally and then distally and proximally with the other limb. A drill is then used to make a unicortical hole in the humerus approximately 1 cm above the inferior border of the pectoralis tendon using a 3.2 mm drill pin. A drill guide can be used to protect the soft tissues. The button is then inserted with a special insertion device to allow the button to make contact with the far cortex. Then by unthreading the button from the inserter and turning counterclockwise and simultaneously pulling on the sutures gently, the button is flipped in the canal and the inserter is removed. Fluoroscopy can be used to confirm the button deployment. The suture limbs are then pulled to reduce the tendon onto the humerus and once the tendon is fully reduced a free needle can be used to pass one limb of the suture through the tendon and knots are tied to complete the repair. Similar soft tissue closure (Fig. 10.10).

Rehabilitation

Tenotomy The rehabilitation for a biceps tenotomy is immediate range of motion with no restrictions. Once pain free and full range of motion is regained, a gentle strengthening program may be initiated. A postoperative sling is not required.

SLAP Repair After SLAP repair a postoperative sling is utilized for approximately four weeks. For the first three weeks, active biceps exercises are prohibited. Gentle range of motion is allowed with table slides and passive motion to approximately 90° of forward flexion and internal/external rotation as tolerated. Over the next three to six weeks, passive range of motion progresses to full motion. Once passive motion has been restored, active biceps motion is then initiated with no resistance. At six weeks a strengthening program is initiated for the rotator cuff and biceps followed by a gradual return to throwing sports occurring over the next two to three months.

Tenodesis After a biceps tenodesis, whether it is using a screw or button the patient is placed in a sling for at least six weeks. The patient is encouraged to remove the sling at least three to five times a day and work on passive and active-assisted (without resistance) range of motion of the elbow and shoulder. Active biceps exercises begin at approximately three to four weeks. After six weeks biceps strengthening is initiated.

Importantly, rehabilitation will often be influenced by concomitant procedures such as rotator cuff repair. In those cases, the range of motion and strengthening may be advanced more carefully.

Outcomes

Tenotomy Most authors agree that tenotomy provides good pain control but cramping and weakness are common. Boileau et al. [42] described cramping in 62% of those treated with tenotomy but according to their report "none were bothered by it".

The other primary concern with tenotomy is the development of a clinical deformity caused be retraction of the biceps muscle belly distally, the so-called Popeye deformity. In one series 70% had a Popeye sign and 38% had fatigue discomfort with resisted elbow flexion but most had good pain control improvements [43].

SLAP Repair Results after SLAP repair, while initially encouraging, have been brought into question over time. Recently there has been a trend away from SLAP repair, especially in certain patient populations [44].

Most studies comparing SLAP repair to tenodesis are limited by a selection bias as younger patients and overhead athletes tend to receive SLAP repair over tenodesis. Despite this limitation results have been conflicting.

Gupta et al. [45] and Ek et al. [46] retrospectively compared the cases of 10 patients who underwent SLAP repair (mean age, 32 years) and compared them to 15 who underwent biceps tenodesis (mean age, 47 years). There was no significant difference in outcome scores.

By contrast, in another study of isolated type II SLAP lesions, 60% of patients were dissatisfied with the results of SLAP repair versus a 93% satisfaction rate among patients undergoing tenodesis. Dissatisfied patients after SLAP repair reported persistent pain and failure to return to previous level of sport. In total 13 patients (87%) were able to return to their previous levels of sports participation following biceps tenodesis, compared with only 20% after SLAP repair. Furthermore, four patients with a failed SLAP repair were revised to biceps tenodesis and reported successful return to previous level of sports activity [47].

Failure of SLAP Repairs Provencher et al. [48] found that 36.8% had problems postoperatively and were unable to return to work or sports successfully. Provencher also discovered that patients greater than 36 years of age had a high-risk for failure.

Using American Shoulder and Elbow Surgeons (ASES) scores (<75), return to full military duties and no need for revision procedures to mark successful cases, the investigators found that 66 patient (36.8%) had failures. Of these, 50 patients failures opted for corrective surgery including 42 patients who underwent biceps tenodesis, four patients had biceps tenotomy and four patients required debridement.

