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Long Head of the Biceps Tendon Pain: Differential Diagnosis and Treatment

The long head of the biceps tendon (LHBT) originates approximately 50% from the superior glenoid tubercle and the remainder from the superior labrum, with 4 different variations identified.⁷³ The proximal tendon is richly innervated, with sensory nerve fibers containing substance P and calcitonin gene-related peptide. These substances are responsible for vasodilatation and plasma extravasation, as well as transmitting pain. As the neural network progresses distally, it becomes more sparse.² The tendon receives its blood supply from the ascending branch of the anterior circumflex humeral artery, which travels along with the tendon in its groove in the proximal humerus. The proximal tendon receives some arterial supply from labral branches

of the suprascapular artery.³ Moving away from the origin, the tendon is encased in a synovial sheath and is, therefore, intra-articular yet extrasynovial, as it courses obliquely through the joint and arches over the humeral head.

As the LHBT then exits the joint and passes through the rotator interval to the intertubercular groove (often referred to as the bicipital groove), between the greater and lesser tuberosities, it is surrounded by a tendoligamentous sling. The coracohumeral ligament (CHL), superior glenohumeral ligament (SGHL), fibers from the supraspinatus, and fibers from the subscapularis are the major contributors to this sling.³⁴ The CHL arises from its broad, thin origin on the lateral coracoid base and then divides into 2 major bands. One band inserts into the anterior border of the supraspinatus and greater tuberosity, and the other inserts into the upper border of the subscapularis and lesser tuberosity.^{15,36} The SGHL arises from the labrum adjacent to the superior glenoid tubercle, travels as the floor of the rotator interval, and crosses under the LHBT forming a U-shaped sling before inserting into the lesser tuberosity. The SGHL seems to stabilize the LHBT against anterior shearing forces proximal to its entry to the groove. The subscapularis contributes fibers to the anterior/floor aspect of the sling while fibers of the supraspinatus insert into the posterior aspect of the roof.⁸¹

Once in the bicipital groove, the tendon passes under the transverse humeral

• **SYNOPSIS:** Though the role of the long head of the biceps tendon (LHBT) in shoulder pathology has been extensively investigated, it remains controversial. Historically, there have been large shifts in opinions on LHBT function, ranging from being a vestigial structure to playing a critical role in shoulder stability. Today, despite incomplete understanding of its clinical or biomechanical involvement, most investigators would agree that LHBT pathology can be a significant cause of anterior shoulder pain. When the biceps tendon is determined to be a significant contributor to a patient's symptoms, the treatment options include various conservative interventions and possible surgical procedures, such as tenotomy, transfer, or tenodesis. The ultimate treatment decision

is based upon a variety of factors, including the patient's overall medical condition, severity, and duration of symptoms, expectations, associated shoulder pathology, and surgeon preference. The purpose of this manuscript is to review current anatomic, functional, and clinical information regarding the LHBT, including conservative treatment, surgical treatment, and postsurgical rehabilitation regimens.

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ligament, which bridges the groove. This ligament is no longer believed to play a primary role in securing the biceps tendon, given that most of the stability is provided by the SGHL and CHL.^{6,65} The groove itself has a mean depth of 4.3 mm, with an average medial wall angle of 56°.¹⁶ After coursing through the groove, the LHBT joins the short head of the biceps to form the biceps muscle belly at the level of the deltoid insertion.

Function

The function of the LHBT at the shoulder is controversial and incompletely understood. Stretching from the scapula to the forearm gives it the potential to have function at both the shoulder and elbow. Its contribution to elbow flexion and forearm supination is well established; however, contradictory experimental proof about its function at the shoulder has left its role unclear.

Neer⁵³ proposed that the tendon served as a humeral head depressor and emphasized the importance of maintaining the tendon for shoulder stability. Andrews et al⁴ noted that electrical stimulation of the biceps during arthroscopy led to humeral head compression within the glenoid. Using a freely hanging arm cadaveric shoulder model, superior humeral migration was noted following LHBT tenotomy,⁴⁵ though these data have been difficult to interpret due to difficulties in reproducing physiologic tension in the remaining cadaveric shoulder girdle. Similarly, superior humeral migration during active abduction has been noted radiographically in patients with isolated LHBT tears when compared to their intact contralateral shoulders.⁷⁸

However, some evidence exists that refutes any major role of the biceps at the shoulder. In most patients with massive rotator cuff tears and absent LHBTs, either from rupture or surgery, superior migration of the humeral head is uncommon.³ Furthermore, based on electromyographic studies that have controlled for elbow motion, no long head of biceps muscle activity was measured during active shoulder motion in patients with in-

tact or torn rotator cuffs.^{46,83} Given vector analysis of the pull of the long head of the biceps, a humeral head depression role would be unlikely in most shoulder positions except in full external rotation.⁶⁵

Several biomechanical studies performed on cadavers have also examined glenohumeral joint stability in relation to the biceps tendon. Paganini et al⁵⁹ found contraction of the biceps to limit glenohumeral translation. Rodosky et al⁶³ showed that simulated contraction of the biceps increases the stability of the glenohumeral joint by increasing the shoulder's resistance to torsional forces in the combined abducted and externally rotated position. Additionally, injury to the biceps anchor results in increased strain on the inferior glenohumeral ligament and increases anteroinferior glenohumeral joint translation.⁵⁸

Though considerable evidence suggests that the biceps is not an active stabilizer of isolated shoulder motion, the LHBT may still contribute passively to glenohumeral stability. It is possible that the biceps serves more as a physical block to superior and anterior glenohumeral translation than as an active contractor against translation. Furthermore, activities that require coordinated shoulder and elbow motions may still receive active stabilization from the biceps. Finally, the proprioceptive influence of the LHBT on shoulder stability has yet to be studied.

Understanding the muscle activation patterns of the biceps during throwing motions can help treat the overhead athlete. Most overhead sports activities, such as pitching a baseball or serving in tennis, are broken down into phases: cocking, acceleration, and follow-through. Significant biceps activity is seen after ball release during follow-through as the forearm is decelerated to prevent hyperextension of the elbow. This eccentric contraction, transferring large forces to the biceps anchor, has been postulated to cause superior labrum anterior-to-posterior (SLAP) tears.⁴ Others hypothesize that SLAP lesions occur not during eccentric contraction but, rather, through

a “peel-back” mechanism during the late cocking phase of throwing. As the arm shifts from resting position to an abducted, externally rotated position, the accompanying change in the force vector of the biceps causes a torsional force at the LHBT insertion. This torsional force may “peel back” the biceps anchor away from its insertion, causing progressive failure over time.¹²

Pathophysiology

Pathologic disorders of the LHBT can be divided into 3 categories: inflammatory/degenerative conditions, instability of the biceps tendon, and SLAP lesions/biceps tendon anchor abnormalities. The 3 categories of disorders may all present with shoulder pain, though they differ widely in patient populations and pathogenesis. Though it may be helpful for treatment purposes to classify a patient's particular disorder, there is significant overlap among the pathologies.

LHBT Degeneration As the synovial lining of the biceps tendon sheath is continuous with the glenohumeral joint and intimately related to the rotator cuff, inflammatory conditions affecting any of these structures can affect the others. Biceps tendonitis, or inflammation of the biceps tendon, is a misnomer, as is lateral epicondylitis, in that histological inflammatory changes in the tendon are rarely seen. Instead, tenosynovitis (inflammation of the tendon sheath) may occur, while changes in the tendon are more appropriately called tendinosis, as degenerative changes occur histologically without evidence of inflammation.¹⁴ It should be noted that the term tendinopathy is also used throughout the literature as a general term for tendon disorders that are characterized by pain, swelling, and impaired performance.⁷⁷ The tendon may initially swell, appearing dull and discolored, but remains mobile. As the stages of degeneration progress, the tendon becomes thickened, irregular, and may become scarred to its bed through hemorrhagic adhesions. When this biceps degeneration accompanies subacromial

impingement and rotator cuff disease, this may be termed secondary biceps tendinopathy. In contrast, primary biceps tendinopathy may occur exclusive of these conditions. In addition, it is our belief that degeneration of the tendon fibers leads to painful symptoms and may occur without any demonstrable change in the gross appearance of the tendon.

