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Biceps Tendon Dislocation and Instability

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Introduction

The long head of the biceps brachii tendon (LHBT) is a common source of pain in the shoulder. Biceps tendon pathology is often associated with rotator cuff (RC) pathology. The spectrum of LHBT injuries includes primary and secondary tendinitis, chronic tendinopathy, superior labrum anterior and posterior (SLAP) lesions, instability, and partial or complete ruptures.[1][2]

Anatomy

The LHBT origin, on average, is 9 cm in length.[3] The tendon is widest at its labral origin, which is primarily posterior about 50% of the time.[4] In 20% of cases, the origin is directly at the supraglenoid tubercle, and the remaining 30% of the time its origin is seen as a combination from the 2 sites.[5] The tendon itself is intra-articular yet extra-synovial, and it progressively gets narrower as it passes obliquely from its origin and heads toward the bicipital groove. As it exits the distal bicipital groove in the upper arm, the LHBT joins the short head of the biceps tendon (SHBT) as both transitions into their respective muscle bellies in the central third of the upper arm. After crossing the volar aspect of the elbow, the biceps brachii inserts on the radial tuberosity and medial forearm fascia. The latter occurs via the bicipital aponeurosis.[4]

Pain Generation

The LHBT is a well-recognized source of anterior shoulder pain. Mechanical causes include repetitive traction, friction, and glenohumeral rotation. The bicipital sheath itself is vulnerable to tenosynovial inflammation by association as it is contiguous with the synovial lining of the glenohumeral joint.[6] The upper one-third of the LHBT demonstrates a rich sympathetic innervation network including neuropeptides such as substance P and Calcitonin gene-related peptide. These factors are present in the sensory nerves in this region of the tendon. This sympathetic network is known to exhibit vasodilatory changes as part of the neurogenic inflammatory process in the LHBT, which may play a critical role in at least the chronic phase of pathophysiology affecting the LHBT.[7][8][9]

The Bicipital Groove

The bicipital groove is an anatomic landmark that sits between the greater and lesser tuberosities, and its osseous and soft tissue components contribute to the inherent stability of the LHBT. The depth, width, and medial wall angle have been studied in relation to overall bicipital groove stability, with significant variability recognized in its components. Many authors attribute these parameters as predisposing factors to pain and instability in both primary and secondary LHBT pathologies.[10][11]

The Soft Tissue Pulley System

The LHBT takes a 30-degree turn as it heads toward the supraglenoid tubercle, relying on the integrity of the enveloping soft tissue sling/pulley system. The most important elements in maintaining stability at this critical turn angle are the most medial structures at the proximal-most aspect of the groove's exit point. The soft tissue components of the biceps pulley system include the following[12]:

- Subscapularis
- Supraspinatus
- The coracohumeral ligament (CHL)
- The superior glenohumeral ligament (SGHL)

The subscapularis has superficial and deep fibers that envelope the groove, creating the "roof" and "floor," respectively. These fibers also coalesce with those from the supraspinatus and SGHL/CHL complex. These structures attach intimately at the lesser tuberosity to create the proximal and medial aspect of the pulley system, with soft tissue extensions serving to further envelope the LHBT in the bicipital groove.

The CHL is a dense fibrous structure connecting the base of the coracoid process to the greater and lesser tuberosities. At its origin, the ligament is thin and broad, measuring about 2 cm in diameter at the base of the coracoid. Laterally, the CHL separates into 2 distinct bands that envelope the LHBT at the proximal extent of the bicipital groove. Once the LHBT exits the groove, it takes a 30- to 40-degree turn as it heads toward the supraglenoid tubercle and glenoid labrum. Thus, the proximal soft tissue elements of the groove are especially critical for the overall stability of the entire complex. In addition to the CHL, the SGHL reinforces the complex at this proximal exit point. The SGHL travels from the superior labrum to the lesser tuberosity, becoming confluent with the soft tissue pulley as it takes on a U-shaped configuration. Warner and colleagues previously demonstrated that the cross-sectional area of the CHL is, on average, 5 times larger than that of the SGHL.[13][14]

Some authors have argued that the CHL is just a thickening of the anterosuperior glenohumeral capsule, while others maintain that the CHL is a unique entity. Advocates supporting the CHL as a distinct anatomic structure cite its role as an important stabilizer to inferior humeral head translation in the adducted shoulder.[15] In addition, studies investigating pathologic changes seen in association with recalcitrant adhesive capsulitis acknowledge the presence of a thickened CHL as the primary source of limitations to the external and internal rotation. Its thickness appears to correlate directly with decreasing degrees of external rotation.[16]

The Transverse Humeral Ligament

Historically, the transverse humeral ligament (THL) was thought to play a primary role in bicipital groove stability. However, more recently, its role in stability has been refuted with many authors questioning its existence as a distinct anatomic structure. The latter remains fairly controversial, with most studies now reporting the THL is, at most, a continuation of fibers from the subscapularis, supraspinatus, and CHL. A histologic study in 2013 identified a distinct fibrous fascial covering in the "roof" of the groove. Neurohistology staining showed the presence of free nerve endings but no mechanoreceptors.[17] Despite the controversial evidence with respect to its definitive existence as an anatomic structure, its location at the distal extent of the bicipital groove inherently refutes the previous dogma of its potential role in LHBT stability. Furthermore, the presence of free nerve endings in the recent histological studies suggests its possible role as a potential pain generator in the anterior shoulder.[17]

Biomechanics

Biomechanically, the LHBT has a controversial role in the dynamic stability of the shoulder joint. It has been demonstrated, mostly in biomechanical cadaveric-based studies and animal models, that the tendon at least plays a passive stabilizing role in the shoulder. Neer proposed in the 1970s that the LHBTs stabilizing role varied depending on the position of the elbow. Several subsequent studies refuted the theory that the LHBT played any active shoulder stabilizing effect.[18] Jobe and Perry evaluated the activation of the biceps during the throwing motion in athletes. The authors reported the peak muscle stimulation occurred in relation to elbow flexion and forearm deceleration, with very little proximal biceps activity during the earlier phases of throwing.[19][20][21][22]

