Original Article With Video Illustration

Midterm Clinical Outcomes for Arthroscopic Subdeltoid Transfer of the Long Head of the Biceps Tendon to the Conjoint Tendon

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Purpose: The aim of this study was to assess the midterm functional outcomes for arthroscopic subdeltoid transfer of the long head of the biceps tendon (LHBT) to the conjoint tendon. **Methods:** Fifty-six shoulders in 54 patients (46 men, 8 women; mean age, 42 years) who underwent isolated arthroscopic subdeltoid LHBT transfer to the conjoint tendon by a single surgeon with a minimum of 4 years follow-up were evaluated with American Society of Shoulder and Elbow Surgeons (ASES) and L'Insalata scores. A subset of patients was available for physical examination. **Results:** At an average of 6.4 years postoperatively, ASES and L'Insalata scores were 86 and 85, respectively, corresponding to 88% of patients rated good to excellent. Twelve shoulders (10 from men patients, 2 from women patients; mean age 41 years; average follow-up, 6.3 years) underwent physical examination. Mean University of California, Los Angeles (UCLA) score was 31, and there were no significant differences in side-to-side elbow flexion strength or endurance using a 10-pound weight. One patient had a Popeye sign. There were no major complications reported in this cohort. **Conclusions:** Arthroscopic transfer of the LHBT to the conjoint tendon is a safe and durable intervention for chronic refractory biceps tendinitis. **Level of Evidence:** Level IV, therapeutic case series.

The long head of the biceps tendon (LHBT) is an important pain generator in the shoulder[1] that is invested by a dense neuronal network consisting of sympathetic and sensory elements.[2] Furthermore, Alpantaki et al.[3] identified neural cell adhesion molecules in pathologic human LHBTS that have been implicated in the neural development and nociceptive pathways. Although the majority of symptomatic LHBT lesions can effectively be managed with conservative measures, surgery may be indicated in a subset of patients with recalcitrant symptoms.[1] Several surgical techniques have been described, including tenotomy,[4,5] open proximal biceps tenodesis,[6,7] proximal and distal arthroscopic biceps tenodesis,[8,9] subpectoral biceps tenodesis,[10-12] and tendon transfer to the conjoint tendon.[13-16]

Drakos et al.,[13] Verma et al.,[14] and O'Brien et al.[15,16] described arthroscopic subdeltoid transfer of the LHBT to the conjoint tendon. The proposed advantages include removal of the LHBT from its potentially pathologic extra-articular enclosure, improved cosmesis, and soft tissue—to—soft tissue fixation. Drakos et al.[13] reported the early functional outcomes and clinical results of this procedure in 40 patients. The status of 80% of these patients was self-reported as good or excellent at an average of 28 months' follow-up (24 to 53 months). Ninety-five percent had resolution of preoperative symptoms, and only 12% reported symptoms of fatigue and discomfort. The authors concluded that this technique is an appropriate and reliable intervention for active patients with chronic refractory biceps symptoms.

Few studies have looked at the midterm and long-term outcomes for surgical treatments of LHBT-related pathologic conditions.[17-20] Additionally, these studies suggest that some of the clinical benefits of biceps tenodesis may, in fact, deteriorate with time. Becker and Cofield[7] reported that although 94% of patients showed symptomatic improvement at 6