“Biceps tenosynovitis” was described by Neer⁵³ as being caused by subacromial impingement. The pathology was initially thought to be limited to the older, rotator cuff population, as Murthi et al⁵² described it correlating highly with rotator cuff disease, and Peterss⁶⁰ dissection of 151 shoulders showed no biceps degeneration in cadavers from people under the age of 60.

Relatively recent interests have focused on repetitive motion in overhead athletes contributing to biceps pathology. Crossbody motion, internal rotation, and forward flexion have been shown to translate the humeral head anteriorly and superiorly. Thus, while the arm is in this position during the follow-through motion of throwing and hitting, anterior structures, like the biceps, are at increased risk of impingement on the coracoacromial arch. A tight posterior capsule, which is found in many overhead athletes, may further exacerbate the anterior translation during these motions.³⁵ Jobe and Bradley³⁷ described repetitive overload to anterior structures from pitching leading to stretching and injury. Once the anterior structures are lax, subtle glenohumeral instability may cause increased anterior humeral translation and increased anterior impingement. Alternatively, the anterior humeral translation can cause “internal impingement” of the posterior rotator cuff on the posterosuperior glenoid labrum during the late cocking and early acceleration phases of throwing, when the shoulder is maximally externally rotated and abducted.³¹ This impingement may result in pathological fraying of the posterior rotator cuff and superior labral biceps anchor. In addition, this rotation may lead to inter-

nal shear forces that overcome the biceps and its anchor, leading to tendon fiber degeneration or frank anchor failure.

LHBT Instability Biceps tendon instability can vary from subluxation to dislocation, and from intermittent to fixed. The tendon angles 30° to 40° laterally from its origin to the bicipital groove; therefore, a medially directed force may displace the tendon into the subscapularis insertion on the lesser tuberosity.⁶¹ These forces are increased during repetitive throwing, when the arm is in the abducted and externally rotated position. The soft tissue sling that secures the biceps within the groove receives contributions from the CHL, SGHL, and the subscapularis, and must be disrupted for the biceps to become unstable. Because the tendon most frequently subluxes medially, the subscapularis tendon insertion and its contribution to the sling are most frequently involved. Although isolated biceps instability has been reported in some young throwers,⁵⁶ most agree that it is extremely uncommon to find biceps tendon instability without some injury to the rotator cuff.²³ Finally, a shallow groove may also predispose the patient’s biceps tendon to instability.

SLAP Lesions/LHBT Anchor Abnormalities Snyder et al⁶⁹ introduced the term “SLAP lesion” to describe a spectrum of injuries to the superior labrum and LHBT origin, and classified the injuries into 4 types. Type I lesions involve a degenerative fraying of the superior labrum, with the biceps anchor intact. Type II injuries are detachments of the biceps anchor from the superior glenoid, and are the most common type. Type III is a bucket-handle tear of the superior labrum, with an intact biceps anchor. Type IV lesions are similar to type III, except that the tear extends into the biceps.

The SLAP lesion has several proposed causes. First, such injury may be the result of a shearing mechanism caused by compression of the superior glenoid rim, which occurs during a fall onto an outstretched arm abducted and flexed slightly forward.²³ Second, a traction mechanism has been suggested, in which

an eccentric firing of the long head of the biceps muscle causes injury to the superior labrum complex and its attachment during the deceleration phase of overhead throwing.⁴ Finally, the peel-back explanation has also been described.¹² When the arm is abducted and maximally externally rotated, the twisting of the biceps tendon may result in the peel-back of the anchor and its subsequent gradual or acute detachment from the superior glenoid. Further, we speculate that injury to the tendon intra-articular or intertubercular fibers may also occur in association with the development of a SLAP lesion.

CLINICAL EVALUATION

History

THE USUAL PRESENTING SYMPTOM is pain localized to the anterior shoulder over the bicipital groove. Often, the pain may be diffuse or vague, especially when another condition, such as rotator cuff disease, subacromial impingement, or shoulder instability, is present. An accurate history includes the description of the onset of symptoms, duration and progression of pain, history of a traumatic event, activities that worsen the pain, and previous treatments and outcomes. Sensations of instability, popping, and grinding should be noted and qualified to location and arm position.

Physical Examination

The following tests are only a small sample of those cited throughout the literature, with no one test offering acceptable sensitivity and specificity. Based on this fact, the clinician must utilize multiple exam findings in combination with the patient history, differential injections, and imaging to determine the appropriate treatment course.

The shoulder should be inspected for symmetry with the unaffected side. A common finding for biceps tendon pain is point tenderness over the bicipital groove.⁶⁵ LHBT pain rotates laterally and medially, with external and internal rotation of the shoulder, respectively; thus it

can be differentiated from painful superficial structures, like the anterior deltoid, which do not move with arm rotation. Assessment of shoulder range of motion should be performed and compared to the contralateral side. Overhead throwers may have a loss of internal rotation in their throwing arm, which can be a normal finding in this population. If a normal total arc of motion is maintained by an associated increase in external rotation, then the internal rotation deficit is less likely to be a contributing problem. LHBT pathology itself can lead to loss of shoulder range of motion, similar to what is seen with rotator cuff tendinopathy. Neer and Hawkins signs will often be positive. The rotator cuff should be tested for strength, which may be normal in the face of isolated biceps disease.

Glenohumeral joint stability testing is particularly important to perform in the athlete. The crank test and the load-and-shift test may be used. Subtle glenohumeral joint instability in the athlete may not produce a feeling of pending subluxation during apprehension testing, but may reproduce the pain that occurs during athletic activities.³¹ Yergason's test of resisted supination causing anterior shoulder pain may be specific for biceps pathology but tends to lack sensitivity.¹⁸ Speed's test is considered positive if pain localized to the proximal biceps area is caused by resisted shoulder forward flexion with the forearm supinated. O'Brien's active compression test can be used to help detect superior labral pathology. For this test, the patient elevates the arm to 90° and adducts the arm 10° to 15°, with the elbow in full extension and the arm internally rotated so that the thumb is pointing to the floor. The patient then resists downward pressure applied by the examiner. The palm is then fully supinated and the patient resists downward pressure again. A positive test for labral pathology is "deep" shoulder pain in the thumb-down position, relieved in the supinated position.⁵⁵

LHBT instability can be difficult to diagnose. One common test involves plac-

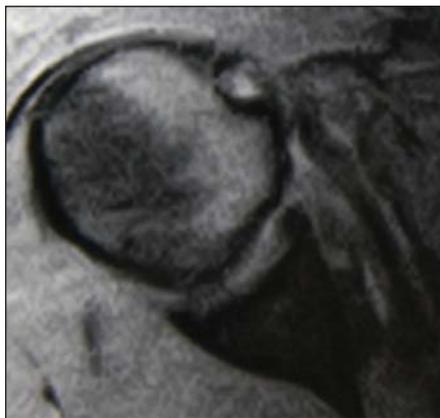


FIGURE 1. Magnetic resonance imaging demonstrating rupture of the subscapularis tendon with instability of the biceps tendon.

ing the patient's arm in the apprehension position of 90° abduction while palpating the bicipital groove. Then, upon approaching 90° external rotation, a clunk may be appreciated near the anterior edge of the acromion, as the biceps tendon subluxes out of its groove.⁸

Once these tests have been performed, differential diagnostic injections can be helpful when considering biceps tendon pathology. A subacromial lidocaine injection should not typically provide significant pain relief when the primary origin of pain is from the biceps, unless a rotator cuff tear is present. It is important to remember, however, that there is often associated pathology in these conditions, including subacromial bursitis, which is addressed with this type of injection. An intra-articular injection should help biceps anchor pain, but groove pain may sometimes persist if marked inflammation or scarring of the surrounding tissues prevents infiltration of the anesthetic into the groove. In such cases, if significant concern for biceps pathology persists, a biceps tendon sheath injection may be attempted with or without the assistance of ultrasound guidance.

