Diagnostic Glenohumeral Arthroscopy Fails to Fully Evaluate the Biceps-Labral Complex

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Purpose: The purpose of this study was to define the limits of diagnostic glenohumeral arthroscopy and determine the prevalence and frequency of hidden extra-articular "bicipital tunnel" lesions among chronically symptomatic patients. **Methods:** Eight fresh-frozen cadaveric specimens underwent diagnostic glenohumeral arthroscopy with percutaneous tagging of the long head of the biceps tendon (LHBT) during maximal tendon excursion. The percentage of visualized LHBT was calculated relative to the distal margin of subscapularis tendon and the proximal margin of the pectoralis major tendon. Then, a retrospective review of 277 patients who underwent subdeltoid transfer of the LHBT to the conjoint tendon were retrospectively analyzed for lesions of the biceps-labral complex. Lesions were categorized by anatomic location (inside, junctional, or bicipital tunnel). Inside lesions were labral tears. Junctional lesions were LHBT tears visualized during glenohumeral arthroscopy. Bicipital tunnel lesions were extra-articular lesions hidden from view during standard glenohumeral arthroscopy. **Results:** Seventy-eight percent of LHBT were visualized relative to the distal margin of the subscapularis tendon and only 55% relative to the proximal margin of the pectoralis major tendon. No portion of the LHBT inferior to the subscapularis tendon was visualized. Forty-seven percent of patients had hidden bicipital tunnel lesions. Scarring was most common and accounted for 48% of all such lesions. Thirty-seven percent of patients had multiple lesion locations. Forty-five percent of patients with junctional lesions also had hidden bicipital tunnel lesions. The only offending lesion was in the bicipital tunnel for 18% of patients. **Conclusions:** Diagnostic glenohumeral arthroscopy fails to fully evaluate the biceps-labral complex because it visualizes only 55% of the LHBT relative to the proximal margin of the pectoralis major tendon and did not identify extra-articular bicipital tunnel lesions present in 47% of chronically symptomatic patients. **Level of Evidence:** Level IV, therapeutic case series and cadaveric study.

Biceps-labral complex lesions present a diagnostic dilemma in the shoulder, both in the differential diagnosis of pain and as a comorbid condition with rotator cuff pathologic conditions, instability, and glenohumeral arthritis. Traditional physical examination maneuvers such as Speed's test and Yergason's test attempt to elicit bicipital symptoms, but they show moderate sensitivity and poor specificity.[1,2] Ultrasonography[3] and magnetic resonance imaging[4] are helpful diagnostic adjuncts but remain operator and reader dependent, limiting their diagnostic utility.[5] Moreover, studies have shown that magnetic resonance imaging has moderate specificity and moderate-to-poor sensitivity for the long head of the biceps tendon (LHBT) pathologic conditions compared with arthroscopy. Thus, the arthroscopic pull test, in which a probe is used to pull the LHBT intra-articularly to provide a more comprehensive view of the tendon's distal segment residing within the bicipital groove, is considered the gold standard diagnostic modality (Fig 1).[2-4,6]

Perhaps diagnostic glenohumeral arthroscopy with the LHBT pull test should not be considered the gold standard? Arthroscopically identified LHBT pathologic conditions treated with surgery may produce undesirable outcomes in nearly a quarter of patients.[7] A systematic review reported persistent biceps symptoms in 19% of tenotomy patients (43 of 226) and in 24% of tenodesis patients (18 of 74).[7] Another study[8] reported

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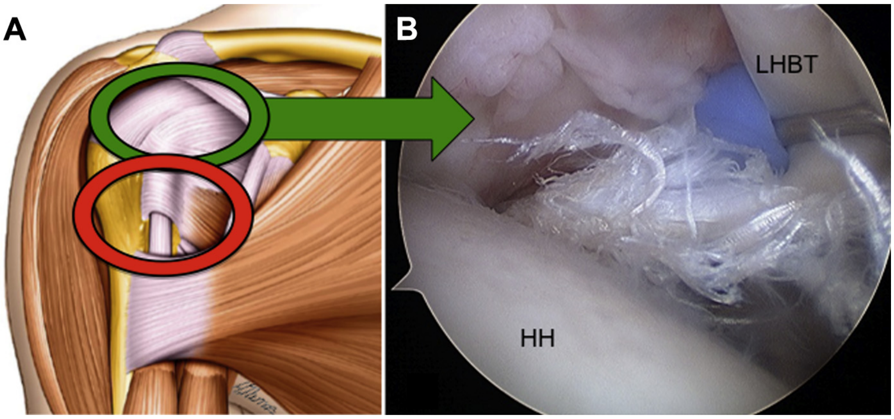

Fig 1. (A) The biceps-labral complex exists in continuum and consists of both an intra-articular component (green circle) and an extra-articular segment (red circle). (B) The long head of the biceps tendon (LHBT) is examined during diagnostic glenohumeral arthroscopy by using a probe to pull it intra-articularly, looking for abnormalities such as partial tearing as seen here in this left shoulder. (HH, humeral head.)

a 15% revision rate for biceps tenodesis. The reasons for failure may be mechanical, technical,[9] or, as we suggest, caused by hidden extra-articular lesions affecting the LHBT[10-16] that go unrecognized during diagnostic glenohumeral arthroscopy with a pull test.