In most normal, healthy patient populations, the LHBT plays a negligible role in the dynamic stability of the shoulder. The general consensus with respect to its overall function is that it is a strong forearm supinator, but a weak elbow flexor.[23]

Etiology

Proximal biceps pathology encompasses 3 pathologic categories:

- Biceps instability
- Inflammatory conditions
- Traumatic pathologies

Biceps Instability

Medial subluxation/dislocation of the LHBT can occur with repetitive mechanical wear, overuse, or acute trauma. While the osseous dimensions of the bicipital groove contribute to the stability of the LHBT, the most important stabilizers are the SGHL, CHL, and the interwoven fibers of the subscapularis and supraspinatus. The SGHL/CHL complex and the subscapularis fibers are intimately coalesced at the lesser tuberosity, serving an integral role as the medial and proximal portion of the soft tissue sling as part of the bicipital groove pulley system. Injury to one, a combination, or all of these components can lead to LHBT instability. Frequently, these structures can avulse from the tuberosity and remain attached to one another in the setting of varying degrees of instability.[24]

Inflammatory Conditions

Biceps tendonitis describes a clinical condition of inflammatory tenosynovitis most commonly affecting the LHBT as it travels within the bicipital groove in the proximal humerus. Chronic pathology results in tendinosis and eventually, severe tendinopathy.

Inflammatory pathologies are often secondary in nature due to the high prevalence of associated or preceding shoulder pathologies. In the 1970s, Neer demonstrated that the proximal biceps tendon is subjected to the same mechanical compressive forces under the coracoacromial arch as the rotator cuff. Thus, he noted their high degree of pathological association. In 1982, Neviaser demonstrated the relationship between increasing LHBT inflammatory changes with severity of rotator cuff (RC) injury and tendinopathy. Other associated shoulder pathologies include shoulder impingement (external or internal) and glenohumeral arthritis.[4][18][25]

Primary bicipital tendinitis is much less common compared to secondary cases. The etiologies for primary bicipital tendinitis are not well understood compared to the more common secondary presentations. A particular subset of patients with primary, isolated biceps tendinitis is recognized in the younger, athletic population. Provocative sports include baseball, softball, and volleyball. Various medical conditions can cause intrinsic degeneration of the tendon, potentially leading to spontaneous rupture. End-stage degenerative LHB tendinopathy can result in spontaneous rupture and resulting “Popeye” deformity in the upper arm.[26]

Traumatic Pathologies

Traumatic pathologies can overlap with instability spectrum. Conditions include superior labrum anterior to posterior

(SLAP) lesions, partial versus complete ruptures, and injury secondary to direct or indirect trauma.[27] The latter injuries would include partial or complete lacerations from a penetrating object or weapon, and indirect damage can occur to the tendon in various fracture patterns at the proximal humerus.[28]

Rupture of the tendon usually occurs at either the musculotendinous junction or the LHBT origin near the supraglenoid tubercle. Just as in cases of LHB tendinitis, most ruptures occur in association with other shoulder pathologies. The most common cause of secondary LHBT rupture is rotator cuff injuries. The pathophysiology of secondary rupture is appreciated due to the loss of the protective role of the rotator cuff in protecting the LHBT from the coracoacromial arch. Primary LHBT rupture occurs at a similar rate to its primary LHB tendinitis counterpart pathology, about 5% of all total cases in each group.

Epidemiology

LHBT instability almost always occurs in association with other shoulder pathologies. In the chronic stages of LHBT tendinopathy, the soft tissue pulley system can become compromised, which can eventually lead to LHBT subluxation and/or dislocation. While this would be the closest clinical entity considered as primary LHBT instability, the consensus in the literature attributes LHBT instability to primary injury to the soft tissue pulley system (including the subscapularis and/or supraspinatus), or secondary to proximal humerus fractures that compromise the osseous integrity of the bicipital groove itself.[27][29]

Pathophysiology

Instability Cascade

Osseous and soft tissue anatomic variables can influence the inherent stability of the LHBT and soft tissue pulley system. Compromise to the soft tissue pulley system can be found in at least 4 different types of lesions. As early as the 1920s, soft tissue injury sequences have been proposed by various investigators and shoulder surgeons.

The exact sequence of events leading to LHBT instability varies based on the multitude of variables including individual patient anatomy, LHBT integrity at the onset of symptoms or injury, and the degree and chronicity of concomitant shoulder pathology. The exact sequence of injury is not as important as understanding how the injured structures factor into bicipital groove complex stability. In 2004, Habermeyer and colleagues identified 4 different subtypes of soft tissue injury groups. These types were similar to those described by Braun and colleagues, also noting 4 different types of soft tissue pulley lesions during shoulder arthroscopy.[3]

- *Type I:* SGHL lesion, isolated
- *Type II:* SGHL lesion and partial articular-sided supraspinatus tendon tear
- *Type III:* SGHL lesion and deep surface tear of the subscapularis tendon
- *Type IV:* SGHL lesion combined with a partial articular-sided supraspinatus and subscapularis tendon tears

Bennett's classification system subdivides biceps soft tissue pulley lesions into types I to V.[30]

- *Type I:* Intra-articular subscapularis injury
- *Type II:* Medial band of CHL incompetent
- *Type III:* Subscapularis and the medial band of the CHL are both compromised; LHBT dislocates intra-articularly, medially
- *Type IV:* A lateral band of CHL along with a leading-edge injury of the subscapularis; Can lead to LHBT

dislocation anterior to the subscapularis

- *Type V:* All soft tissue pulley components are disrupted

Walch classified biceps pulley lesions based on the observed LHBT instability pattern.[31]

- *Type I:* SGHL/CHL injury; Superior LHBT subluxation at the proximal groove entrance; Subscapularis remains intact, preventing frank LHBT dislocation
- *Type II:* At least partial subscapularis injury is seen in association with the onset of pathology; Medial LHBT subluxation or dislocation
- *Type III:* Secondary to proximal humerus fracture; usually a lesser tuberosity fracture that is prone to malunion or nonunion

Walch popularized the term "hidden" rotator interval lesions to describe the presence of LHBT instability in the presence of an intact subscapularis muscle. The inciting injury involves compromise to the articular side of the supraspinatus tendon, with tear propagation leading to subsequent injury and compromise to the SGHL/CHL complex, specifically the medial band of the CHL. In this specific soft tissue injury sequence, the LHBT will be located anterior to the intact subscapularis muscle.