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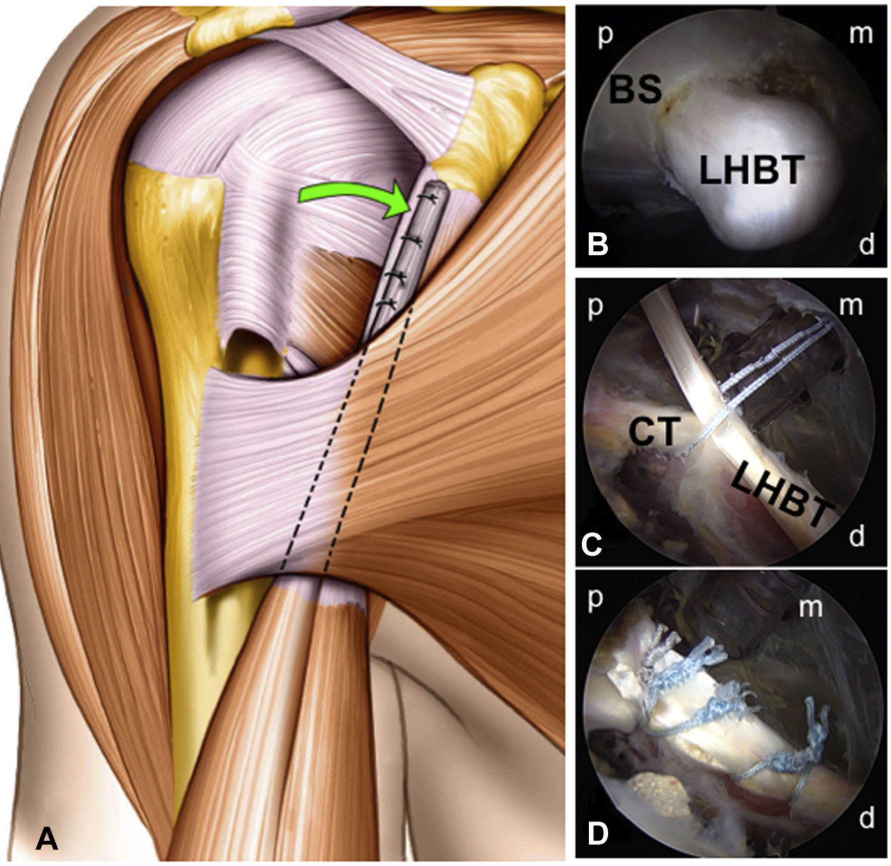

Fig 1. (A) Subdeltoid transfer (arrow) of the long head of the biceps tendon (LHBT) to the conjoint tendon (CT). (B) An aperture is created in the overlying bicipital sheath (BS) so that the LHBT can be delivered into the subdeltoid space. (C) The LHBT is then tensioned in parallel with the conjoint tendon and (D) is secured with sutures. (d, distal; m, medial; p, proximal.)

months postoperatively, only 50% of patients sustained this relief 13 years later at final follow-up. For this reason, midterm outcome data for LHBT transfer to the conjoint tendon would provide valuable insight about the durability of the previously reported short-term improvements in functional outcomes. The purpose of this study was to assess the midterm functional outcomes for arthroscopic subdeltoid transfer of the LHBT to the conjoint tendon. We hypothesized that this is a safe procedure and that previously reported 2-year outcomes would persist into the midterm.

Methods

This study was approved by our institutional review board. Arthroscopic subdeltoid transfer of the LHBT to the conjoint tendon was performed in accordance with previous descriptions[13-16] for chronic refractory LHBT-related symptoms. No other tenodesis techniques were used. However, it should be noted that low-demand patients older than 65 years of age with biceps—labrum complex—related symptoms were treated with simple tenotomy alone and thus were not included in this series. Our diagnostic algorithm included a history of anterior shoulder pain present for at least 3 months. Symptoms were reproducible by provocative maneuvers such as the “3-pack” physical examination (tenderness with palpation of the bicipital groove, positive throwing test result, and positive active compression test result)[21] or other traditional tests. Advanced imaging results, most commonly magnetic resonance imaging, were reviewed for all patients. For patients with equivocal examination and imaging results, a diagnostic injection with local anesthetic that produced symptomatic relief confirmed a diagnosis of biceps tendinitis.

A single senior surgeon (S.J.O.) performed all procedures. American Society of Shoulder and Elbow Surgeons (ASES) and L’Insalata scores were collected and analyzed at the time of most recent follow-up. A convenience sample composed of all geographically available and willing patients underwent an independent clinical follow-up examination by a physician other than the treating surgeon and completion of the University of California, Los Angeles (UCLA) shoulder assessment score.

During transfer of the LHBT to the conjoint tendon, it is first tenotomized at its intra-articular origin (Fig 1, Video 1, available at www.arthroscopyjournal.org). Once the subdeltoid space has been exposed,[16] the LHBT is delivered through an aperture created in the bicipital sheath just proximal to the proximal margin of the pectoralis major tendon. The LHBT is then transferred medially, positioned anterior to the lateral edge of the conjoint tendon in parallel, and secured with sutures.