Imaging

Imaging of patients suspected to have LHBT pathology begins with standard plain radiographs consisting of a true anterior posterior (AP), axillary, and outlet view. Concomitant osteoarthritis, acro-

mial hooks, and acromioclavicular joint lesions can be identified with these views. A special "groove view" may permit measurement of the width, depth, and medial wall angle of the biceps groove, and allow evaluation for degenerative changes.¹⁶ Ultrasound imaging has the advantage of being inexpensive and noninvasive. Diagnoses of bicipital tendinopathy and ruptures can be accurate; however, SLAP lesions can be more difficult to diagnose with ultrasound.⁶² The radiologic study of choice for biceps tendon pathology is magnetic resonance imaging (MRI). Biceps tendon subluxation with subscapularis and rotator interval lesions can be readily identified with this modality (**FIGURE 1**). Associated tears of the rotator cuff are also best defined by MRI. MRI also has a reported 98% sensitivity, 89.5% specificity, and 95.7% accuracy for detection of SLAP lesions.¹⁷

NONOPERATIVE TREATMENT

TREATMENT OF SUSPECTED LHBT tendinopathy begins with first attempting to make an accurate diagnosis of the primary pathology. As previously discussed, this can be difficult to determine, given the multiple conditions, including rotator cuff disease, instability, impingement, and SLAP lesions, which often accompany disorders of the biceps tendon.^{1,3,6,72} Initial treatment of both primary and secondary bicipital tendinopathy is nonoperative and begins with a period of rest and withdrawal from aggravating activities, ice, a course of anti-inflammatory medication, and formal physical rehabilitation. There are limited studies detailing the conservative management of biceps lesions alone, as they usually occur in combination with other pathologies. A Cochrane review³³ looked at 26 different studies involving physical therapy for shoulder conditions and concluded that there is some role for mobilization and exercise in the management of rotator cuff disease; but none of these studies specifically evaluated the management of biceps pathology in isola-

tion. This review also evaluated the use of therapeutic ultrasound and laser therapy in the treatment of these conditions and could not find any evidence to support their utilization.³³

The first consideration for nonoperative biceps rehabilitation is to establish a causal relationship between physical impairments and biceps pathology. It is then necessary to develop a treatment plan specifically designed to address the impairments. The patient is advanced through the phases of rehabilitation, with particular attention paid to patient response to treatment in terms of changes in pain, swelling, or motion. The patient progresses through phases similar to postoperative biceps rehabilitation (**APPENDIX A**). Phase 1 consists of pain management, restoration of full passive range of motion, and restoration of normal accessory motion. Phase 2 consists of active range-of-motion exercises, and early strengthening. Phase 3 entails rotator cuff and periscapular strength training, with a strong emphasis on enhancing dynamic stability. Finally, the return-to-sport phase focuses on power and higher-speed exercises similar to sport-specific demands. Conservative management of biceps pathology is highly variable among patients, depending on their clinical presentation. Some patients will present with near full passive and active shoulder range of motion and be ready to begin resistance training on their first visit. Conversely, individuals with acute injuries or acute irritation of the biceps tendon may present with significant range-of-motion and strength deficits and need to be progressed more slowly. The therapist plays an instrumental role in developing a treatment plan in which the patient is progressed efficiently through the phases of rehabilitation with minimal irritation to the healing tissue.

It is imperative to remember that any comprehensive rehabilitation program following biceps injury should focus on restoring dynamic stability to the shoulder. Rotator cuff strengthening has been recommended to improve shoulder func-

tion following biceps surgery.³ In addition to a rotator cuff strengthening program, rhythmic stabilization exercises can be used to retrain dynamic stability of the shoulder. Rhythmic stabilization exercises should be performed at varying shoulder and elbow positions, because elbow position is thought to affect the function of the biceps at the shoulder. At our clinic, incorporation of these neuromuscular re-education exercises has helped us achieve favorable outcomes.

Injections are an additional intervention that can be very useful in the treatment of this disease process, both therapeutically and diagnostically. Subacromial steroid injections can provide pain relief when treating biceps tendinopathy.¹³ These injections are typically utilized for patients with severe night pain or symptoms that fail to resolve after 6 to 8 weeks of conservative measures.⁶⁵ Individuals with significant biceps tendinopathy may be more resistant to treatment and may not respond as well to this type of injection.^{13,54} In these cases, injections directly into the tendon sheath of the biceps can be beneficial, with studies reporting as high as 74% good to excellent results.³⁹ These blind injections should be done carefully, as detrimental effects on healing and atrophic changes of the tendon have been reported with direct tendon injections,⁷⁰ including tendon rupture.²⁵ An alternative option is injection directly into the glenohumeral joint, which avoids the potential complications of direct tendon injection and delivers the anti-inflammatory medication directly to the intra-articular portion of the biceps, which is often irritated.⁶

The nonoperative treatment of LHBT instability is less well studied and many times less successful in practice. This condition usually follows the development of significant rotator cuff disease and, therefore, the treatment should focus on management of the rotator cuff tear. Intra-articular injections can often be helpful especially in the older, sedentary patient; but prolonged activity restrictions are often necessary to mini-

mize the symptoms. In younger, active patients, this more often requires surgical intervention to address the pathology.^{6,65} When the symptoms are secondary to impingement, subacromial injections can often be helpful, and the rehabilitation once again focuses on the rotator cuff. In all these situations, failure to make significant improvement after 3 to 4 months may indicate the need for surgical intervention.

When biceps-related pain is secondary to a SLAP lesion, especially type II and IV lesions, the initial treatment once again includes rest, anti-inflammatory medication, stretching, and strengthening, especially focusing on scapula stabilization, shoulder conditioning, and shoulder range of motion. Care should be taken to prevent the patient from placing the shoulder in positions that apply adverse stresses to the biceps anchor. For example, patients who suffer SLAP lesions from a compressive injury mechanism should refrain from upper extremity weight bearing to minimize shear and compression on the superior labrum.⁸² Likewise, excessive external rotation should be avoided in overhead athletes who most commonly suffer peel-back mechanisms of injury.¹² A third subgroup of patients include traction-related injuries, which require the avoidance of heavy eccentric or resisted biceps contractions.⁸² It should be noted that conservative management for type II and IV SLAP lesions is often unsuccessful secondary to labral instability and often requires surgical intervention.^{6,82}

SURGICAL MANAGEMENT

A GREAT DEAL HAS BEEN WRITTEN about LHBT disease and the various surgical treatments available,^{1,3,6,8,44,51,56,64,65,74} with little consensus among the experts.⁵ Much of the disagreement can be traced to the complexity of the glenohumeral joint and the lack of clear understanding of the actual function of the biceps tendon within that system. Clearly, the biceps tendon has some role, but to what extent

is up for debate.^{4,45,46,58,59,63,78,83} The most important factors in selecting a surgical treatment are the primary cause of the condition, the integrity of the tendon, the extent of tendon involvement, and any related pathology, such as impingement and rotator cuff disease, that also needs to be addressed.^{1,3,6}

LHBT Decompression

Decompressing the biceps tendon by releasing the transverse humeral ligament and releasing the bicipital tendon sheath within the groove with either open or arthroscopic surgery has been described.⁵² The use of tendon release within the groove is limited to intact tendons with mild inflammation that lack additional pathologies. In addition, severe recalcitrant tendinopathy and tendinopathy outside the groove will not respond. Failure to comply with these tight indications significantly decreases the effectiveness of the procedure, thus it is performed infrequently.¹

Subacromial Decompression

Subacromial decompression with both open and arthroscopic techniques has been described in the past to address tendinopathy of the biceps secondary to “impingement syndrome.”⁵³ As mentioned above, when utilized in conjunction with debridement of the biceps tendon for mild disease this option can be very effective. In fact, Neer⁵³ demonstrated that only 30% of the 50 patients in his study who had a diagnosis of tendinopathy preoperatively actually had significant biceps disease that could be verified, and good results were obtained with addressing the impingement component using acromioplasty alone. In a series of 307 cases, Walch et al⁷⁵ found that acromioplasty, in association with biceps tenodesis or tenotomy, was only beneficial in those patients with an acromiohumeral distance of greater than 7 mm and an isolated supraspinatus tear. In addition, patients with proximal migration of the humeral head may actually have a poorer outcome by performing the procedure.