A recent study investigated concomitant bicipital groove soft tissue injuries in patients presenting with an injury to the subscapularis. The authors noted about 10% of patients maintained LHBT stability during arthroscopic examination and direct visualization. Those patients that remained stable demonstrated a maintained pulley system via the SGHL/CHL complex. However, the authors reported varying degrees of macroscopic tendinosis and partial fraying in all patients in their study. It is reasonable to conclude that in the presence of an injury to the subscapularis, all patients will have a corresponding macroscopic lesion of the LHBT.[24]

In the setting of at least a partial injury to the subscapularis muscle, medial LHBT subluxation can further compromise the soft tissue complex and stability. Pathologic contact can occur between the LHBT and the subscapularis on its articular side. Pathologic stress and shear forces are highest at the vulnerable critical 30-degree turning point as the tendon proximally exits the groove to head toward the labrum. Habermeyer advocated for the SGHL/CHL complex injury as essentially a mandatory pre-requisite in the setting of frank dislocation of the LHBT medially.[5]

This far into the instability cascade, patients will often report "popping" or "locking" sensations in the anterior shoulder with various shoulder movements. In the setting of anterosuperior instability patterns, associated SLAP tear patterns can be seen in association.[32]

Overhead Throwing

During an overhead throw, such as pitching in baseball, the thrower's shoulder is brought into a position of maximum shoulder abduction and external rotation during the late cocking phase. Biceps injuries occur in this position secondary to the peel-back phenomenon. The term "thrower's shoulder" implies a pathologic constellation of anatomical changes during shoulder development, including GIRD and humeral head retroversion compared to the contralateral extremity. Posterior capsular contractures are often present, altering the point of maximal contact forces during overhead throwing. The articular side of the supraspinatus tendon abuts between the greater tuberosity and the posterosuperior labrum. Significant shear forces cause the soft tissue pulley system to become injured.[27]

Subcoracoid Impingement

Subcoracoid impingement, defined as pathologic abutment of the subscapularis tendon between the coracoid process and lesser tuberosity, has also been described as a possible reason of degeneration of the soft tissue pulley sling and subscapularis tendon insertion. Narrowing of the coracohumeral interval, in other words, the distance between the humeral head and the coracoid tip, is related to LHB and rotator cuff abnormalities.[33]

Histopathology

Currently, the degree of histologic severity of LHBT disease states does not correlate with the degree of pathology demonstrated on either MRI or from direct intra-operative inspection. Furthermore, other studies suggest that the duration of symptoms does not correlate with histologic severity. In addition, the more proximal zones of the LHBT (i.e., the intra-articular and bicipital groove portions) consistently demonstrate higher histologic grades of tendinopathy compared to tissue specimens examined from more distal LHBT zones.[34]

Grading

While histologic grading of the severity of tendinopathic changes remains separate from the clinical presentation and MRI and/or intra-operative findings, there are some noteworthy pathologic patterns associated with increasing grades of severity of tendinopathy.[34][35]

Grade 0

- Tenocytes are normal in appearance
- Myxoid degenerative material not present
- Collagen remains arranged in tight, cohesive bundles
- Blood vessels arranged inconspicuously between collagen bundles

Grade I

- Tenocytes are rounded
- Myxoid degenerative material present in small amounts between collagen bundles
- Collagen remains arranged in discrete bundles, but a slight separation between bundles becomes apparent
- Capillary clustering is evident (less than 1 cluster per 10 high-power fields)

Grade II

- Tenocytes are rounded and enlarged
- Myxoid degenerative material evident in moderate to large amounts
- Collagen bundles lose discrete organization as the separation between individual fibers and bundles increases
- Capillary clustering is increased (1 to 2 clusters per 10 high-power fields)

Grade III

- Tenocytes are rounded and enlarged with abundant cytoplasm and lacuna
- Myxoid degenerative material abundant
- Collagen disorganized, loss of microarchitecture
- Capillary clustering is increased (greater than 2 clusters per 10 high-power fields)

Other Changes Associated with Tendinopathy

Tenosynovium

- Irrespective of histologic grade of tendinopathy, the surrounding bicipital sheath/synovium demonstrates varying degrees of synovial hypertrophy, hyperplasia, and proliferation

Low-Grade Degenerative Tendinopathy

- Total cellularity (cell density, cells/ mm): Minimal increase
- Apoptotic index (percent relative to total number of cells counted): Minimal increase

Moderate Grade Degenerative Tendinopathy

- Total cellularity (cell density, cells/ mm): Peak increase
- Apoptotic index (percent relative to total number of cells counted): Moderate increase

Severe Grade Degenerative Tendinopathy

- Total cellularity (cell density, cells/ mm): Decreases
- Apoptotic index (% relative to total number of cells counted): Peak increase

Histologic studies have consistently reported that irrespective of patient age, the severity of symptoms, and duration of symptoms, acute inflammatory changes are rarely evident upon histologic specimen analysis.

History and Physical

A comprehensive history should be acquired by clinicians evaluating patients presenting with acute or chronic shoulder pain. When assessing patients presenting with history/symptoms concerning for LHBT instability, it is important to evaluate for co-existing shoulder injuries or pathology clinically. Often, a thorough history taking of the mechanism of injury can aid the clinician in the preliminary differentiation between various shoulder pathologies. For example, AC joint pathology often presents secondary to acute trauma, with the patient reporting either trauma directly to the shoulder during a contact sport, or the patient may report a history of a fall directly onto the shoulder.