Patients who underwent arthroscopic subdeltoid LHBT transfer to the conjoint tendon from 2002 to 2008 were included. These dates were chosen to allow for a minimum of 4 years' follow-up and yielded 93 shoulders for potential inclusion. Thirty-seven shoulders were excluded for having undergone one or several concomitant procedures (acromioplasty, labral repair, or capsulorrhaphy, acromioclavicular joint excision, or rotator cuff repair, or a combination of these procedures), leaving 56 shoulders in 54 patients for final analysis. Those who underwent removal of loose bodies, limited labral debridement, or bursal subacromial decompression (without acromioplasty) were not excluded because of the common nature of these procedures. Bursal debridement was considered separately from acromioplasty because it was commonly performed for visualization during the procedure. Those who underwent acromioplasty were excluded because bony resection is not typically required of subdeltoid exposure and may reflect a larger clinical picture of impingement and cuff disease. The average time to follow-up was 6.4 years (range, 4 to 10 years). Patient-reported functional outcomes included the ASES evaluation form (100-point scale) and the L'Insalata shoulder rating questionnaire (100-point scale). Patients also completed a visual analog scale (VAS) pain score (scored 0 to 10). Patient demographics are noted in Table 1. In patients who underwent staged bilateral procedures, each shoulder was considered independently in the subsequent analysis.

A subset of patients with 12 operated shoulders returned for follow-up physical examination and evaluation with the UCLA outcomes instrument. Patients with the remaining 44 shoulders cited either time or distance as their reason for refusal but agreed to fill out the aforementioned outcome surveys. Those who underwent examination had an average age of 41 years, and average time to follow-up examination was 6.3 years. Additionally, these patients were asked to perform isolated biceps curls with a 10-lb weight to failure or until 50 repetitions were achieved to calculate differences in biceps endurance between sides. Elbow flexion repetitions were performed in maximal forearm supination to minimize the contribution of the brachioradialis muscle, and failure was defined as a patient's inability or unwillingness to perform additional repetitions. Patients were interviewed about postoperative symptoms of fatigue and discomfort.

A member of the research team with advanced training in biostatistics performed statistical analyses using SAS software, version 9.3 (SAS Institute, Cary, NC). Descriptive statistics were used to determine the distribution of continuous data. Unpaired Student *t* tests were used to evaluate differences in continuous outcomes between patient groups; paired Student *t* tests were used to compare continuous variables collected bilaterally (e.g., number of biceps curls). χ-square and Fisher exact tests were used, as appropriate, to compare frequencies of count variables (e.g., provocative tests and concomitant procedures) between patient groups. All comparative analyses were 2-tailed and used $P = .05$ as the threshold for statistical significance.

To evaluate for sampling bias in this convenience sample, demographics and predictor variables were compared between those who were available for follow-up and those who were not.

Table 1. Patient Demographics of the 56 Shoulders Analyzed

Demographic Variable	Mean ± SD	Range
Age	42 ± 16	15-79
	Frequency	Percent
Sex		
Male	46	85.2
Female	8	14.8
Dominant-side surgery		
Yes	34	60.7
No	22	39.3
Job activity		
Active	42	77.8
Inactive	12	22.2
Sports participation		
Yes	26	48.1
No	28	51.9

NOTE. Dominant-side surgery calculated by number of shoulders (N = 56). Sex, job activity, and sports participation calculated by number of participants (N = 54).

SD, standard deviation.

Results

In the 56 shoulders in 54 patients (46 men, 8 women; mean age, 42 years) evaluated, ASES composite, ASES function, and L'Insalata scores were 86, 2.6, and 85, respectively. The mean VAS pain score was 1.47. According to the ASES composite score, 88% of patients reported good to excellent results. Outcome scores are seen in Table 2. There were no differences in ASES composite (P = .50), ASES function (P = .30), and L'Insalata (P = .56) scores between those who were included and those who were excluded for concomitant pathologic conditions.

Twelve shoulders (10 from men and 2 from women; mean age, 41 years; average follow-up, 6.3 years) were available for clinical examination by an independent orthopaedic surgeon. The UCLA score for this group was 31. Eighty-three percent of patients had no tenderness on palpation of the bicipital groove, 83% had a negative throwing test result, and 100% of patients had a negative active compression test result. There were no significant differences in side-to-side

Table 2. Functional Outcome Scores of the 56 Shoulders Analyzed

Outcome Score	Mean ± SD	Range
ASES Composite	86 ± 21	17-100
ASES function	2.6 ± 0.6	0.5-3.0
L'Insalata	85 ± 18	15-100
UCLA*	31 ± 7	2-35
ASES Rating	**Frequency**	**Percent**
Excellent	25	44.6
Very good	19	33.9
Good	5	8.9
Fair	2	3.6
Poor	5	8.9

ASES, American Society of Shoulder and Elbow Surgeons; SD, standard deviation; UCLA, University of California, Los Angeles.