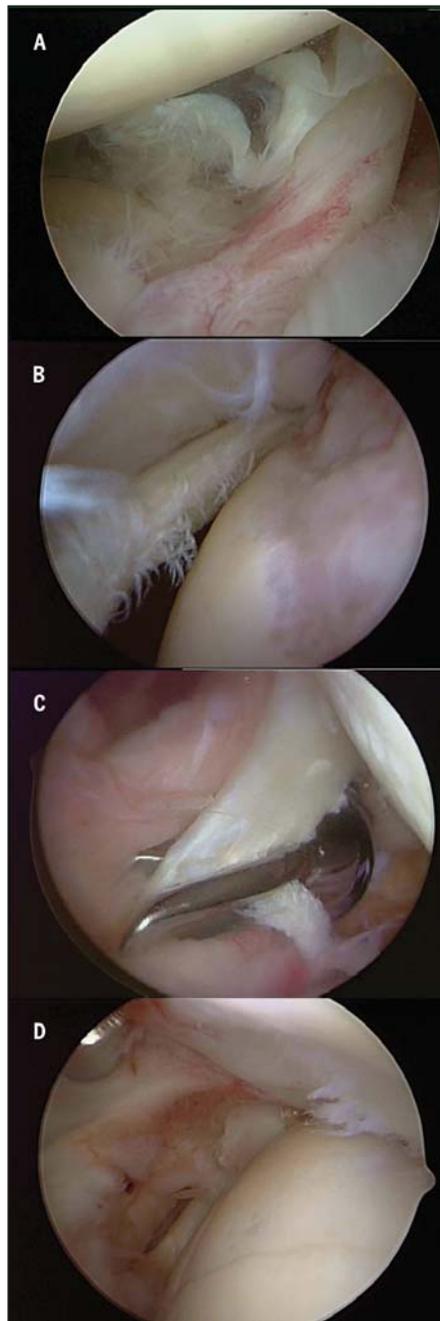


FIGURE 2. Arthroscopic views of degenerative biceps tendons within the glenohumeral joint. Note the hyperemia (A) and the frayed degenerative condition of the tissue (B). The use of an arthroscopic biter to perform a tenotomy (C) with the final result (D).

However, the utilization of acromioplasty alone for isolated biceps pathology has not been studied. We postulate that failed decompressions or acromioplasties occur because of unrecognized biceps disease that is not effectively treated by acromioplasty alone.

LHBT Debridement

Debridement of the intra-articular portion of the biceps tendon has been suggested for partial tears, including delamination and fraying that involves less than 25% of the tendon in young, active patients^{5,6,65} or less than 50% of the tendon in older, sedentary patients.⁶ Often, this is accompanied by a decompression of subacromial soft tissue alone in younger patients, or bursectomy and acromioplasty in older patients. Many authors believe that debridement alone is not effective in eliminating symptoms or preventing eventual biceps rupture, thus biceps tenotomy or tenodesis should be undertaken in these situations.^{1,11,30,38,76}

LHBT Tenotomy

Throughout the literature there is a clear debate between tenotomy and tenodesis for the treatment of biceps pathology.^{1,5,6,9,10,65} Tenotomy consists of cutting the LHBT prior to its intra-articular superior labral insertion (FIGURE 2). In contrast, tenodesis also requires a tenotomy of the LHBT, but with the additional step of anchoring the tendon along its original course more distally. Traditionally, a variety of tenodesis techniques have been described as the surgical treatment of choice,^{7,9,11,22,28,43,44,47,51,64} providing maintenance of the form and possibly function of the biceps, while at the same time providing pain relief.⁵ Numerous authors have questioned the long-term results of this procedure.^{7,9,22,30,38,76}

Biceps tenotomy was initially proposed by Walch⁷⁶ in an attempt to provide pain relief in the setting of massive rotator cuff tears, which were not repairable using an open technique. Gill et al³⁰ then reported the results of 30 patients treated with intra-articular tenotomy as the primary procedure for biceps degeneration, instability, and recalcitrant tendinopathy (FIGURE 2). An associated subacromial decompression was performed in 2 cases. Seventeen of the patients in the study group participated in athletics less than 3 days per week, 12 were recreational athletes with



FIGURE 3. “Popeye” deformity secondary to ruptured long head of the biceps.

participation 4 to 7 days per week, and 1 participated at a professional level. Postoperatively, only 2 patients complained of activity-related pain that was moderate in nature, 90% returned to their previous level of sports, and 97% returned to their previous occupation at an average follow-up of 19 months. There was an overall complication rate of 13.3% with 2 cases of impingement-related overhead-activity pain, 1 instance of painless “Popeye” deformity (**FIGURE 3**) that resolved with tenodesis, and 1 continued complaint of biceps pain. The mean American Shoulder and Elbow Surgeons (ASES) score was 81.8.

These results were reconfirmed in a separate, 2-year-minimum follow-up study of 40 patients with refractory biceps tendinopathy who underwent arthroscopic release alone or in combination with other shoulder procedures. In this series, the mean ASES was 77.6; but in those patients with an isolated LHBT release, this increased to 87.8, with only 1 patient having a poor result, secondary to severe arthritis of the glenohumeral joint. This same study reported no loss of biceps curl strength in individuals over 60, and minimal strength loss overall. Even more importantly, 100% of patients reported a pain-free biceps at rest, 95% experienced a significant decrease in overall biceps tendon pain, and 95% had relief of their anterior shoulder pain upon palpation. There was a 70% incidence of Popeye deformity,³⁸ which is higher than that reported in the literature.^{30,57,76} Osbahr et al⁵⁷

reported no significant difference in the levels of anterior shoulder pain, cosmetic deformity, or muscle spasm between patients treated with tenotomy versus tenodesis for chronic bicipital pain, and Gill et al³⁰ had only 1 tenotomy patient out of 30 who required a tenodesis to address an unacceptable Popeye deformity.

Shank et al⁶⁶ further compared the 2 procedures by using Cybex isokinetic strength testing. Their results demonstrated no statistical difference in either forearm supination or elbow flexion strength when comparing 31 control subjects, 17 patients posttenotomy, and 19 patients posttenodesis. In comparison, papers specifically looking at ruptures report loss of forearm supination strength of 10% to 20% and up to 8% loss of elbow flexion strength in the acute setting.^{50,79} However, Warren⁷⁹ demonstrated no change in the flexion strength in a series of patients with chronic ruptures. Pronation, grip, and elbow extension strength were all normal throughout the various studies.

LHBT Tenodesis

As stated previously, the traditional indications for tenodesis have been partial tears of the biceps involving greater than 25% of the tendon, subluxation, disruption of the soft tissue stabilizers of the groove, recalcitrant tendinopathy, chronic tendon atrophy, and significant biceps disease following failed rotator cuff or impingement treatment.^{21,51,56,65} This procedure can be performed either in an open fashion^{9,24,26,51,56} or arthroscopically.^{11,28,43,44,47,64} Gilcreest²⁹ in 1926 first described tenodesis to the coracoid for rupture of the LHBT. This was followed by methods that secured the tendon within the groove, but left a proximal stump. Later Froimson and Oh²⁶ described an open keyhole interosseous tunnel technique that relocated the tendon within the groove after amputating the proximal stump. Although rather tedious, Froimson and Oh's technique was a superior clinical advancement and led others to develop simpler techniques. Mazzocca et al⁵¹ and Edwards and Walch²⁴ have de-

scribed open techniques utilizing interference screws with good success.