Characteristics of proximal biceps instability include:

- Patients often report painful “clicking” or audible “popping” noted with shoulder abduction, extension, and rotational movement of the shoulder. The patient often can reproduce this during the actual office visit.
- LHBT instability (or tendinopathy) often manifests as pain at the anterior aspect of the shoulder, with or without radiation down the anterior arm over the biceps brachii muscle belly

Other symptoms often related to LHBT pathology, although less specific for instability, include:

- Atraumatic, insidious onset of anterior shoulder pain; often acute or acute-on-chronic exacerbations
- Symptom exacerbation with overhead activities
- Pain at rest, pain at night
- History or current overhead sport participation

- History or current manual/physical laborer occupations

A thorough history includes a detailed account of the patient's occupational history and current status of employment, hand dominance, history of injury/trauma to the shoulder(s) and/or neck, and any relevant surgical history.

Cervical Spine/Neck Exam[36]

Co-existing cervical pathology, especially radiculopathy, should be ruled out in any situation where shoulder pathology is possible. Observation of neck posturing, muscular symmetry, palpable tenderness, and active/passive ROM should be evaluated. Special tests that are helpful in this regard include Spurling's maneuver, myelopathic testing, reflex testing, and a comprehensive neurovascular exam. The clinician should assess bilateral upper extremity motor exam and sensory testing, testing both components for the respective C5 through T1 nerve distributions.

Shoulder Exam[37][38][39][40][41]

Clinicians should observe the overall shoulder girdle to assess symmetry, shoulder posturing, and overall muscle bulk and symmetry. Scapular winging should also be ruled out. The skin should be checked for the presence of any previous surgical incisions, lacerations, scars, erythema, or induration. In the setting of proximal biceps pathology, especially in traumatic or spontaneous LHB tendon ruptures, patients will typically exhibit significant ecchymosis in the upper arm over the area of the biceps brachii muscle itself, and an associated "Popeye" deformity is characteristic for a complete rupture. The latter is more readily appreciated in fit or thin patients and can be a rather subtle finding in patients with a large body habitus. Comparison to the contralateral extremity is helpful.

After the observations mentioned above, the active and passive ROM is documented. In the setting of both primary and secondary proximal biceps tendinitis cases, full ROM should be observed. In the absence of advanced glenohumeral arthritic changes affecting, limited passive ROM is considered diagnostic for adhesive capsulitis.

Provocative Examinations

Proximal Biceps Provocative Testing[42]

There is a multitude of focused physical examination maneuvers reported in the literature. Specific testing targets either LHBT pathology localized to the bicipital groove, or more proximally near its origin at the supraglenoid tubercle.

Bicipital groove palpation: Direct palpation over the patient's bicipital groove elicits a painful response in the setting of pathology.

Speed's test: A positive test consists of pain elicited in the bicipital groove when the patient attempts to forward elevate the shoulder against examiner resistance; the elbow is slightly flexed, and the forearm is supinated.

Uppercut test: The involved shoulder is positioned at neutral, the elbow is flexed to 90 degrees, the forearm is supinated, and the patient makes a fist. The examiner instructs the patient to perform a boxing "uppercut" punch while placing his or her hand over the patient's fist to resist the upward motion. A positive test is pain or a painful pop over the anterior shoulder near the bicipital groove region.

Yergason's test: The arm is stabilized against the patient's trunk, and the elbow is flexed to 90 degrees with the forearm pronated. The examiner manually resists supination while the patient also externally rotated the arm against resistance. A positive test is noted if the patient reports pain over the bicipital groove and/or subluxation of the LHB tendon.

Dynamic tests for bicipital groove symptoms:

- The examiner brings the patients shoulder to 90 degrees of abduction and 90 degrees of external rotation. The examiner passively rotates the shoulder at this position in an attempt to elicit the patient-reported audible "popping" or "clicking" sensations. Sometimes passively maneuvering the shoulder from the extension to cross-body plan is helpful in eliciting instability symptoms.

- At the 90/90 shoulder abduction/external rotation position, the patient is asked to "throw forward" while the examiner resists this forward motion. A positive test for groove pain must be localized to the anterior aspect of the shoulder to enhance diagnostic sensitivity and specificity.

Proximal biceps pathology is often associated with concomitant shoulder pathologies. Thus, it is important to differentiate the primary sources of patient-reported pain and symptoms clinically. Other important, provocative testing categories include the AC joint, the glenohumeral labrum, and rotator cuff muscles. The latter includes special consideration for subscapularis given the common pathological associations.

AC Joint Provocative Testing[43]

Observation and direct palpation: Patients presenting with chronic AC joint pain and/or arthritic pathology often will have clinically obvious AC joint hypertrophy that can be appreciated solely with observation and/or direct palpation over the joint.

Cross-body adduction: The examiner may find it helpful to directly localize the AC joint with direct palpation before initiating any shoulder movement. Subsequently, the examiner brings the shoulder into about 90 degrees of flexion in front of the plane of the scapula, and a positive test includes patient-reported symptom reproduction as the arm is brought into cross-body adduction positions. The physician should be able to discern the exact location of pain reproduction with the cross-body adduction maneuvers.

Superior Labrum Anterior-Posterior (SLAP) Lesions

O'Brien's test/Active compression test: The patient is standing, and the arm of interest is positioned at 90 degrees of forward flexion, 10 degrees of adduction, and internally rotated so the thumb points toward the floor. The examiner places his or her hand over the patient's elbow while instructing the patient to resist the examiner's downward force applied to the arm. This maneuver is repeated with the patient's arm now rotated, so the palm faces the ceiling. A positive test is denoted by pain located at the joint line during the initial maneuver (thumb down/internal rotation) in conjunction with reported improvement or elimination of the pain during the subsequent maneuver (palm up/external rotation).

Anterior slide test: The patient stands with his or her hand of the involved arm placed on the ipsilateral hip with the thumb pointing posteriorly. The examiner places one hand on the joint line of the shoulder and the other hand on the elbow. The examiner then applies an axial load in an anterosuperior direction from the elbow to the shoulder. A positive test includes pain or a painful click on the anterior or posterior joint line.