Age was a major factor in whether the repair was successful. The mean age in the failures was 39 years; successes were 29 years. There was no association with etiology, smoking history or preoperative outcome scores.

Waterman et al. [49] studied a similar population of 192 patients with two year follow up and found 37% of patients reported some level of activity-related shoulder pain and 16% were described as failures. Among the failures those revised to biceps tenodesis had a 76% return to activity versus 17% with revision SLAP repair.

Denard et al. [50] reviewed isolated type II SLAP lesions in patient's older than 35 years of age and found equivalent results for postoperative ASES, University of California, Los Angeles (UCLA) and SANE ratings. However, full range of motion recovery was delayed by approximately three months in the repair group compared with the tenodesis group and two patients in the repair group required a secondary capsular release. They concluded that individuals greater than 35 years of age with an isolated type II SLAP lesion had a shorter postoperative recovery, a more predictable functional outcome, a higher rate of satisfaction and return to activity with a biceps tenodesis compared to those who had a biceps repair.

Given the tenuous blood supply, the uncertain function of the intraarticular LHBT, the exponential difference in recovery time, and the marginal outcomes for some patient populations, it is not surprising that there is a trend towards SLAP repair only in younger and more active patients while expanding the relative prevalence of primary tenodesis.

The young, overhead throwing athlete remains the most compelling candidate for SLAP repair as it restores native anatomy while biceps tenodesis does not. Chalmers et al. [52] recently described motion analyses with simultaneous surface electromyography measurements in 18 baseball pitchers. Of these 18 players, seven were uninjured (controls), six were pitching after SLAP repair, and five were pitching after subpectoral biceps tenodesis. There were no significant differences between controls and postoperative patients with respect to pitching kinematics. Interestingly, compared with the controls and the patients who underwent open biceps tenodesis, the patients who underwent SLAP repair had altered patterns of thoracic rotation during pitching. However, the clinical significance of this finding and the impact of this finding on pitching efficacy are not currently known [45].

Werner et al. [51] confirmed that biceps tenodesis was a successful treatment after failed SLAP repair.

Considering the superior results, shorter rehabilitation, and uncertain functional changes in high level throwing athletes as well as the fact the tenodesis appears to be an effective treatment in the revision of the failed SLAP repair, it is reasonable to consider whether tenodesis should be the treatment of choice in the management of the primary SLAP tear in all populations. Unfortunately, high quality studies are not currently available to definitively answer this questions.

Tenodesis The high rates of deformity prompted development of techniques for restoring the length tension relationship of the biceps. Techniques using screws or buttons are the most common and have shown good outcomes ([53, 54], and [55]). Despite similar subjective reports, tenodesis has reported supination peak torque is better preserved with tenodesis over tenotomy [56].

Concern about proximal humerus fracture due to the large size of the drill hole required for some tenodesis screw fixation prompted development of unicortical and bicortical button techniques that required smaller drill holes [57]. Clinical results of this technique are still pending publication.

Location of Tenodesis More proximal tenodesis of the biceps lends itself to arthroscopic techniques; however, the primary argument against arthroscopic suprapectoral tenodesis is that lesions of the biceps groove may not be treated as effectively. Moon et al. [58] found that in approximately 80% of the intra-articular biceps tears evaluated in their study, a "hidden lesion" was observed going beyond the bicipital groove and extending to the distal extra-articular portion. Therefore, the subpectoral portion may be considered the optimal tenodesis site for the complete removal of all hidden biceps lesions.

Despite this, Millett et al. [55] showed that many patients complain of groove tenderness despite technically successful biceps tenodesis.

To date, most studies reviewing this question support equal clinical results for supraspinatus or subpectoral tenodesis and a systematic review has supported this finding, citing 98% good to excellent results for both techniques [59]. Others have confirmed arthroscopic biceps tenodesis performed at the articular margin results in a low surgical revision rate, a low rate of residual pain, and significant improvement in objective shoulder outcome scores [60].

Fixation Methods Golish et al. [61] found biceps tenodesis with interference screw fixation has been shown to be superior to placing a suture anchor and tying the tendon to the bone itself. However, other authors have demonstrated equivalent biomechanical properties for all fixation techniques except a simple bone tunnel technique [62].