Building upon these advances, numerous other authors have developed all arthroscopic techniques.^{11,28,43,44,47,64} Gartsman and Hammerman²⁸ in 2000 presented a technique using suture anchors for tenodesis. Several others have developed procedures using interference screw technology, with variations on passing the tendon, including Boileau et al,¹¹ using a transhumeral guide pin, Klepps et al,⁴⁴ employing a bone anchor at the bottom of the tunnel to act as a pulley, and both Romeo et al⁶⁴ and Lo and Burkhart,⁴⁷ using the Arthrex (Arthrex, Inc, Naples, FL) biotenodesis system. Boileau et al¹¹ reported the early results of 43 patients who underwent their procedure, with a minimum 1-year follow-up. In this study, the absolute Constant score increased from 43 to 79 points, with no loss of elbow motion, and the overall biceps strength was 90% of the contralateral side. There were 2 cases of rupture of the tenodesis, which was attributed to using screws of insufficient diameter early in the study, and no cases of neurologic or vascular compromise. It should be noted that the prolonged ache and spasm often discussed in relation to tenotomy is actually an uncommon long-term complication and has been described in relation to tenodesis as well.

Boileau et al¹⁰ in 2007 reported their retrospective data on 68 consecutive patients, in whom existed a total of 72 irreparable rotator cuff tears with biceps pathology, and who were treated with arthroscopic biceps tenotomy (39 cases) or tenodesis (33 cases). Seventy-eight percent of the patients were satisfied with their result, and the average Constant score increased from 46.3 to 66.5. There was no difference in the results between the procedures when utilized in this patient population. The authors noted that atrophy of the teres minor significantly decreased shoulder function, and pseudoparalysis of the shoulder and severe rotator cuff arthropathy are contraindications to this procedure.

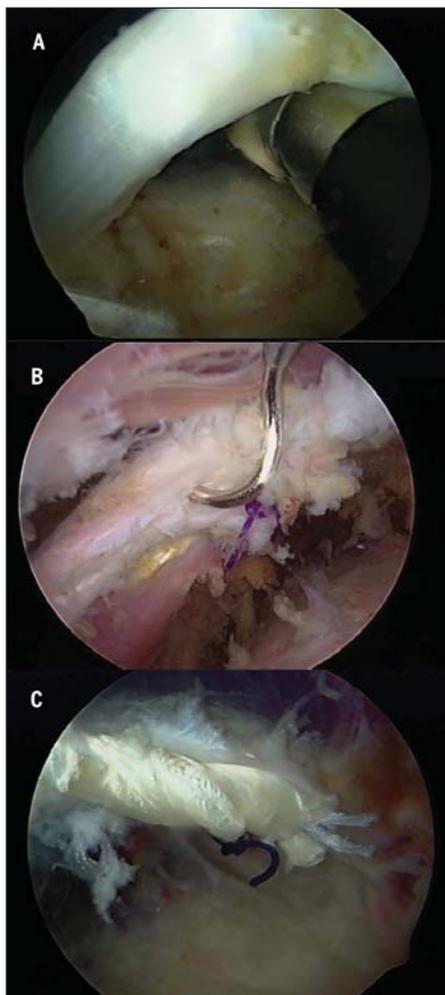


FIGURE 4. Arthroscopic view in the subacromial space, demonstrating the steps of a biceps tendon transfer. The biceps tendon being released from the groove (A), during passing of the sutures (B), and the final attachment of the long head of the biceps to the conjoint tendon (C).

At our clinic, the decision to utilize tenotomy or tenodesis is based upon a lengthy discussion with the patient regarding the risks and benefits of each procedure, the time required for rehabilitation following surgery, and the individual patient expectations. In older patients who desire pain relief with a quick return to their activities, tenotomy is often the treatment of choice. In contrast, the young laborer, who is most concerned with cosmesis and supination strength, will often prefer tenodesis. It is important to remember that both of these procedures offer excellent treatment options, and the ultimate selection should

be made in partnership with the individual patient.

LHBT Transfer

In response to the potential cosmetic deformity and occasional painful cramping that can accompany biceps tenotomy, and the persistent local pain often seen after tenodesis, the technique of all arthroscopic transfer of the LHBT to the conjoint tendon was developed (FIGURE 4). First described by O'Brien,⁷⁴ this procedure is a soft tissue variation of the earlier described techniques of transferring the tendon to the coracoid process using anchors. This transfer is felt to more closely approximate the normal anatomical axis of the biceps muscle and should have improved results over conventional tenodesis. In addition, the authors feel the technique offers a simpler option by working in an avascular plane without implants. Other authors point out that this changes the course of the tendon nonetheless and may result in pain secondary to traction or adhesions under the insertion of the pectoralis major.¹ In addition, some authors feel the increased force on the scapula may lead to anterior scapular tilting and ultimately contribute to subacromial impingement. As previously stated, this is a relatively new variation of an old technique and no long-term studies comparing the 2 methods have been reported in the literature.

Surgical Management of LHBT Instability

A chronically subluxating or dislocating LHBT will often show signs of advanced inflammation or degeneration. There is usually pathology traceable to the rotator interval as well as rotator cuff tearing, primarily involving the subscapularis. The indications for tenotomy or tenodesis parallel those discussed previously for significant biceps tendinopathy and these are the most common procedures performed in this setting. If the patient is young and active, one might consider a tenodesis; along with a subscapularis repair via an

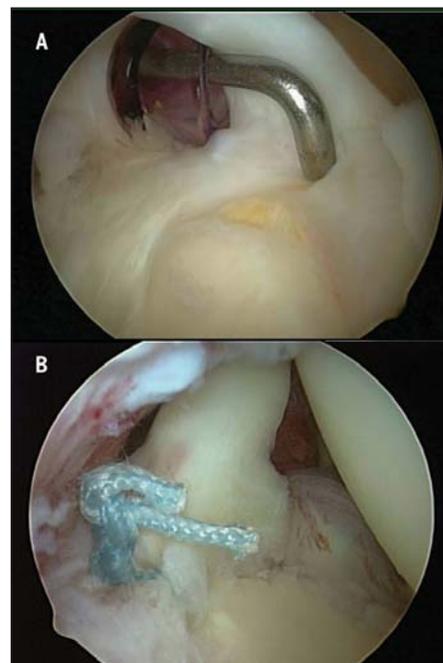


FIGURE 5. Arthroscopic view of a superior labral (SLAP) lesion, demonstrating detachment of the biceps tendon anchor from the glenoid (A). A similar SLAP lesion has been repaired using a suture anchor, once again providing fixation between the biceps anchor and glenoid rim (B).

open deltopectoral approach, or, if only a partial tear of the deep superior portion of the tendon exists, an arthroscopic approach can be used.³ If the patient is less active, a tenotomy with or without a subscapularis repair may be a better option.⁶ O'Donoghue⁵⁶ reported on a series of 53 throwers (56 cases) with isolated biceps tendon subluxation treated with tenodesis. In this study, 71% of patients reported excellent progress, with 77% able to throw satisfactorily and 77% able to return to their sport of choice. Of those patients unable to return to play, 4 had unrelated problems, 6 had pain and restricted range of motion, and 1 injured his shoulder in a fall.

An attempt at relocation of a subluxated or dislocated tendon may be possible if the tendon is still mobile and significant degeneration has not occurred. It is extremely important to repair and tighten the rotator cuff interval in this situation to maintain the position of the tendon in the groove. In addition, following the repair, it is imperative to

verify the location of the tendon within the center of the groove and adequate stability throughout the shoulder range of motion.³ Recurrent instability, with a resulting stenosed, painful tendon, is a common long-term complication following any procedure that attempts to repair the sling and stabilize the tendon in the groove.