Modified O'Driscoll test/Modified dynamic labral shear test: The patient stands with his or her involved arm flexed 90 degrees at the elbow and the shoulder is abducted in the scapular plane to above 120 degrees. The examiner then applies terminal external rotation until resistance is appreciated. Next, the examiner applies a shear force through the shoulder joint by maintaining external rotation and horizontal abduction and lowering the arm from 120 to 60 degrees abduction. A positive test includes a reproduction of the pain and/or a painful click or catch in the joint line along the posterior joint line between 120 and 90 degrees of abduction.

Rotator Cuff Muscle Testing[39][44]

Supraspinatus (SS)

- Jobe's test: Positive test is pain/weakness with resisted downward pressure while the patient's shoulder is at 90 degrees of forward flexion and abduction in the scapular plane with the thumb pointing toward the floor.

- Drop arm test: The patient's shoulder is brought into a position of 90 degrees of shoulder abduction in the scapular plane. The examiner initially supports the limb and then instructs the patient to adduct the arm to the side of the body slowly. A positive test includes the patient's inability to maintain the abducted position of the shoulder and/or an inability to adduct the arm to the side of the trunk in a controlled manner.

Infraspinatus (IS)

- Strength testing is performed while the shoulder is positioned against the side of the trunk, the elbow is flexed to 90 degrees, and the patient is asked to externally rotate the arm while the examiner resists this movement.
- External rotation lag sign: The examiner positions the patient's shoulder in the same position, and while holding the wrist, the arm is brought into maximum external rotaions (ER). The test is positive if the patient's shoulder drifts into internal rotation (IR) once the examiner removes the supportive ER force at the wrist.

Teres Minor

- Strength testing is performed while the shoulder positioned at 90 degrees of abduction and the elbow is also flexed to 90 degrees. Teres minor (TM) is best isolated for strength testing in this position while the examiner resists ER.
- Hornblower's sign: The examiner positions the shoulder in the same position and maximally ERs the shoulder under support. A positive test occurs when the patient is unable to hold this position, and the arm drifts into IR once the examiner removes the supportive ER force.

Subscapularis

The high rate of associated pathologies with the LHBT and the subscapularis (SubSc) makes the subscapularis evaluation component significantly important in this clinical setting. The diagnosis of injuries to the subscapularis remains a challenge in any setting of shoulder pathology. Multiple provocative maneuvers and special exams exist in the literature, with the bear-hug test being the most sensitive exam modality although it only boasts a 60% sensitivity rate:

- Bear-hug test: The patient places his or her hand on the contralateral (normal) shoulder in a “self-hug” position. The palm is on the anterior aspect of the contralateral shoulder with the elbow flexed to 90 degrees. The examiner applies a perpendicular external rotational force to try and lift the patient's hand off of the shoulder. A positive test results when the patient cannot hold the hand against the shoulder as the examiner applies an external rotation force.
- IR lag sign: The examiner passively brings the patient's shoulder behind the trunk (about 20 degrees of extension) with the elbow flexed to 90 degrees. The examiner passively IRs the shoulder by lifting the dorsum of the hand off of the patient's back while supporting the elbow and wrist. A positive test occurs when the patient is unable to maintain this position once the examiner releases support at the wrist (i.e., the arm is not maintained in IR, and the dorsum of the hand drifts toward the back)
- Passive ER ROM: A partial or complete tear of the SubSc can manifest as an increase in passive ER compared to the contralateral shoulder.
- Lift off test: More sensitive/specific for lower SubSc pathology. In the same position as the IR lag sign position, the examiner places the patient's dorsum of the hand against the lower back and then resists the patient's ability to lift the dorsum of the hand away from the lower back.

- Belly press: More sensitive/specific for upper subscapularis pathology. The examiner has the patient's arm at 90 degrees of elbow flexion, and IR testing is performed by the patient pressing the palm of his/her hand against the belly, bringing the elbow in front of the plane of the trunk. The examiner initially supports the elbow, and a positive test occurs if the elbow is not maintained in this position upon the examiner removing the supportive force.

External Impingement/SIS

- *Neer impingement sign:* Positive if the patient reports pain with passive shoulder forward flexion beyond 90 degrees.
- *Neer impingement test:* Positive test occurs after a subacromial injection is given by the examiner and the patient reports improved symptoms upon repeating the forced passive forward flexion beyond 90 degrees.
- *Hawkins test:* Positive test occurs with the examiner passively positioning the shoulder and elbow at 90 degrees of flexion in front of the body; the patient will report pain when the examiner passively internally rotates the shoulder.

Internal Impingement

- *Internal impingement test:* The patient is placed in a supine position, and the shoulder is brought into terminal abduction and external rotation; a positive test consists of a reproduction of the patient's pain.

Evaluation

Radiographic imaging should be obtained in all patients with acute or chronic shoulder pain.

Radiographs

Clinicians should obtain a true anteroposterior image of the glenohumeral joint also known as the "Grashey" view. The true anteroposterior image is taken with the patient rotated between 30 and 45 degrees offset the cassette in the coronal plane. The beam can otherwise be rotated while the patient is neutral in the coronal plane. The distance between the acromion and the humeral head, in other words, the acromiohumeral interval can be computed. A normal interval is between 7 and 14 mm. This interval decreases in cases of advanced degenerative arthritis and RCA. Other standard views include the lateral, or "scapular Y," view and an axillary view.

Ultrasound (US)

Ultrasound (US) is highly operator-dependent but is touted as a fast, cost-effective tool for diagnosing LHBT pathology. Characteristic findings include tendon thickening, tenosynovitis, and synovial sheath hypertrophy, and fluid surrounding the tendon in the bicipital groove. The ability to perform a dynamic examination increases the sensitivity and specificity for detecting subtle instability. The diagnostic accuracy of US in detecting LHB pathology ranges from 50% to 96% (sensitivity) and 98% to 100% (specificity) when compared to Magnetic resonance arthrography (MRA).

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is useful in evaluating the LHBT, bicipital groove, and any fluid or edema that may be indicative of pathology. MRI helps define other associated shoulder pathologies, and in the setting of LHBT instability, particular attention should be given to evaluating for concomitant subscapularis injury. Most of the previous studies that have investigated the accuracy of preoperative MRI scans have used open surgical approaches to correlate MRI with surgical findings.