To this end, our clinical experience suggests that the extra-articular segment of the LHBT consistently resides within a closed fibro-osseous tunnel that extends from the articular margin through the subpectoralis region. We prefer the term "bicipital tunnel" to describe this extra-articular fibro-osseous structure through which the LHBT courses (Fig 2). It is important to note that the bicipital groove and bicipital tunnel are not synonymous. In fact, the bicipital groove represents only the proximal one third of the bicipital tunnel.[15] Space-occupying lesions within the bicipital tunnel such as loose bodies, scar tissue, bony stenosis, and osteophytes may produce a "bicipital tunnel syndrome." Currently, there is a paucity of literature about such extra-articular lesions. This study presents a novel concept and in so doing expands our collective acumen.

The purpose of this study was to define the limits of diagnostic glenohumeral arthroscopy and determine the prevalence and frequency of hidden extra-articular bicipital tunnel lesions among chronically symptomatic patients. We hypothesized that diagnostic glenohumeral arthroscopy offers an incomplete evaluation of the extra-articular LHBT and that concealed extra-articular bicipital tunnel lesions are common among chronically symptomatic patients.

Methods

The study was approved by our institutional review board. The Surgeon-in-Chief Fund for resident/fellow research at Hospital for Special Surgery provided funding. No external funding sources were used.

Cadaveric Assessment

Ten adult human fresh-frozen cadaveric specimens were considered for arthroscopic evaluation and dissection. Two specimens were excluded after diagnostic arthroscopy revealed the presence of a massive rotator cuff tear in one and absence of the LHBT in the other. The remaining 8 specimens, with a mean age of 78.25 years ($\pm$ 13.7 years) were included in the data analysis. Upper extremity specimens extended from midclavicle to finger tips. No surgical scars, evidence of previous trauma, gross deformities, or Popeye signs were identified in any of the specimens. Passive glenohumeral and elbow range of motion were full for all specimens.

Diagnostic glenohumeral arthroscopy was performed through a single standard posterior viewing portal. All included specimens had an intact rotator cuff and an LHBT in continuity without visible intra-articular pathologic processes. A standard anterior rotator interval portal was placed under direct visualization and spinal needle localization. To obtain maximal biceps visualization, as reported by Hart et al.,[17] the upper extremity was maintained in the 30-40-90 position (30° of shoulder forward flexion, 40° of abduction, and 90° of elbow flexion). Angular measurements were made with a goniometer.

With the arthroscope in the posterior portal, the LHBT was tagged twice under direct arthroscopic visualization using a percutaneous spinal needle and passage of a No. 0 polydioxanone suture. The first polydioxanone suture tag was placed "at rest" in the most distally visualized portion of the LHBT without any tension applied (Fig 3A). An arthroscopic grasper was then introduced through the anterior rotator interval portal and used to grasp the LHBT at a distance halfway between the first tag suture and the proximal insertion of the LHBT at the supraglenoid tubercle to approximate the force vector applied by a probe during the pull test in clinical practice and according to precedent in the literature.[17] A posteroinferiorly directed force was applied manually until maximal tendon excursion was achieved. The same investigator (S.A.T.) performed this portion of the experiment in all specimens. Although this traction was maintained, as was the LHBT, in a position of maximal intra-articular excursion, a second polydioxanone suture tag was