Surgical Management of Type II and IV Slap Tears

An entire contribution within this special issue is devoted to the recognition and treatment of SLAP tears, thus we will only make a few brief comments as it relates to type II and IV tears involving the proximal biceps tendon. Type II tears have, by definition, a detached biceps anchor and therefore require stabilization usually with suture anchor fixation or bioabsorbable tacks (**FIGURE 5**). A type IV SLAP tear includes a bucket-handle portion of the labrum that extends into the biceps tendon. In these cases, if the tendon is not too degenerative and the tear involves less than 30% to 40% of the tendon anchor, the tendon can simply be debrided and the superior labrum either debrided or reattached, provided the flap is large enough.⁸² If more than 40% of the tendon is involved, usually a side-to-side repair is performed, where possible, along with treatment of the labrum, as above. However, in cases where the biceps origin is more significantly damaged or if there is a great deal of degeneration of the tendon, biceps tenodesis or tenotomy offers a better option to direct repair.³

REHABILITATION PRINCIPLES: BICEPS TENOTOMY OR TENODESIS

Treatment Philosophy: Team Concept

ALL CAREGIVERS WORKING TOGETHER as a cohesive team improve patient management and help to ensure optimal patient outcomes. Due to the variety of surgical techniques used to manage biceps pathology, it is impera-

tive that the therapist communicates frequently with the physician to ascertain the type of surgery performed, the type of fixation, the patient's tissue quality, the quality of the repair, concomitant procedures performed, and any special instructions specific to the patient's rehabilitation. To facilitate this communication, doctors at our clinic typically visit with the patients during the first therapy session with the physical therapist. Patient understanding and compliance are improved when there is consistent communication from all members of the team regarding precautions, sling use, activity restrictions, and a timeline for return to activities.

Patient Education

There are differences in the management of biceps tenotomy compared to tenodesis. Tenotomy rehabilitation will be more aggressive and advance more quickly, because the necessary protection for healing tissue is minimal. The primary risk of an aggressive approach is a Popeye deformity (**FIGURE 3**). The Popeye deformity has been reported to be present in 62% to 70% of patients following tenotomy.^{10,38} However, the resultant negative consequences of a Popeye deformity are relatively benign.^{10,38} Conversely, rehabilitation following tenodesis will progress more slowly over the first 6 weeks to protect the healing biceps tendon. The patient is instructed on several behavior modification strategies to protect the repair. They are taught that activities causing contraction of the biceps muscle should be avoided, such as resisted elbow flexion and forearm supination.⁶⁷ The practical implication is that the patient needs to refrain from activities such as lifting, opening door knobs, or using a screw driver with the involved extremity. Clear instruction to the patient regarding activity and behavior modifications from all members of the "clinical team" will help protect the repair and ensure optimal outcome.

In general, in our clinic, each patient receives instruction on a comprehensive, individualized, written home exercise

program. The program is routinely reviewed with the patient and updated with more challenging exercises as the patient progresses.

Basic Science

Successful biceps rehabilitation requires the therapist to create a healing environment based on soft tissue healing properties. Creating a healing environment involves controlling pain, swelling, irritation, and the loads placed on the healing tissue. Tendons have 7.5 times lower oxygen uptake than skeletal muscles, which may explain why tendons can be slow to heal after an injury.⁶⁷ Progressively loading a healing tissue can promote soft tissue healing, as long as the applied load is appropriate to the patient's stage of healing.

Sharma and Maffuli⁶⁷ state that tendon healing occurs in 3 broadly overlapping stages. Patients will progress through the stages at different rates. Treatment must be individualized, based on soft tissue healing as well as the patient's clinical presentation. Therefore, decisions to advance patients through the phases of rehabilitation should be based on soft tissue healing times, as well as clinical presentation and response to treatment.

Clinical Concepts

The proposed functions of the biceps at the shoulder include joint compression, anterior stabilization, and superior stabilization.^{4,41,42,45,53,78} It is difficult to determine the extent to which biceps surgery will affect shoulder function, because the role of the biceps at the shoulder is not fully understood. Maintaining the biceps muscle length-tension relationship and the axis of the biceps muscle is thought to be important for preserving biceps function at the shoulder.⁷⁴ Biceps tenodesis provides the opportunity to maintain tension in the tendon along its original alignment, but the attachment site is distal to the shoulder. Techniques such as the biceps transfer will attach the LHBT proximal to the shoulder but in a different alignment along the con-

joint tendon. Regardless of the surgical procedure, there will likely be alterations in shoulder proprioception and function that will have to be addressed during rehabilitation.

POSTOPERATIVE REHABILITATION

Overview

THERE IS MINIMAL RESEARCH SPECIFICALLY relating to the rehabilitation of the long head of the biceps. In the latest Cochrane review³³ of physical therapy for shoulder pain there were no studies specific to long head of biceps lesions. Currently, the best evidence for postoperative rehabilitation is surgeon and physical therapist experience. Our clinic has developed protocols that are used as an outline to guide the rehabilitation process (APPENDICES B AND C). The protocols are divided into 3 phases. Adjustments are made depending on the presentation of the individual patient. It is important to take into account pertinent patient history, mechanism of injury, and patient goals when planning the course of treatment for the patient. Decisions to advance through the phases of rehabilitation are based on protecting the healing tissue, applying controlled loads to the healing tissue, and monitoring patient response to treatment in terms of changes in pain and swelling.

Manual Therapy Treatment

Manual therapy treatments, such as range-of-motion exercises and glenohumeral joint mobilizations, are most appropriate during phases 1 and 2 (APPENDICES B AND C). Particular attention is focused on the posterior and inferior capsule. Tightness of these structures is linked to impingement.^{27,37,48} Soft tissue mobilizations are utilized to decrease pain and spasms of the biceps or other shoulder muscles. As patient range of motion increases, manual interventions are decreased in favor of active exercises.



FIGURE 6. Lawn chair active range-of-motion progression from supine to sitting. The patient is progressed through increasingly upright positions to gradually increase the effect of gravity on the shoulder.

Phase 1

Rehabilitation begins 1 day postoperatively. A standard sling is used as needed for comfort. An elastic wrap is placed over the upper arm to provide support to the healing biceps. A transcutaneous electrical nerve stimulation unit is applied in the recovery room and sent home with the patient for pain management. The goals for phase 1 are to decrease pain and swelling, initiate gentle rhythmic stabilization exercises, initiate scapular stabilization exercises, and restore full passive shoulder range of motion. Passive shoulder external rotation is often painful, and placing half of a foam roll under the patient's arm during supine exercises helps to relieve some of the discomfort. Full passive motion is expected 1 to 2 weeks postoperatively, with patients posttenotomy typically achieving full motion slightly ahead of those posttenodesis. Manual therapy treatments and modalities are utilized as needed to decrease pain and improve range of mo-

tion. During this phase, nothing supercedes the importance of protecting the healing tissue.

Particular attention is placed on rhythmic stabilization and scapular stabilization exercises during phase 1. Isolated scapular retraction, with the arm immobilized, has been shown to produce low levels of biceps activity.⁶⁸ Therefore, scapular retraction exercises are initiated early in phase 1 to improve neuromuscular control. This sets the stage for the scapular stabilization and rhythmic stabilization exercises performed in phases 2 and 3. Gentle rhythmic stabilization exercises are initiated with the patient supine, the arm at 0° of shoulder flexion, and half of a foam roll supporting the elbow, then progressed to 90° of forward elevation.

At our clinic, to advance the patient from phase 1 to phase 2, patients should be able to perform passive range of motion to 80% or greater of the uninjured shoulder, 1 minute of rhythmic stabiliza-

tion in the supine position with arm at 90° forward elevation, and no increase in pain or swelling after treatments. Typically, both biceps tenodesis and tenotomy patients are able to advance beyond phase 1 after the first week.

Phase 2

At this point, patients are typically out of the sling and experiencing minimal pain. Some patients will attempt to resume activities too early, which can result in irritation to the biceps. Patient education about proper behavior modification becomes important for maintaining a healing environment for the biceps. The goal for phase 2 is to increase active range of motion, activity tolerance, and muscle endurance.