Over 90% of subscapularis tendon injuries begin on the articular side. Therefore, it is important to correlate suspected

MRI pathology with direct visualization during shoulder arthroscopy. A 2010 study demonstrated that preoperative MRI interpretations (by radiologists) did not correlate with arthroscopic findings in the setting of suspected injury.[24]

MRI is useful in identifying the LHBTs position with respect to the bicipital groove. The absence of the tendon within the groove would suggest subluxation and/or dislocation. Given the relatively poor reliability of MRI capabilities in diagnosing subscapularis injuries, the presence of LHBT subluxation/dislocation has been advocated for diagnostic capability improved accuracy by association. A 2015 study by Warner and colleagues investigated 100 patients with shoulder pathologies, of which 26 were diagnosed with LHBT subluxation based on preoperative MRI. Results indicated that the presence of LHBT subluxation was a predictor for full-thickness subscapularis tears, with a sensitivity of 82%, specificity of 80%, the positive predictive value of 35%, and the negative predictive value of 97%. LHBT subluxation was directly correlated with the severity of the subscapularis tendon tear.[45]

Other associated shoulder pathologies and rotator cuff integrity can also be evaluated with MRI. Other common sources of acute or chronic shoulder pain can be evaluated on MRI, including subdeltoid and/or subacromial bursitis, acromioclavicular (AC) joint pathology and morphology. A systematic approach to review shoulder MRIs is essential, especially when tying the MRI findings with patient-reported symptoms and clinical examination.

MR Arthrography

Many studies have suggested MR arthrography (MRA) as the best imaging modality for the detection of biceps soft tissue pulley lesions. Walch previously described the “pulley sign” on MRA, suggesting a lesion to the soft tissue pulley structures. The “pulley sign” is an extra-articular collection of contrast material anterior to the upper subscapularis muscle. A 2012 study established MRA criteria for diagnosing biceps pulley lesions. The findings on MRA included[46]:

- LHBT displacement relative to subscapularis tendon on oblique sagittal series; Up to 86% sensitive, 98% specific
- LHBT tendinopathy on oblique sagittal image series; Up to 93% sensitive, 96% specific
- Medial LHBT subluxation on axial image series; Up to 64% sensitive, 100% specific
- Discontinuity of the SGHL; Up to 89% sensitive, 83% specific

Other pertinent MRA findings include contrast material extending to the coracoid, indicative of a potential lesion of the rotator interval. Recent studies have highlighted the importance of advanced imaging as well as diagnostic arthroscopy for evaluating for the presence, and extent of biceps soft tissue pulley injuries. Advancements in imaging and arthroscopic techniques have become increasingly important as the clinical examination is prone to equivocal results.

Treatment / Management

Nonoperative Management

The initial management of LHBT instability is nonsurgical. A period of rest and activity modification is beneficial in the acute setting, coupled with nonsteroidal anti-inflammatory drugs (NSAIDs). Most authors agree that especially in the setting of significant LHBT instability, especially in younger active patients involved in sports or manual laborers, surgical treatment is usually necessary.

Physical Therapy[4]

Successful physical therapy regimens target the underlying source(s) contributing to the LHBT pathology. For example, early instability in overhead athletes can be managed with earlier aggressive intervention focused on improving pitching/overhead throwing mechanics.

The physical therapist should recognize the concomitant shoulder pathologies as part of the entire constellation at presentation. LHBT pathology can be seen in association with GIRD in overhead athletes/baseball pitchers, poor trunk control, scapular dyskinesia, and internal impingement.

Strengthening protocols should focus on restoring muscle balance across the shoulder girdle, including rotator cuff and periscapular muscle strengthening programs. Focused stretching on the anterior shoulder structures, including pectoralis minor, should also be considered. Other modalities such as dry needling have demonstrated promise in preliminary animal studies.

Injections[47][48][49][48]

In the setting of most LHBT pathology, including potential subtle instability, injections represent a reasonable consideration in the nonoperative modality arsenal. There is some controversy with respect to the type of technique used (ultrasound [US]-guided versus blind injection) and exact location utilized for the injection (subacromial, intra-articular, bicipital groove/sheath). Theoretically, in the setting of concomitant shoulder pathologies, an intra-articular injection would also reach the LHBT in the bicipital groove, as the sheath is contiguous with the glenohumeral joint synovial tissue.

Direct injection is targeted to the sheath, and not the LHB tendon directly. Although not definitively documented, an intratendinous LHB tendon injection may predispose the patient to tendon rupture. In a 2011 randomized controlled trial (RCT) comparing injection accuracy (with post-injection CT imaging to confirm injection placement by location) of US-guided versus blind bicipital sheath injections at its location in the groove. Potential injection location results included (1) solely in the tendon sheath, (2) inside the tendon, in the tendon sheath, and surrounding (but outside) the tendon sheath, and (3) confined to only the area outside the tendon sheath. The US-guided injections resulted in 87% accuracy for injecting the tendon sheath alone (location "1"). By stark contrast, the blind injection was accurate only 27% of the time, and one-third of the time the tendon itself and the entire bicipital sheath was missed altogether.

Surgical Management

In most cases of true LHBT instability, either in isolation or the setting of associated shoulder injuries, nonoperative management often fails. Indications for surgical management include:

- Persistent symptoms despite a trial of attempted nonoperative management
- LHBT instability, including persistent subluxation and/or dislocation causing patient-reported pain and disability with desired activities
- Concomitant shoulder pathologies in the setting of LHBT instability including:
  - Partial-thickness tears of the LHB tendon (greater than 25% to 50%)
  - Biceps soft tissue pulley lesions (subscapularis, supraspinatus, SGHL/CHL complex)
- Lesser tuberosity injuries causing persistent LHBT instability and/or functional compromise
  - Includes a history of injury with malunion, nonunion, or acute avulsions

Surgical Techniques

Diagnostic Approach and Dynamic Exam[50]

After performing a standard diagnostic arthroscopy sequence, A 30-degree scope is advanced into the anterior compartment of the shoulder with attention on the soft tissue pulley components. The arm is internally and externally rotating to evaluate for the presence of any LHB instability or laxity of the soft tissue pulley. A probe is used to assist in the dynamic examination to assess LHBT instability, and additionally bringing the arm into forward elevation with rotation, the LHBT is evaluated for possible medial/inferior subluxation of the LHB tendon. In the setting of LHB tendon instability, this maneuver will lead to tendon entrapment within the joint. The entrapment is relieved with external rotation of the arm. The SGHL/CHL complex and the subscapularis are individually probed and inspected for the presence of any lesions.