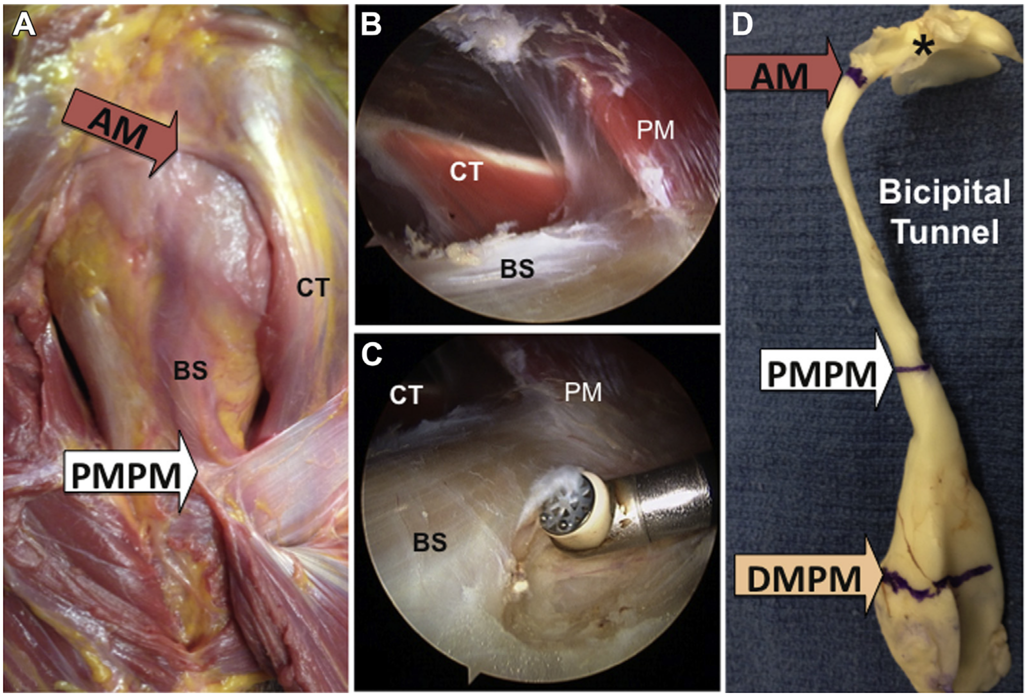

Fig 2. (A) Gross dissection of a right shoulder shows that the bicipital sheath (BS) that envelops the long head of the biceps tendon (LHBT) and runs in continuum with it from the articular margin (AM) through the subpectoralis region distally to the distal margin of the pectoralis major tendon (DMPM). (B) The arthroscopic anatomy is clearly defined in a right shoulder viewed from an anterolateral portal within the subdeltoid space. (C) The bicipital sheath was present in all patients who underwent surgery and can be quite robust. (D) The bicipital tunnel was injected with methacrylate bone cement, allowed to harden, and then dissected to show that the bicipital tunnel is a completely closed space in which space-occupying lesions such as scars, loose bodies, osteophytes, or bony stenosis may become pathologic. (Asterisk defines intra-articular space.) (CT, conjoint tendon; PMPM, proximal margin pectoralis major tendon; PM, pectoralis major.)

placed at the most distally visualized portion of the tendon (Fig 3A).

Specimens were then dissected through an extended deltopectoral exposure with the upper extremity "at rest" in the 30-40-90 position. The LHBT was tagged at accepted and reproducible anatomic landmarks[7,18,19]: the distal margin of the subscapularis tendon (DMSS) as a reproducible landmark to approximate the distal extent of the bony bicipital groove, the proximal margin of the pectoralis major tendon, and the musculotendinous junction (MTJ) were marked on the LHBT with suture tags (Fig 3 B and C). The extra-articular soft tissues constraining the LHBT were then released and the glenohumeral joint accessed through the rotator interval. The LHBT was tenotomized under direct visualization from its origin using curved Mayo scissors. Distances were measured from the proximal tenotomized LHBT stump to the 2 arthroscopic tag sutures and to each landmark (DMSS, pectoralis major tendon, and MTJ). All measurements were performed by the same coinvestigator (S.A.T.) and confirmed at the time of measurement by a second coinvestigator (M.M.K.). Multiple measurements were not performed because these were static distances. These measurements were then used to calculate primary outcomes: percentage of the LHBT visualized at rest and with maximal excursion relative to the aforementioned anatomic landmarks. Secondary outcomes included the presence of extra-articular hidden LHBT pathologic processes identified during dissection.

Clinical Case Series

Inclusion criteria were arthroscopic transfer of the LHBT to the conjoint tendon as described by Verma et al.[20] for chronic biceps-labral complex symptoms refractory to conservative therapeutic modalities, surgery occurring between January 2002 and September 2011, and complete charts with intraoperative images and operative reports. Exclusion criteria were not having undergone arthroscopic transfer of the LHBT to the conjoint tendon. Patients with concomitant pathologic conditions were not excluded. Two hundred seventy-seven patients met inclusion and exclusion criteria and were considered in this retrospective review. The senior surgeon (S.J.O.) performed all procedures. No other tenodesis techniques were used. Low-demand patients older than 65 years of age with symptoms related to the biceps-labrum complex who were treated with simple tenotomy alone were thus not included in this series