A key rehabilitation regimen used during this phase is the lawn chair progression (FIGURE 6), which involves transitioning from supine active range of motion to more functional active range-of-motion exercises sitting upright. Flexion above 90° in the supine position will be gravity assisted. As the patient becomes increasingly upright, the external torque on the shoulder is increased due to the orientation of the upper extremity in relation to gravity and the related increased length of the upper extremity moment arm. The ultimate result of this higher load is an increased muscle demand, which is necessary to maintain proper shoulder kinematics. Any upper trapezius substitution noted at this point should be addressed immediately. Side-lying shoulder flexion is a good alternative exercise if the patient struggles with proper technique during the lawn chair progression. If this substitution is necessary, the lawn chair progression should be reinstated once the patient demonstrates mastery of the side-lying flexion maneuver. In addition, rhythmic stabilization exercises are advanced in accordance with the lawn chair progression, so that the effect of gravity on the arm is gradually increased with this regimen as well.

At our clinic, to advance from phase 2 to phase 3, patients should be able to

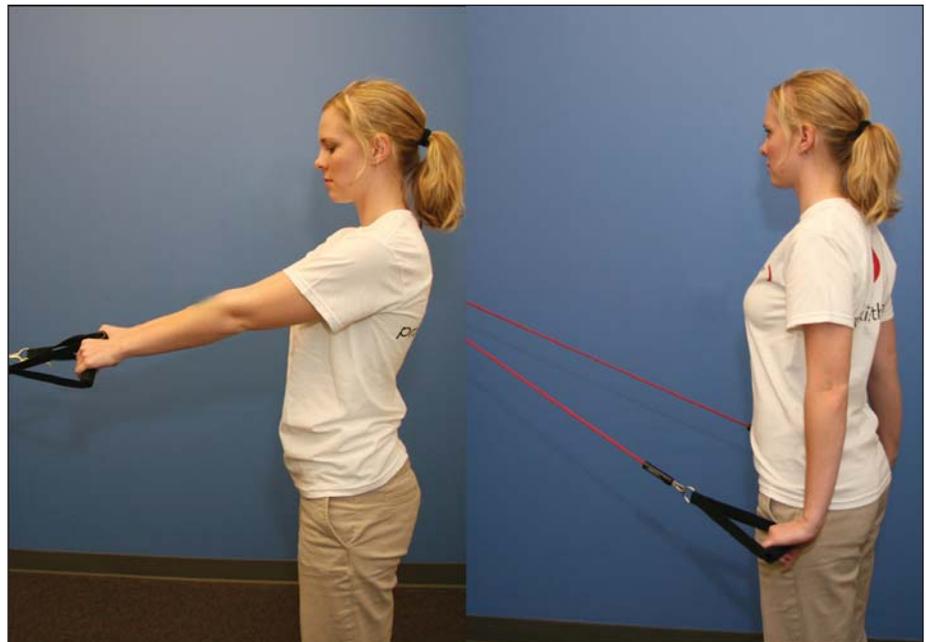


FIGURE 7. Resisted shoulder extension performed with red sport cord resistance. The focus is on scapular retraction with minimal upper trapezius activity.

perform 30 repetitions of active shoulder elevation in standing to 80% or greater of the uninvolved shoulder, without upper trapezius substitution, and 30 repetitions of side-lying external rotation to 80% or greater of the uninvolved side, with no increase in pain or swelling after treatments. Patients posttenotomy typically advance more quickly than those posttenodesis. Phase 2 lasts approximately 2 weeks for tenotomy compared to 6 weeks for tenodesis.

Phase 3

The goals for the third phase are increased endurance and strength. Biceps strengthening should begin week 3 for patients posttenotomy and week 7 for those posttenodesis. Isotonic exercises should begin with eccentric biceps contraction only, then progress to a full isotonic exercise range, including concentric and eccentric biceps contraction, as tolerated by the patient. Biceps strengthening should include both supination and elbow flexion exercises. Exercise selection is based on patient goals and activity demands. For example, baseball players require eccentric control of elbow flexion during throwing, whereas a manual

laborer may require supination strength for screwdriver use.

Proprioception and neuromuscular re-education exercises are important to counteract the inhibitory effects pain and inflammation have on the rotator cuff and scapular stabilizers.^{40,49} Resisted shoulder extension is a good exercise to emphasize lower trapezius muscle activity, while minimizing upper trapezius substitution (FIGURE 7). Proper scapular stabilization will provide a stable base for glenohumeral joint movement, as well as maintain optimal length-tension relationships for the rotator cuff muscles.^{20,80} With our scapular and rotator cuff-strengthening programs, muscle endurance is emphasized, because muscle response times at the shoulder have been shown to decrease after fatiguing exercise.¹⁹ Therefore, neuromuscular re-education should include multijoint and multiplanar endurance exercises. Flex bar and Bodyblade rhythmic stabilization exercises are performed at varying shoulder and elbow positions. Strengthening exercises focus on incorporation of the entire kinetic chain, including coordinated lower extremity, trunk, and shoulder movements in multiple planes.



FIGURE 8. Shoulder external rotation performed at 30° of abduction with red sport cord resistance.



FIGURE 9. Rhythmic stabilization performed at 90° of abduction and 90° external rotation with red sport cord resistance.

Rotator cuff strengthening begins with basic sport cord external and internal rotation exercises performed with the arm supported at 30° of abduction (FIGURE 8). The position of 30° abduction with an isometric adduction force will increase the subacromial space, which is advantageous in minimizing risk for impingement during rotator cuff strengthening.³² At our clinic, exercises with shorter lever arms and exercises below 90° of arm elevation are utilized for strengthening the shoulder. In this position, strength and endurance can be increased with minimal risk of impingement. Once the patient has developed an adequate strength base, the focus shifts to improving neuromuscular control in functional positions. We do not perform heavy resistance strengthening exercises

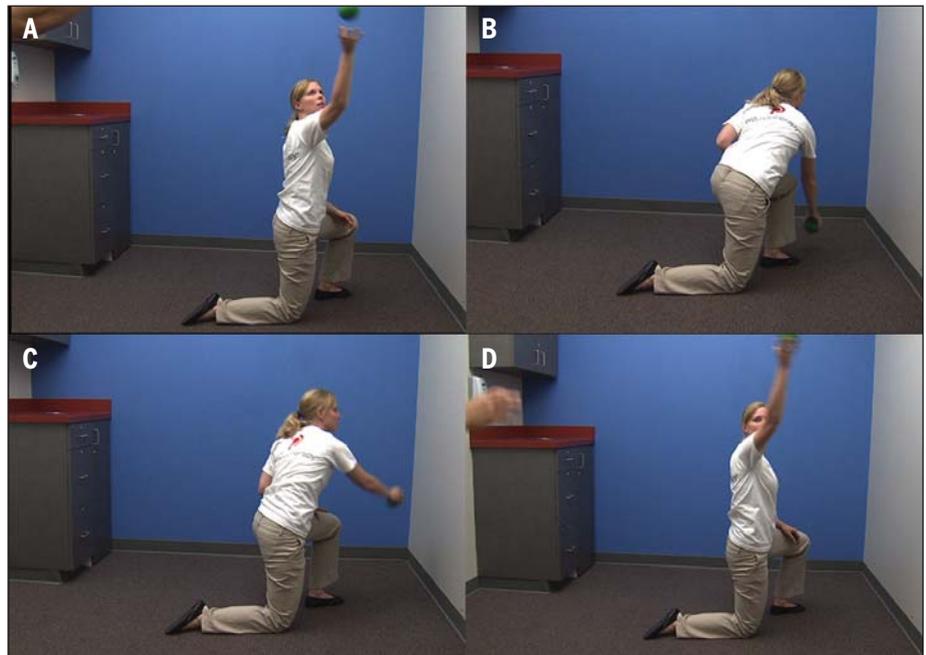


FIGURE 10. This series of pictures demonstrates plyometric proprioceptive neuromuscular facilitation D2 reverse throws with a small, green, 1-kg medicine ball. (A) To start, the therapist throws the ball over the patient's shoulder. (B) The patient catches the ball and decelerates it down to the front foot, (C) then accelerates the ball back over the shoulder, (D) throwing it to the therapist.

in positions above 90° of elevation or with long lever arms. In our opinion, the increased risk for impingement outweighs the potential benefits. Exercises with longer lever arms and exercises above 90° arm elevation are utilized for muscle endurance and neuromuscular re-education only.