*UCLA score was calculated only in those who were available for clinical examination (n = 12).

elbow flexion strength or endurance using a 10-lb weight (unpaired *t* test; $P > .05$).

Ninety-two percent of shoulders had a normal biceps contour (Fig 2). One patient (8%) had a Popeye sign. Five patients (8.9%) underwent a second procedure to the ipsilateral shoulder. One patient underwent a total shoulder arthroplasty 8 years after biceps transfer. Four patients (7.1%) underwent arthroscopic excision of scarring; all of these patients had undergone a previous surgical procedure by another orthopaedic surgeon before biceps transfer (rotator cuff repair [n = 2], SLAP repair [n = 1], and anterior stabilization [n = 1]). No major complications, including chronic regional pain syndrome, fracture, permanent or temporary neurologic injuries, vascular injuries, or infection occurred in this cohort.

Fig 2. Clinical case example. An active-duty firefighter after bilateral arthroscopic subdeltoid LHBT transfer procedures. Biceps contour and strength was preserved.

Through comparative analyses using the Wilcoxon rank-sum test and the Fisher exact test, no differences were noted in any demographic variable (age, $P = .49$; sex, $P = 1.0$, sports participation, $P = .52$; job activity, $P = .71$), surgical variable (dominant-side surgery, $P = .33$), or functional outcome score (ASES composite, $P = .79$; ASES function, $P = .84$; and L'Insalata scores, $P = .38$) between those who were examined and those who were unavailable for examination.

Discussion

Although the majority of patients with LHBT pathologic conditions respond favorably to conservative measures, a subset of patients have persistent symptoms that may benefit from surgical intervention. Many different operative techniques have been described.[4-9,12-15] They vary by anatomic location of tenodesis (proximal or distal), tissue healing (metaphyseal bone, diaphyseal bone, or soft tissue), and mode of fixation (suture anchors, screws, or sutures). The successful midterm functional and clinical outcomes for LHBT transfer to the conjoint tendon reported here may stem from technical factors such as decompression of the bicipital tunnel[22,23] and soft tissue—to—soft tissue suture fixation.

The extra-articular segment of the LHBT and bicipital groove is difficult to assess with an arthroscope and is also a common location of pathologic processes (Fig 3).[22] Although positioning the arm in 30° forward flexion, 40° abduction, and 90° elbow flexion was shown to improve proximal excursion of the LHBT during simulated pull of an arthroscopic probe,[24] Taylor et al.[22] recently showed that a substantial portion of the LHBT remains hidden from arthroscopic view even under ideal circumstances (45% relative to the proximal margin of the pectoralis major tendon). Furthermore, they showed that 47% of patients (129 of 277) with chronic biceps symptoms had extra-articular lesions that were concealed from view during standard diagnostic arthroscopy Of particular relevance to technique, 45% of patients in their series with arthroscopically identified intra-articular lesions also had hidden extra-articular lesions. This suggests that proximal tenodesis techniques that do not address the extra-articular segment may result in unaddressed lesions and persistent symptoms.

The clinical impact of such hidden lesions may be extrapolated from a recent clinical series from Sanders et al.[6] that stratified outcomes based on surgical technique. They reviewed 127 bicep surgical procedures for clinical failure, which they defined as persistent pain to the bicipital groove significant enough to necessitate a revision procedure. They found a significantly higher revision rate for procedures in which the bicipital sheath was not released compared with those that did release the sheath (20.6% *v* 6.8%). Taylor et al.[23]