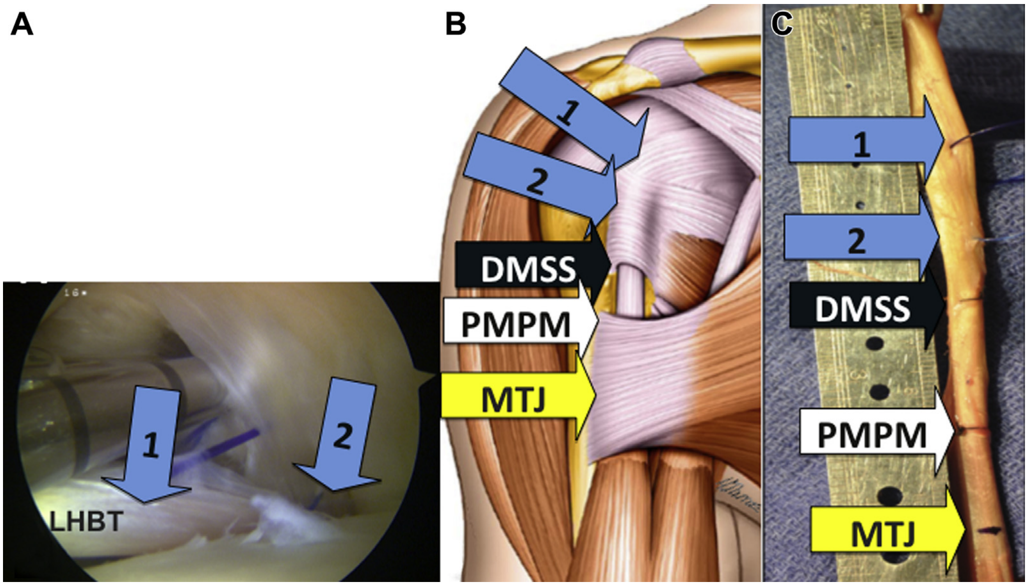

Fig 3. (A) The long head of the biceps tendon (LHBT) was tagged at the most distal portion visualized arthroscopically using a spinal needle and polydioxanone stitch at rest (1), representing the articular margin, and again with maximal excursion of the tendon (2) produced by an arthroscopic grasper. (B and C) The cadaveric specimens were then dissected, and the LHBT was tagged at 3 anatomic landmarks: distal margin of the subscapularis tendon (DMSS), proximal margin of the pectoralis major tendon (PMPM), and the musculotendinous junction (MTJ). (C) The LHBT was then tenotomized at its origin, and the distances were measured to each tagged point.

because the extra-articular bicipital tunnel was not accessed or evaluated in these patients. 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—(1) tenderness with palpation of the bicipital tunnel, (2) positive throwing test, (3) positive active compression test—[21] or other traditional tests (Speed's or Yergason's test). The throwing test is performed with the shoulder abducted to 90°, the elbow flexed to 90°, and maximal external rotation as if to throw a ball overhand in the late-cocking position. The patient steps forward with the contralateral leg and moves into the acceleration phase of throwing while the examiner provides resistance. A positive result is indicated by reproduction of the patient's pain anteriorly in the bicipital tunnel. Advanced imaging, most commonly magnetic resonance imaging, was reviewed for all patients. For patients with equivocal examination and imaging, a diagnostic/therapeutic injection with local anesthetic and corticosteroid that produced symptomatic relief confirmed a diagnosis of biceps tendinitis. Ultrasonographic guidance was used for patients whose body habitus precluded accurate localization. The mean patient age was 44 years (range, 13 to 83 years). Two hundred fifteen (78%) were male patients and 62 (22%) were female patients.

Transfer of the LHBT to the conjoint tendon through the subdeltoid space[14,16,22,23] offered a unique opportunity to visualize the biceps-labral complex along its entire course from its origin to the proximal margin of the pectoralis major tendon. Lesions were categorized as "inside," "junctional," or "bicipital tunnel" based on their anatomic location. In all cases, lesions were categorized based on direct visual assessment during glenohumeral arthroscopy (inside and junctional lesions) and subdeltoid arthroscopy (bicipital tunnel lesions).

The aforementioned categories are defined as follows:

"Inside" lesions were assessed during diagnostic glenohumeral arthroscopy and included SLAP tears, anterior labral tears, posterior labral tears, and positive arthroscopic active compression test results.[24] While we did report the prevalence of the arthroscopic active compression test in this chronically symptomatic cohort, it was excluded from final analysis of pathologic lesions to avoid controversy since it may be a normal finding in a subset of asymptomatic individuals.

"Junctional" lesions were those visualized during diagnostic glenohumeral arthroscopy including the arthroscopic pull test in which a probe was used to pull the LHBT intra-articularly. These intra-articular lesions included partial tears of the LHBT greater than 10%, synovitis, proximal instability (caused by subscapularis tears or pulley lesions), and biceps chondromalacia.[25-29] Although we report the prevalence of biceps chondromalacia, it was excluded from final analysis because it is not yet an accepted pathologic lesion. Synovitis was excluded because it was not consistently reported in the operative record.