The LHBT is then probed and pulled into the joint under traction, allowing for inspection of the proximal portion of the extra-articular tendon. The presence of tenosynovitis is often indicated by a "rush" of yellow synovial fluid emanating from the bicipital groove itself. The tendon itself is inspected for any fraying or peritendinitis.

The rotator cuff is assessed during shoulder motion. The subscapularis is inspected during dynamic internal rotation movement, and the supraspinatus is inspected during external rotation and abduction of the shoulder.

Biceps Tenotomy[51]

Arthroscopic inspection of the tendon allows for estimation of the relative percentage of the LHB tendon that is compromised. A popular classification system utilized for the intra-operative grade corresponding to the degree of LHB tendon macroscopic pathology is the Lafosse grading scale[52]:

- *Grade 0:* Normal tendon
- *Grade 1:* Minor lesion (partial, localized areas of tendon erosion/fraying, focal areas affect less than 50% of the tendon width)
- *Grade 2:* Major lesion (extensive tendon loss, compromising greater than 50% of the tendon width)

Some surgeons solely debride the tendon in the setting of less than 25% to 50% tendinous compromise. Arthroscopic biceps tenotomy is performed by releasing the tendon as close as possible to the superior labrum. As long as the tendon is free from intimate soft tissue adhesions to surrounding structures, the tendon should retract distally toward the bicipital groove. If adhesions are present, all efforts should be made to mobilize the tendon to allow for retraction following the tenotomy. In cases where the LHB tendon is particularly hypertrophic and scarred to other soft tissue structures in the joint, this serves as a potential source of postoperative pain.

Biceps Tenodesis[50][51][53][54]

- Recommended over tenotomy in the setting of LHBT instability
- Preferred technique in younger patients, athletes, laborers, and those patients specifically concerned with postoperative cosmetic ("Popeye") deformity
- Optimizes the length-tension relationship of the biceps muscle; mitigates the postoperative risk of muscle atrophy, fatigue, and cramping

Various locations for the tenodesis itself, in addition to the fixation technique used provide equivalent results in terms of patient satisfaction and clinical outcomes. In general, the purpose of a tenodesis procedure is to anchor the biceps tendon in a new location (i.e., out of the bicipital groove itself).

A spinal needle is used to "tag" the tendon near its entrance into the bicipital groove with fiberwire. Next, an arthroscopic cutter is used to release the intra-articular portion of the tendon close to its origin. The residual "stump" is shaved back to the superior labrum.

Next, the arthroscope is taken into the subacromial space, and the tagging sutures help localize the LHBT. A subdeltoid and subacromial decompression/bursectomy are performed as needed depending on the extent of bursal adhesions.

This step also helps with visualization.

Next, the bicipital groove is opened up with a cautery device at the distal extent of the groove. After the sheath is opened, the LHBT is visualized and mobilized. Various tenodesis sites and fixation components can be used (suture anchors, interference screws, bone tunnels). As the all-arthroscopic techniques are improved, most surgeons began advocating to utilize the suprapectoral region, distal to the bicipital groove, after debriding the soft tissue in the desired location between the subscapularis and pectoralis major. Care is taken to maintain the appropriate position to optimize the length-tension relationship. Once fixation is complete, any residual tendon that remains prominent from the fixation point is carefully resected.

An alternative to the all-arthroscopic tenodesis procedure is the open subpectoral approach. Several studies have compared outcomes between the 2 techniques, with most reporting equivalent results and patient-reported outcomes. An additional incision must be used, followed by removal of the LHBT entirely from the bicipital groove, and tenodesis fixation utilizing the options mentioned above. Again, attention is given to maintaining the appropriate length-tension relationship of the tendon fixation and tension on the biceps muscle belly.

Differential Diagnosis

Impingement

- External/SIS
- Subcoracoid
- Calcific tendonitis
- Internal (including SLAP lesions, glenohumeral internal rotation deficit (GIRD), Little league shoulder, posterior labral tears)

RC Pathology

- Partial- versus full-thickness tears (PTTs versus FTTs)
- RCA

Degenerative

- Advanced DJD, often associated with RCA
- Glenohumeral arthritis
- Adhesive capsulitis
- Avascular necrosis (AVN)
- Scapulothoracic crepitus

Proximal Biceps

- Subluxation: Often seen in association with SubSc injuries
- Tendonitis and tendinopathy

AC Joint Conditions

- AC separation
- Distal clavicle osteolysis
- AC arthritis

Instability

- Unidirectional instability: Seen in association with an inciting event/dislocation (anterior, posterior, inferior)
- Multidirectional instability (MDI)
- Associated labral injuries/pathology

Neurovascular conditions

- Suprascapular neuropathy can be associated with a paralabral cyst at the spinoglenoid notch
- Scapular winging: Medial or lateral
- Brachial neuritis
- Thoracic outlet syndrome (TOS)
- Quadrilateral space syndrome

Other Conditions

- Scapulothoracic dyskinesia
- Os acromiale
- Muscle ruptures (pectoralis major, deltoid, latissimus dorsi)
- Fracture (acute injury or pain resulting from long-standing deformity, malunion, or nonunion)

Prognosis

Patients with persistent, debilitating symptoms (including instability symptoms) in the setting of known proximal biceps tendon pathology are good surgical candidates for either a tenotomy or tenodesis procedure. In the setting of significant instability, including frank dislocation, proximal biceps tenodesis is preferred over tenotomy.