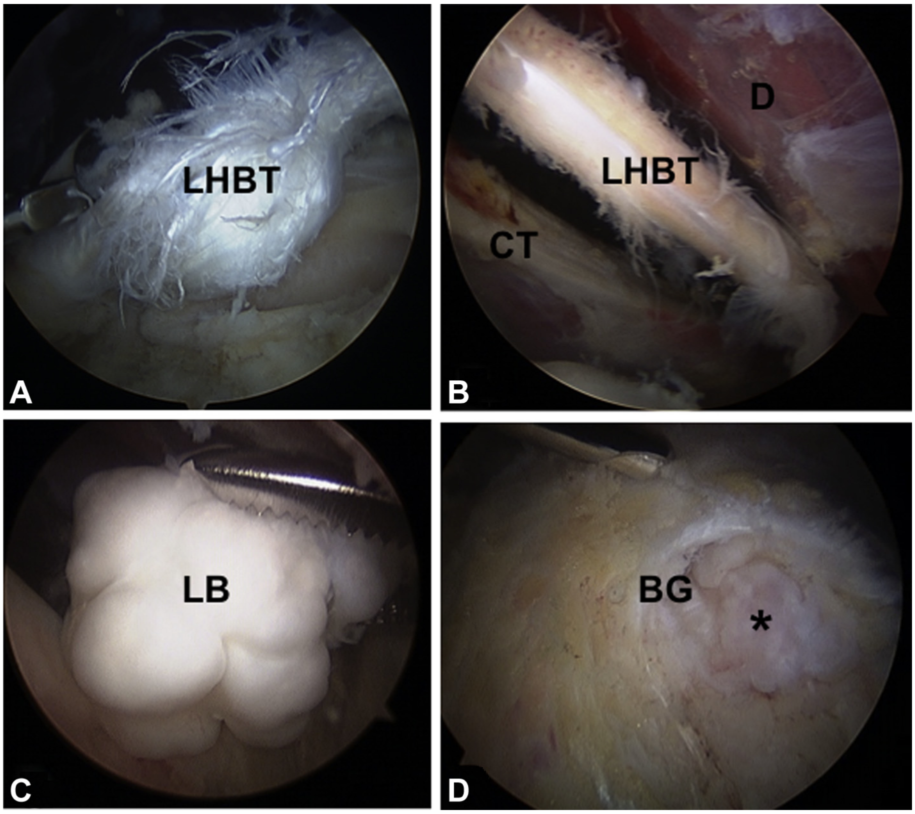

Fig 3. Symptomatic hidden lesions may occur within the bicipital tunnel. Such lesions can include (A) partial tearing of the long head of the biceps tendon (LHBT), (B) scar/adhesion formation, (C) loose body collection, and (D) osteophyte formation (asterisk) along the floor of the bicipital tunnel. (CT, conjoint tendon; D, deltoid; BG, bicipital groove; LB, loose body.)

defined the extra-articular fibro-osseous confinement of the LHBT from the articular margin through the subpectoral region as the “bicipital tunnel.”

Subpectoral tenodesis has become a commonly used surgical technique.[10-12] This procedure effectively decompresses the aforementioned bicipital tunnel (much like transfer to the conjoint tendon). In so doing, it has the advantage of addressing the high incidence of hidden extra-articular bicipital tunnel lesions.[22] Subpectoral tenodesis, however, is not without complications. Although Nho et al.[25] reported only a 2% complication rate in their series of 353 patients treated with subpectoral biceps tenodesis, others have reported major complications, including fracture[26-30] and neurologic injury.[31,32] The musculocutaneous nerve, radial nerve, and deep brachial artery are within 1 cm of the standard medial retractors used for exposure.[33] Rhee et al.[31] described cases in which the musculocutaneous and median nerves inadvertently underwent tenodesis instead of the LHBT. They also described a radial nerve injury from Beath pin penetration and a traction injury of the posterior cord during subpectoral tenodesis.

The drill hole made in the humeral shaft during subpectoral tenodesis forms a stress riser. Two early reports attributed postoperative humeral fracture to the stress riser created by the diaphyseal keyhole.[28,29] Three more recent reports identified patients who sustained proximal humeral fractures after subpectoral tenodesis with interference screw fixation.[26,27,30] Sears et al.[26] concluded that, “it may also be advisable to limit activities during the postoperative period that increase stress levels across the cortical defect… prior to filling in the cortical defect in bone.” LHBT transfer to the conjoint tendon relies on a soft tissue–to–soft tissue suture fixation and thus obviates the need for osseous drilling or the introduction of hardware.