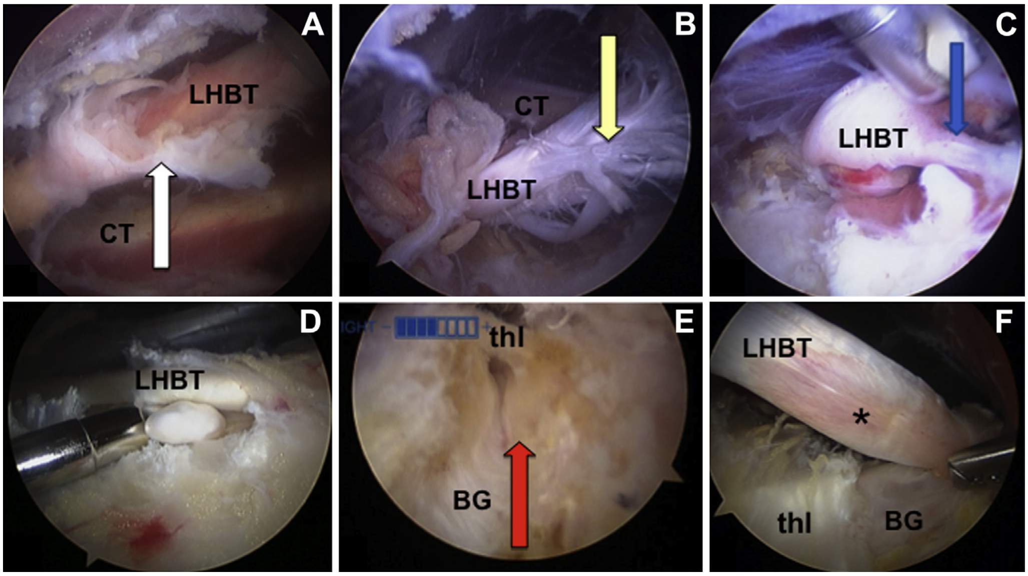

Fig 4. Several abnormal lesions were identified in the fibro-osseous extra-articular segment of the long head of the biceps tendon (LHBT) from within the subdeltoid space during arthroscopic transfer of the LHBT to the conjoint tendon (CT), despite a normal intra-articular arthroscopic examination. Representative examples included (A) scarring (white arrow), (B) partial tearing (yellow arrow), (C) symptomatic vincula (blue arrow), (D) loose bodies, (E) bony stenosis of the bicipital groove (red arrow), and (F) instability characterized by a shallow broad osseous floor, gossamer transverse humeral ligament (thl), and resulting irritation of the LHBT (asterisk). (BG, bicipital groove.)

"Bicipital tunnel" lesions were extra-articular lesions that remained hidden from view during glenohumeral arthroscopy and the pull test but were directly visualized during subdeltoid arthroscopy[22] after release of the bicipital sheath. Although we define the bicipital tunnel as extending into the subpectoralis region, our arthroscopic technique limited visualization to the section of the bicipital tunnel between the articular margin and the proximal margin of the pectoralis major tendon, because this was the distal extent of dissection. Bicipital tunnel lesions included scarring,[30-32] instability, stenosis, partial tears of the LHBT greater than 10%, loose bodies, synovitis, and symptomatic vincula (Fig 4). Scarring was defined as abnormal tissue adherent to the LHBT and surrounding fibro-osseous bicipital tunnel. Instability was defined by a thin overlying bicipital sheath, broad and flat osseous floor, and corresponding gross injury to the LHBT. Symptomatic vincula were defined by their thickened, indurated, and inflamed appearance, which differentiated them from normally occurring vincula.[33] Synovitis was excluded because it was not consistently reported in the operative record.

Primary outcomes included (1) prevalence of inside lesions during diagnostic glenohumeral arthroscopy, (2) prevalence of junctional lesions during diagnostic glenohumeral arthroscopy, and (3) prevalence of extra-articular bicipital tunnel lesions visualized after the bicipital sheath was released during subdeltoid arthroscopy. Secondary outcomes included lesion subcategory and age analyses by unpaired homoscedastic 2-tailed *t* test.

Results

Cadaveric Dissection

The average length of the LHBT arthroscopically visualized at rest was 35.6 mm ± 6.2 mm (Table 1). This represents an average of 56.3% ± 6% of the total length of the LHBT relative to the DMSS, 39.6% ± 6% of the total length of the tendon with respect to the proximal margin of the pectoralis major tendon, and 33.0% ± 5.2% relative to the MTJ. With maximal pull on the LHBT into the glenohumeral joint, an additional 13.9 mm of tendon could be visualized. The average percentage of LHBT visualized was improved to 78.4% ± 5.2% with respect to the DMSS, 55% ± 6.1% with respect to the pectoralis major tendon, and 45.9% ± 5.2% with respect to the MTJ (Table 2).