Use of a unicortical button has been validated as a reasonable alternative to a screw and has the potential advantage of a smaller drill hole in the humerus [63]. Indeed, it may be superior to screw fixation as in one small cadaveric study intramedullary cortical button fixation showed no failure during cycling testing while interference screw fixation had a 30% failure rate [64].

Complications

Complications of biceps tenotomy as described above are cramping, strength deficits in elbow flexion and supination, and cosmetic deformity which can be common.

Complications after SLAP repair include recurrent SLAP tear, failure of SLAP repair, continued pain, stiffness, decreased throwing velocity, adhesive capsulitis, and inability to return to previous level of sport [65, 66].

Complications after subpectoral biceps tenodesis have been reported around 2% and can include deep infection, hardware failure, reflex sympathetic dystrophy, neurologic injury, and persistent bicipital pain [67].

While uncommon, proximal humerus fracture has been described after subpectoral tenodesis. Euler et al. [68] performed a biomechanical analysis and determined laterally eccentric malpositioned biceps tenodesis caused significant reduction in humeral strength and concluded that concentric screw placement and a smaller screw size would minimize this risk (Fig. 10.11).

The use of a bicortical button in a suprapectoral location results in instrumentation in close proximity to the axillary nerve where it lies posterior to the posterior cortex of the humerus. Therefore, an intramedullary button fixation is preferred in this area. In the subpectoral location, unicortical or bicortical fixations are safe as long as the direction of drilling is perpendicular to the axis of the humerus [69, 70].

Fig. 10.11 X-ray image demonstrating proximal humerus fracture through prior subpectoral tenodesis drill hole (black arrow)

Summary

The role of the LHBT complex in shoulder pain is well established. However, anatomic and functional questions remain. Diagnosis of lesions of the LHBT requires a thorough history and combination of physical exam maneuvers. No single diagnostic test is confirmatory in all cases.

In the setting of continued or severe shoulder dysfunction surgical treatment of LHBT pathology should be considered. Treatment options include tenotomy, SLAP repair, and one of a myriad of forms of tenodesis.

Recovery after SLAP repair can be prolonged, complicated by postoperative stiffness, and may result in not returning to their previous level of sport. As such, the role and frequency of biceps tenodesis as a primary treatment for all LHBT complex disorder is expanding.

Further research is required to compare primary biceps tenodesis in a young active population of throwing athletes to primary SLAP repair.

Clinical Pearls

- Patients with SLAP tears often complain of being unable to sleep on that shoulder, unable to reach behind i.e. into the backseat of a car, unable to perform military press during weight-lifting.
- Often a combination of physical exam tests provides the most reliable method of diagnosis. It is helpful to first test the opposite arm for comparison. Do not allow the patient to torque their body or scapula to compensate or lean on something with their other arm during testing of the affected limb.
- It is not uncommon an MRI and even an MRA report stating "Normal Labrum and Biceps" demonstrate clear pathologic changes during diagnostic arthroscopy. The shoulder surgeon needs to have an index of suspicion based on the history and physical exam and explain to the patient that a dynamic arthroscopic examination is still the gold standard to diagnose lesions of the LHBT and SLAP tears. When preoperative diagnostic studies are unclear, it is encouraged to initiate non-surgical treatment with rest, modification of activity, physical therapy, medication etc. If pain persists, it can be useful to apply a SANE rating. Even in the face of a normal MRI, if the patient states the affected shoulder is 50 or below out of 100, after reasonable non-operative treatment, surgery is a rational option.
- By marking the musculotendinous junction at the sub-pectoral region on the humerus prior to pulling the tendon from it's position in the groove allows the surgeon to plan where to cut the tendon after whipstitching to restore the correct length tension relationship. Using a screw assumes approximately 1.5 cm of tendon will be placed into the humerus along with the screw in an interference technique.
- SLAP repair results in lower return to previous level of activity, requires a longer recovery, and has inferior outcomes in patients over 35 years of age when compared to biceps tenodesis.
- Results of arthroscopic suprapectoral and open subpectoral biceps tenodesis appear to be equivalent.

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