Furthermore, subdeltoid arthroscopy affords excellent visualization of the extra-articular anterior shoulder structures[16] (Fig 4). The musculocutaneous nerve usually pierces the conjoint tendon 4.9 cm from the tip of the coracoid but was found to have a variable range from 2.0 to 9.0 cm.[34] When present proximally, the musculocutaneous nerve is readily visualized and easily avoided by restricting sutures to the lateral third of the conjoint tendon (Fig 4D).

The LHBT is easily identified and exposed within the bicipital tunnel just proximal to the proximal margin of the pectoralis major tendon. A radiofrequency device is used to open the bicipital tunnel along its lateral margin under direct visualization. This prevents errant medial dissection and mitigates risk to the aforementioned neurovascular structures. The LHBT is then sutured to the conjoint tendon in a soft tissue–to–soft tissue fashion. One potential criticism would be that unlike open subpectoral tenodesis, which excises the proximal

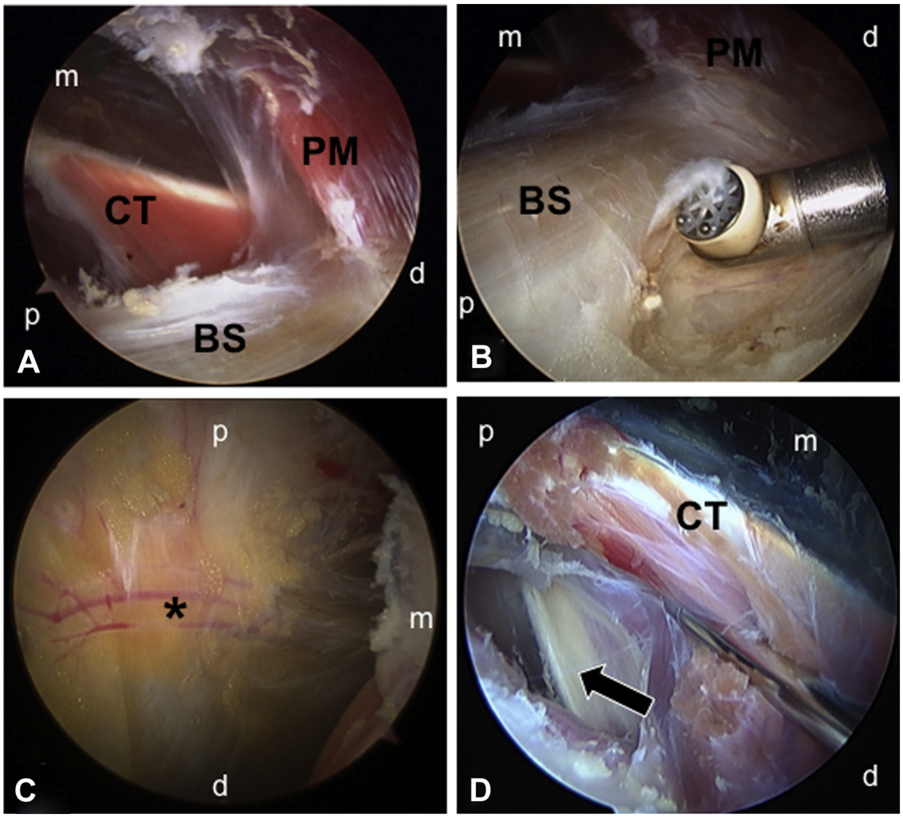

Fig 4. (A, B) Structures visualized with the arthroscope in the subdeltoid space include the conjoint tendon (CT), bicipital sheath (BS), and the pectoralis major (PM). (C) The "3-sisters" vessels (asterisk) can be identified along the inferior margin of the subscapularis. (D) When present more proximally, the musculocutaneous nerve (arrow) is readily identifiable. (p, proximal; d, distal; m, medial.)

segment of tendon, our transfer procedure uses it for fixation to the conjoint tendon. Although we commonly observe this segment of tendon to be diseased, fixation is achieved over approximately 3 cm of tendon length with 4 separate sutures, enabling easy bypass of the potentially diseased tendon segment. In addition to the soft tissue—to—soft tissue fixation, this technique also has the added advantage of direct decompression of the bicipital tunnel to ensure that extratendinous pathologic conditions within the bicipital tunnel, such as synovitis and loose bodies, are not left behind.