Table 1. Cadaveric Measurements

Distance From LHBT Insertion at Superior Labrum to:	Millimeters	Standard Deviation
Tag at rest (1)	35.6	6.2
Tag at maximal excursion (2)	49.5	6.6
DMSS	63	5.8
PMPM	89.9	3.1
Distance to musculotendinous junction	107.9	6.6
Between DMSS and PMPM	27.1	3.8

DMSS, distal margin of subscapularis tendon; LHBT, long head of the biceps tendon; PMPM, pectoralis major tendon.

Table 2. Percentage of LHBT Visualized During Diagnostic Glenohumeral Arthroscopy

Distance From LHBT Insertion at Superior Labrum to:	At Rest (Tag No. 1)		Maximal Excursion (Tag No. 2)	
	(%)	Standard Deviation	(%)	Standard Deviation
Distal margin subscapularis tendon	56.3	6	78.4	5.2
Proximal margin pectoralis major tendon	39.6	6	55	6.1
Musculotendinous junction	33	5.2	45.9	5.2

LHBT, long head of the biceps tendon.

Coincidentally, 2 of the 8 cadaveric specimens (25%) had LHBT lesions distal to the most distal arthroscopically visualized portion of tendon. More than 50% degenerative partial tearing was identified in one specimen and partial tearing with hypertrophic scar was seen in the other. Detailed orthopaedic histories for cadaveric specimens were unavailable.

Clinical Series

Two hundred seventy-seven patients who underwent a transfer of the LHBT to the conjoint tendon with complete charts were available for review. Average age was 44 years (14 to 78 years), and there was a male predominance (215 male patients and 62 female patients). Concomitant lesions are listed in Table 3. The prevalence of lesions with corresponding ages are listed in Table 4. One hundred twenty-nine patients (47%) had extra-articular bicipital tunnel lesions that were unrecognized during diagnostic arthroscopy. The most common lesions were scarring (n = 62), instability, (n = 30), stenosis (n = 21), LHBT partial tearing (n = 16), loose bodies (n = 12), and pathologic vincula (n = 9). One hundred twenty-eight patients (37%) had concomitant lesions occurring in more than one zone (Fig 5).

An analysis of lesion type by age is listed in Table 4. Comparisons between groups showed a trend toward significance for junctional and bicipital tunnel lesions occurring in older patients that was greater than that of inside lesions ($P = .059$ and $P = .088$, respectively). No age difference was found between patients with junctional lesions and those with bicipital tunnel lesions ($P = .917$).

Table 3. Concomitant Procedures

Concomitant Procedures	No. of Patients
Subacromial decompression	39
Rotator cuff repair	33
Acromioplasty	29
Excision acromioclavicular joint	25
Manipulation under anesthesia	21
Glenohumeral debridement	14
Anterior stabilization	13
Chondroplasty	12
Subscapularis repair	4
Removal of loose bodies	3
Rotator cuff debridement	1
Excision calcific tendinitis	1
Excision of os acromiale	1

Discussion

This study showed 2 very important concepts. First, diagnostic glenohumeral arthroscopy visualizes only 55% of the LHBT relative to the proximal margin of the pectoralis major tendon. Second, 47% (129 of 277) of chronically symptomatic patients had extra-articular lesions within the bicipital tunnel that were concealed from view during diagnostic glenohumeral arthroscopy.

There has been a surge of interest in LHBT-related pathologic conditions.[7,18,19] Several authors have identified dynamic LHBT lesions of the LHBT that may represent instability of the tendon or abnormal tracking. Verma et al.[24] described a subset of symptomatic patients with arthroscopically normal LHBTs but in whom the tendon incarcerated between the glenoid and humeral head with the arm positioned in forward flexion and internal rotation (i.e., mimicking the active compression test or O'Brien's test). Byram et al.[25] identified a group of patients with humeral head abrasion below the intra-articular portion of the LHBT. Boileau et al.[34] described an "hourglass biceps" lesion in which the tendon hypertrophies proximal to the bicipital groove, resulting in symptomatic entrapment that prevents normal LHBT excursion during shoulder range of motion. Further, they showed that biceps surgery significantly improved the Constant scores in this cohort. The authors cautioned that tenotomy alone might not produce positive clinical outcomes because it fails to address the essential pathologic lesion.

Similarly, we believe that extra-articular scarring and adhesions within the bicipital tunnel can have a significant impact on LHBT excursion that impairs normal glenohumeral motion and kinematics. This hypothesis is supported by a cadaveric model created by McGahan et al.[19] that showed up to 47.3° of lost glenohumeral internal rotation resulting from simulated biceps scarring and adhesion (in situ tenodesis). Our clinical series found that scarring within the bicipital tunnel was by far the most commonly occurring lesion, with a prevalence of 30% among all chronically symptomatic patients, and was present in 48% of those patients in whom extra-articular lesions were identified in this series. In all such cases, standard diagnostic pull-test arthroscopy was unable to visualize this lesion.