For patients to advance to the return-to-sport phase, they must be able to perform 1 minute of red sport cord external rotation at 30° of abduction, 1 minute of rhythmic stabilization standing with arm at 90° forward elevation, and no increase in pain or swelling after treatments. Patients with tenotomy usually make the transition 4 to 6 weeks postoperatively, whereas those posttenodesis will not advance until weeks 8 to 12.

Return to Sport

The goals for this phase are to increase muscle strength, increase muscle power, successfully complete an interval throwing program, and return to the previous level of sport participation. Plyometric exercises are appropriate at this phase to enhance dynamic stability, enhance

proprioception, and gradually increase the sport-specific loads applied to the shoulder. For example, Swanik et al⁷¹ demonstrated that a 6-week internal rotation plyometric training program performed by female swimmers enhanced proprioception, kinesthesia, and muscle performance characteristics. Plyometric exercises should be chosen individually for each athlete based on sport-specific demands. Plyometric exercises are advanced from 2-arm, short-lever-arm activities below 90° of arm elevation, to single-arm long-lever-arm activities above 90° of arm elevation. A sample plyometric progression could begin with a chest pass exercise and progress to a proprioceptive neuromuscular facilitation (PNF) D2 pattern exercise.

Our athletes are able to return to sport if they have minimal pain, full motion, and full strength. The athlete should be able to tolerate 1 minute of rhythmic stabilization at 90° of abduction and 90° of external rotation with red sport cord resistance (FIGURE 9), 1 minute of forward PNF D2 plyometrics, and 1 minute of backward PNF D2 plyometrics (FIGURE

10). The patient must also be free of pain during sport activities.

SUMMARY

THERE HAS BEEN AN INCREASING focus on the involvement of the LHBT in shoulder dysfunction and pain generation, but there is little consensus on the overall function of the tendon at the glenohumeral joint. In addition, the diagnosis of biceps pathology is difficult secondary to the high incidence of concurrent disease processes, that occur about the shoulder when biceps problems are encountered. We have obtained an increased understanding since the advent of diagnostic arthroscopy, but there are still numerous questions to be answered. The lack of agreement is most evident when discussing treatment options that include tenotomy versus tenodesis. Despite the controversy, most authors would agree that the primary treatment principle is the removal of the proximal biceps from the shoulder joint. The LHBT clearly has some role in the shoulder, but, based on current information, the loss of this function is much less detrimental than retaining a diseased tendon.

We have only begun to fully comprehend the complex dynamics of the shoulder, but it is clear that a comprehensive multidisciplinary team approach will be required to achieve good patient outcomes. The rehabilitation team will play an instrumental role in that process. We recommend postoperative rehabilitation based on the specific pathology and procedures performed with adjustments made, depending on the presentation of the individual patient. Decisions to advance through the phases of rehabilitation are based on protecting the healing tissue, applying controlled loads, and monitoring the patient response to treatment, with an ultimate goal of a safe return to functional activities. Given the paucity of outcome literature regarding the rehabilitation protocols utilized in the treatment of biceps lesions, all patients would benefit from further studies in this area. ●

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APPENDIX A

BICEPS TENDINOPATHY NONOPERATIVE REHABILITATION PROTOCOL*

Phase 1: Acute Phase

Clinical modalities as needed

Glenohumeral range of motion

- Apply appropriate joint mobilization to restrictive capsular tissues
- Implement wand stretching, as indicated
- Supplement with home program
 - Cross-arm stretch
 - Sleeper stretch

Early scapular strengthening

- Begin scapular stabilization with instruction in lower trapezius facilitation

Phase 2: Subacute Phase, Early Strengthening

Continue with modalities and range of motion as outlined in phase 1

Begin rotator cuff strengthening

- Sport cord internal/external rotation (30° abduction)
- Sport cord low rows
 - Prone I, T, Y, W
 - Scaption (not above 90°)
 - Ceiling punch
 - Biceps
 - Triceps

Phase 3: Advanced Strengthening

Continue with phase 2 strengthening, with the following additions:

- Resisted PNF patterns
- Sport cord bear hug
- Sport cord reverse fly
- Sport cord IR/ER at 90° abduction for neuromuscular

re-education

- Push-up progression
- Begin 2-arm plyometric exercises, advancing to 1-arm exercises
- Weight training
 - Keep hands within eyesight, keep elbows bent
 - Minimize overhead activities
 - No military press, upright rows, or wide grip bench

Phase 4: Return to Activities

Continue with phase 3 program

Re-evaluation with physician and therapist

Advance to return-to-sport program, as motion and strength allow

* Produced with the help of Dr Richard Hawkins and Howard Head Sports Medicine at Vail, CO. This protocol is intended to provide a general guideline to treating biceps tendinopathy. Progress should be modified on an individual basis.

APPENDIX B

BICEPS TENOTOMY POSTOPERATIVE REHABILITATION PROTOCOL*

- Sling for comfort, discontinue as tolerated
- May advance rehabilitation as rapidly as pain and swelling allow

Phase 1: Passive

Pendulums to warm-up

Passive range of motion

Week 1

Full passive elbow flexion/extension

Full passive forearm supination/pronation

Full passive shoulder range of motion

Seated scapular retractions

Phase 2: Active

Pendulums to warm-up

Active range of motion, with terminal stretch to prescribed limits

Week 2

Full active shoulder range of motion, lawn chair progression

Active elbow flexion and extension, full range of motion allowed

Active forearm supination/pronation, full range of motion allowed

Phase 3: Resisted

Pendulums to warm-up and continue with phase 2

Week 3

Sport cord internal rotation at 30° abduction

Sport cord external rotation at 30° abduction

Prone I, T, Y, W

Sport cord standing forward punch

Sport cord low rows

Sport cord bear hugs

Bicep curls

Resisted supination/pronation

Weight Training

Week 4

Keep hands within eyesight, keep elbows bent

Minimize overhead activities

(No military press, upright rows, or wide-grip bench)

Return to Activities

Computer: 1-2 wk

Golf: 4 wk

Tennis: 8 wk

*Produced with the help of Dr Richard Hawkins and Howard Head Sports Medicine at Vail, CO.

APPENDIX C

BICEPS TENODESIS POSTOPERATIVE REHABILITATION PROTOCOL

- Sling for comfort, discontinue as tolerated

Phase 1: Passive

Pendulums to warm-up supported
Passive range-of-motion exercises

Week 1

Full passive shoulder range of motion
Full passive elbow flexion/extension
Full passive forearm supination/pronation
Seated scapular retraction

Phase 2: Active

Pendulums to warm-up
Active range of motion, with terminal stretch to prescribed limits

Weeks 1-6

Full active shoulder range of motion: lawn chair progression
Active elbow flexion and extension: full ROM allowed
Active forearm supination/pronation: full ROM allowed

Phase 3: Resisted

Pendulums to warm-up and continue with phase 2

Week 7

Sport cord internal rotation at 30° abduction
Sport cord external rotation at 30° abduction

Prone I, T, Y, W

Sport cord standing forward punch

Sport cord low rows

Sport cord bear hugs

Bicep curls

Resisted supination/pronation

Weight Training

Week 8

Keep hands within eyesight, keep elbows bent

Minimize overhead activities

(No military press, upright rows, or wide grip bench)

Return to Activities

Computer: 4 wk

Golf: 8 wk

Tennis: 12 wk

* Produced with the help of Dr Richard Hawkins and Howard Head Sports Medicine at Vail, CO.

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