In this series of 56 shoulders that underwent subdeltoid transfer of the LHBT to the conjoint tendon, no major complications such as neurovascular injury, fracture, infection, or chronic regional pain syndrome were encountered. The one patient with a Popeye sign ruptured the transfer fixation in the early postoperative period when he lifted a propane tank with the ipsilateral arm. Revision surgery was offered but not pursued. A recent systematic review reported a Popeye sign prevalence of 8% and 43% among patients who underwent tenodesis and tenotomy, respectively.[35] One patient in our series underwent total shoulder arthroplasty 8 years after his biceps transfer procedure. Despite his advanced glenohumeral osteoarthritis, biceps transfer was indicated because of a large loose body within the bicipital tunnel and biceps symptoms that predominated. As a result, his arthroplasty was effectively delayed for 8 years. Four patients (7.1%) underwent subsequent arthroscopic debridement for symptoms attributed to formation of subdeltoid scar. All 4 of these patients had undergone a previous surgical procedure by another orthopaedic surgeon before biceps transfer (rotator cuff repair [n = 2], SLAP repair [n = 1], and anterior stabilization [n = 1]). At final follow-up, the status of 2 of the 4 patients were rated as very good, one was rated fair, and one was rated poor.

It should be noted that this soft tissue—to—soft tissue tenodesis of the LHBT to the conjoint tendon can also be performed through the deltopectoral interval with a miniopen incision. Some surgeons at our institution prefer the miniopen version of the procedure because it may be more expeditious and comfortable for those who do not routinely navigate the subdeltoid space with an arthroscope.

The current study, to our knowledge, is the largest midterm or long-term series in the literature for any LHBT procedure. Becker and Cofield[7] reported that the beneficial effects of open biceps tenodesis dissipated over time. In their series of 51 patients, 94% showed symptomatic improvement 6 months postoperatively, but only 50% achieved satisfactory results at an average of 13 years' follow-up. In their small series, Berlemann and Bayley[20] found that only 64% of patients (9 of 14) had good or excellent results 7 years after biceps tenodesis. Edwards et al.[17] reported that a biceps procedure (tenodesis or tenotomy) was associated with improved outcome measures at 45 months postoperatively in their series of 84 shoulders that underwent open subscapularis repair.

Our findings show the efficacy and durability of clinical and functional outcomes for subdeltoid transfer of the LHBT to the conjoint tendon. Drakos et al.[13] reported good short-term outcomes after subdeltoid LHBT transfer to the conjoint tendon at an average of 28 months postoperatively. They found ASES, L'Insalata, and UCLA scores to be 79.6, 78.9, and 27.8, respectively. Five percent of patients had a Popeye sign postoperatively. The current study reveals that these results are durable in to the midterm to long term as well at a mean follow-up of 5 years. In the current study, those who underwent concomitant procedures had favorable outcomes similar to those who underwent isolated LHBT transfer to the conjoint tendon.

Limitations

There are some limitations to this study. A single surgeon performed all the procedures, which may limit the generalizability of the outcome data. During the time of this study, our treatment algorithm called for simple tenotomy for chronically symptomatic low-demand patients older than the age of 65 years. This adds the potential for selection bias because these patients did not undergo a biceps transfer procedure and thus were not included in the analyzed cohort. Furthermore, the senior surgeon has been performing this procedure for 14 years. Patients from the first 2 years were not included in this series because the details of the technique were still under development, and thus this series does not consider the learning curve. A prospective study is under way to elucidate the learning curve. The subset of patients who were examined was made up of a regional convenience sampling, which may have induced some selection bias. Examined and nonexamined patients, however, were statistically similar with regard to all collected demographic, surgical, and outcome variables, suggesting comparability and lack of selection bias. Although supination strength would have been a better assessment of biceps strength symmetry, simple biceps curls with a 10-lb weight were used in this study because of precedent in the literature.[5,13] Furthermore, we had patients perform curls with the forearm supinated to limit the contribution of the brachioradialis muscle and more aptly isolate the biceps muscle contribution to elbow flexion. Despite these limitations, the midterm outcomes and results of the current study are valuable to shoulder surgeons who treat this common clinical entity.

Conclusions

Arthroscopic subdeltoid transfer of the LHBT to the conjoint tendon is a safe and durable intervention for patients with chronic refractory biceps tendinitis.

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