In our cadaveric model, we were able to produce an average of 13.9 mm of LHBT excursion. It is likely that extra-articular scar/adhesion would prevent normal

Table 4. Prevalence of Biceps-Labral Complex Lesions With Age Comparison by Unpaired *t* Test

Prevalence of Biceps-Labral Complex Lesions								
		Positive for Condition			Negative for Condition			
Lesion Location and Type	Prevalence, %	No.	Mean Age, y	SD	No.	Mean Age, y	SD	*P* Value
Inside	35	96	40.1	14.1	181	46.1	15.9	.002
Arthroscopic ACT*	44	123	37.5	14.6	154	49.2	14.8	< .001
Any labrum	35	96	40.1	14.1	181	46.1	15.9	.002
SLAP	22	60	42.6	10.7	227	42.4	16.5	.929
Anterior labrum	5	14	35.9	14.9	263	44.4	15.6	.048
Posterior labrum	8	22	36.1	16.8	255	44.7	15.3	.013
Junctional	44	121	43.6	15.6	156	44.3	15.8	.713
Biceps Chondromalacia*	41	113	46.5	14.5	164	42.3	16	.028
Partial tear	41	113	43.3	16.2	164	44.5	15.1	.529
Subscapularis/pulley	3	8	48	14	269	43.9	14.9	.443
Bicipital tunnel	47	129	43.8	14.8	148	38.2	16.2	.003
Scarring	22	62	43.1	14.9	215	44.3	15.4	.587
Instability	11	30	44.1	16.7	247	44	15.5	.974
Stenosis	8	21	44.3	14.4	256	44	15.2	.931
Partial tear	6	16	40.2	10.9	261	44.2	15	.295
Loose body	4	12	52.7	12.6	265	43.6	14.9	.038
Symptomatic vincula	3	9	45.3	12.3	268	44	14.9	.796

ACT, active compression test.

*Nontraditional lesions (biceps chondromalacia and arthroscopic active compression test) are listed here but were excluded from further analysis.

excursion during examination. For this reason, we recommend that the surgeon have a high index of suspicion for bicipital tunnel scar/adhesion if they encounter abnormally limited LHBT excursion during the pull test.

Although we are not the first to describe extra-articular lesions, this study represents the first study to determine their prevalence in a large cohort of chronically symptomatic patients. A plethora of other lesions have been reported in the literature, including bony stenosis,[35] loose bodies,[36] rice body formation,[37,38] partial tearing,[37] osteochondroma,[39] dysplasia,[40] tendonitis,[41,42] and vincula.[41] We identified extra-articular bicipital tunnel lesions in 47% (129 of 277) of chronically symptomatic patients. Interestingly, more than half (75 of 129) of patients with extra-articular lesions had completely normal-appearing intra-articular LHBTs (junction) during diagnostic arthroscopy. Even in our small cadaveric series, 25% (2 of 8) of the specimens had abnormal findings of the LHBT distal to the most visualized segment of tendon.

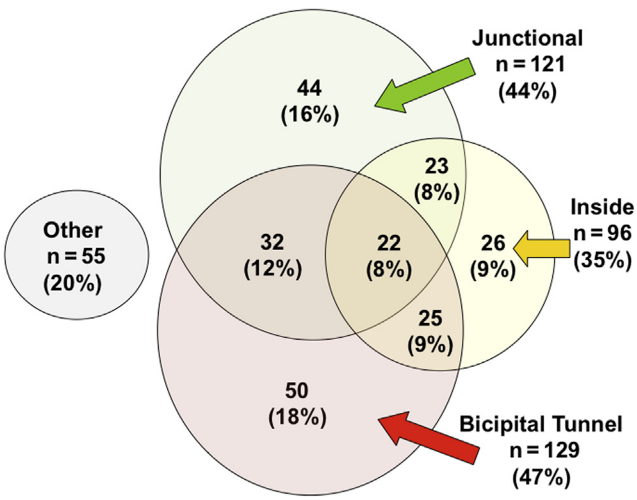

Fig 5. The distribution of biceps-labral complex lesions in this series of 277 symptomatic shoulders that underwent subdeltoid transfer of the LHBT to the conjoint tendon showed that lesions often occurred in multiple anatomic zones (inside, junction, and bicipital tunnel) concomitantly. Biceps chondromalacia and the arthroscopic active compression test, which were not included in our analysis, are represented as "other."