Comparing the 2two procedures in the setting of LHBT pathology, the literature demonstrates a high level of patient satisfaction and patient-reported pain and overall outcome scores at long-term follow-up. A 2017 study of greater than 100 patients that were 1-year out from surgical arthroscopy procedures with concomitant biceps tenotomy revealed that greater than 90% of patients were "satisfied" or "very satisfied" with their outcome. Also, 95% stated that they would have the same surgery again.[55] Similar positive results are demonstrated in studies following biceps tenodesis patients at long-term follow-up. The majority of reports have noted no appreciable difference between tenotomy and tenodesis patients with respect to elbow flexion and forearm supination strength recovery.[56]

Complications

The approximate rates of the most common postoperative surgical complications are as follows.

Biceps Tenotomy

- Cosmetic (“Popeye”) deformity
    - Reported rates during follow-up: 10% to 70%
    - Rates of patient dissatisfaction secondary to the deformity: Less than 5% to 10%
- Muscle spasm/cramping: 15% to 25%
- Biceps pain: 10% to 20%
- Residual weakness:
    - Mild: Up to 30%
    - Moderate to severe: 10% to 15%

Biceps Tenodesis

- Residual anterior shoulder/groove pain:
    - Currently heavily debated in the literature. Previous reports have documented as high as a 45% revision surgery rate for residual biceps/groove pain following biceps tenodesis[57]
    - A 2015 study from Burkhart and colleagues contrasted previous reports suggesting high revision surgery rates and postoperative persistent/residual groove pain following tenodesis procedures. Burkhart's study was a retrospective multicenter study reported follow-up results from 7 different surgeons performing an all-arthroscopic biceps tenodesis procedure[58]:
        - 1083 patients, mean follow-up of 136 weeks
        - Revision surgery rate: 4.1%
        - Revision related to complications or symptoms attributed to the actual biceps tenodesis: 0.4%
- Cosmetic (“Popeye”) deformity: 5% to 10%
- Muscle spasm/cramping: 5% to 10%
- Biceps pain: 5% to 10%

Postoperative and Rehabilitation Care

Postoperative Protocols

Biceps Tenotomy

Rehab Phases

- Sling use for 1 to 2 weeks
- Active ROM begins at 2 to 4 weeks postop; sling discontinued
- Strengthening starts at 4 to 6 weeks postoperatively

Return to Work/Activity

- Patients typically can resume light work by 3 to 4 weeks postop

- Depending on occupational demands, return to full duty ranges from 1 to 3 months after surgery
- Most patients return to unrestricted activities at 3 to 4 months postoperatively

Biceps Tenodesis

Rehab Phases

- Sling use for 3 to 4 weeks
- Initial period includes passive elbow ROM and grip strengthening
- Avoid resisted elbow flexion and forearm supination until about 6 weeks
- Goal of achieving full active and passive shoulder ROM by 6 weeks

Return to Work/Activity

- Patients typically can resume light work by 3 to 4 weeks postop
- Depending on occupational demands, return to full duty ranges from 2 months to 4 months from surgery
- Most patients return to unrestricted activities at 3 to 4 months postoperatively

Consultations

The majority of patients with LHB pathology can be managed nonoperatively. Consideration for referral should be in the setting of persistent pain/symptoms despite 6 to 8 weeks of nonoperative management. Referral for the appropriate physical therapy program focused on correcting any existing muscular imbalances about the shoulder girdle, including scapular dyskinesia.

A subtle caveat in clinical management is the young athlete or manual laborer presenting with symptoms primarily secondary to LHBT instability. In this situation, a brief trial of nonoperative management is reasonable, but early referral to an orthopedic surgeon should be considered in this setting.

Overall, referral principles include:

- Persistent/worsening symptoms despite PT/NSAIDs/activity modification/injections
- Diagnostic imaging confirming evidence of tendon subluxation and/or dislocation
- In the setting of either post-operative "Popeye" deformity, failed biceps tenodesis techniques, or spontaneous rupture, referral to a surgeon with experience in correcting the deformity should be considered

Deterrence and Patient Education

Patients should be educated on the possible etiologies and concomitant shoulder pathologies seen in association with proximal biceps pathologies. A point of emphasis should be given to including any LHBT pathology that may be seen in association with other known shoulder pathologies. For example, a patient should be not only educated on the injury affecting the rotator cuff itself, but also the potential for co-existing injury to the biceps tendon. A discussion should be had, especially with older patient populations, that the concomitant procedure to be planned (i.e., the tenotomy or tenodesis procedure) may or may not occur. In doing so, the patient's postoperative expectations can be adequately managed before performing surgery.

Enhancing Healthcare Team Outcomes

Long head of the biceps tendon (LHBT) pathologies spans a clinical spectrum, from acute tendinitis to chronic degenerative tendinopathy and spontaneous tendon rupture. In athletic populations, the physician must coordinate and work in tandem with his or her physical therapists to ensure the athlete's potential co-existing shoulder girdle risk factors are addressed appropriately. In throwers, it is critical to recognize that poor trunk control, scapular dyskinesia, shoulder girdle atrophy, and muscular imbalances all can contribute to the proximal biceps tendinitis. Thus, the comprehensive management of these injuries often involves head coaches and athletic trainers in the athletic populations, all the way to general practitioners, geriatricians, sports medicine primary care physicians, and orthopedic surgery sports medicine specialists.

Failed nonoperative management is an indication for proceeding with surgical treatment. Other indications for surgery include:

- Acute, primary, or associated LHBT instability and/or frank dislocation causing significant patient-reported pain and disability
- Partial-thickness tears of the LHB tendon (greater than 25 to 50%)
- LHB tendon subluxation/dislocation with associated bicipital groove soft tissue stabilizer injury; also may or may not include injuries to the subscapularis or supraspinatus muscle

The 2 most common surgical techniques employed include biceps tenodesis and biceps tenotomy procedures. The literature demonstrates equivalent outcomes between each type of procedure, and both techniques yield a high rate of patient satisfaction and clinical outcomes at long-term follow-up with each type of procedure.

(Level I)

Questions

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