Our cadaveric data clearly show that even in a best-case scenario, diagnostic arthroscopy cannot visualize a substantial portion of the extra-articular biceps tendon or the bicipital tunnel through which it courses. This begs the question: What is the clinically significant portion of the LHBT? In our clinical series, we identified lesions as far distal as the proximal margin of the pectoralis major tendon. Therefore, if we consider the proximal margin of the pectoralis major tendon to be the distal landmark of clinical significance, conventional arthroscopy fails to visualize 45% of the clinically significant portion of the LHBT. Furthermore, diagnostic arthroscopy is completely blind to lesions occurring within the interval between the distal margin of the subscapularis tendon and the proximal margin of the pectoralis major tendon. As previously noted, although we define the bicipital tunnel as extending from the articular margin through the subpectoral region, our extra-articular visualization was limited to the space proximal to the proximal margin of the pectoralis major tendon. This limited our ability to confirm the

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absence of lesions below this structure, and this may be better evaluated by surgeons performing an open subpectoral tenodesis.

Forty-five percent of the patients with arthroscopically confirmed junctional lesions also had hidden extra-articular bicipital tunnel lesions. In this setting, improper surgical technique selection (a proximal tenodesis without bicipital tunnel decompression) would fail to address concomitant extra-articular pathologic conditions. In fact, we hypothesize that these findings may help explain previously published data regarding failure rates for various biceps surgery techniques.[43] The authors retrospectively reviewed 127 patients who underwent biceps surgery for clinical failure, which they defined as persistent pain severe enough to necessitate a revision procedure.[43] They determined that the revision rate was significantly higher for procedures in which the bicipital sheath was not addressed (20.6% *v* 6.8%).

Equally concerning was our finding that 27% of patients (75 of 277) had a completely normal LHBT as visualized by diagnostic glenohumeral arthroscopy but were found to have lesions within the bicipital tunnel. In such a case, the surgeon may errantly choose not to address the biceps tendon because of the paucity of intra-articular (junctional) findings and in so doing leave the patient with an unaddressed pathologic process.

Future studies should help develop diagnostic modalities (imaging and examination) to improve our collective ability to identify hidden extra-articular bicipital tunnel lesions, which we identified in 47% of chronically symptomatic patients.

Limitations

Our study has several limitations. First, regarding the cadaveric analysis, the position of the arm during arthroscopic tagging of the LHBT was manually controlled and thus subject to variability, although this manual positioning with the use of a goniometer is clinically representative. Similarly, the force applied to the LHBT was not standardized, thus producing variability but again attempting to mimic a best-case clinical scenario. As such, a single investigator (S.A.T.) applied maximal force with the use of an arthroscopic grasper to the LHBT until maximal excursion was achieved. Although fresh-frozen cadaveric specimens were used, the excursion produced in our experiment may not exactly mimic in vivo conditions. The average amount of force applied during delivery of the LHBT with an arthroscopic probe is 2 lb[17]; that force was exceeded during our cadaveric experiment. Also, we used a 30° arthroscope to visualize the distal extent of the LHBT. Although a 70° arthroscope could possibly visualize a greater percentage of the tendon, this would not represent customary practice. Finally, it is possible that the percutaneously placed polydioxanone tag sutures could have migrated proximal or distal to their original placement because of needle defect propagation along the longitudinal fibers of the LHBT. To mitigate this type of error, all tagging sutures were placed on first needle pass and statically positioned on gross inspection at time of measurement.

For the clinical series, we recognize the limitations inherent to a retrospective analysis of prospectively collected data. A single surgeon performed all arthroscopies, limiting the generalizability of the data but increasing the consistency of diagnosis. Furthermore, the senior surgeon (S.J.O.) has a well-established referral practice for patients with symptoms related to the biceps-labral complex, and thus the patient population may not be representative of the general population. Finally, we recorded scarring, stenosis, instability, loose bodies, partial tearing, and symptomatic vincula as pathologic lesions. Although there is no consensus on the clinical importance of each of these lesions, they do represent an objective finding that is anatomically and morphologically abnormal. Of the 277 chronically symptomatic patients in our study, 20% (55 patients) had normal arthroscopic findings as determined by this study's inclusion criteria. Although excluded from this study, biceps chondromalacia or a positive arthroscopic active compression test, or both, were found in 50 of 55 patients. No abnormalities were found in 5 patients. Some clinical vindication is offered by Taylor et al.[14] who reported 88% good-to-excellent midterm outcomes (4 to 10 years) among a subset of 56 shoulders that underwent isolated arthroscopic subdeltoid transfer of the LHBT to the conjoint tendon for the same lesions deemed pathologic in the present study. It should be noted that although we define the bicipital tunnel as extending from the articular margin through the subpectoral region, our extra-articular visualization was limited to the space above the proximal margin of the pectoralis major tendon, which limited our ability to confirm the absence of lesions below this structure.

Conclusions

Diagnostic glenohumeral arthroscopy fails to fully evaluate the biceps-labral complex because it visualizes only 55% of the LHBT relative to the proximal margin of the pectoralis major tendon and did not identify extra-articular bicipital tunnel lesions present in 47% of chronically symptomatic patients.

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