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MRI, arthroscopic and histopathologic cross correlation in biceps tenodesis specimens with emphasis on the normal appearing proximal tendon

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ABSTRACT

Purpose: To correlate the histopathologic appearances of resected long head of the biceps tendon (LHBT) specimens following biceps tenodesis, with pre-operative MRI and arthroscopic findings, with attention to the radiologically normal biceps.

Material and methods: Retrospective analysis of patients who had undergone preoperative MRI, subsequent arthroscopic subpectoral tenodesis for SLAP tears and histopathologic inspection of the excised sample between 2013 and 16. Those with a normal MRI appearance or mildly increased intrasubstance signal were independently analyzed by 2 blinded radiologists. A blinded orthopedic surgeon and pathologist reviewed all operative imaging and pathologic slides, respectively.

Results: Twenty-three LHBT resected samples were identified on MRI as either normal (Reader 1 n = 15; Reader 2 n = 14) or demonstrating low-grade increased signal (Reader 1 n = 8; Reader 2 n = 9). Of these, 86.9% demonstrated a histopathological abnormality. 50% of samples with histopathological abnormality demonstrated normal appearance on MRI. The most common reported histopathology finding was myxoid degeneration (73.9%) and fibrosis (52.2%). The most common arthroscopic abnormality was fraying (18.2%) and erythema (13.6%). Utilizing histopathology as the gold standard, the two radiologists demonstrated a sensitivity of 35.0% v 42.9%, specificity of 66.7% v 100%, PPV of 87.5% v 100%, and NPV of 13.3% v 14.3%. Corresponding arthroscopic inspection demonstrated a sensitivity of 31.6%, specificity of 66.6%, PPV 85.7% and NPV of 13.3%. There was moderate agreement between the two radiologists, $\kappa = 0.534$ (95% CI, 0.177 to 0.891), $p = 0.01$.

Conclusion: Histopathological features of low grade tendinosis including mainly myxoid degeneration and fibrosis are frequently occult on MR imaging.

1. Introduction

The long head of the biceps tendon (LHBT) is recognized as an important, but sometimes difficult to diagnose pain generator in the shoulder [1–3,14,15]. Arthroscopic surgical techniques and the clinical success of procedures such as biceps tenotomy and tenodesis emphasize the significance of LHBT pathology and the importance of an accurate preoperative diagnosis [14,18].

MRI represents a key tool in the diagnosis of LHBT pathology [5] with the most reliable imaging findings for tendinopathy regarded as a caliber changes and signal abnormalities [22]. Numerous reports comparing arthroscopy and MRI have demonstrated poor concordance with arthroscopic findings in the detection of proximal biceps pathology including poor to moderate sensitivity for inflammation, partial-thickness tears, and rupture [6,12,16,20].

The correlation of arthroscopic and histologic findings in the abnormal LHBT has identified histologic features including varying degrees of chronic inflammation, fibrosis, mucinous degeneration, vascular congestion, dystrophic calcification and acute inflammation [10,13,17]. Histological and molecular analysis post-tenotomy has demonstrated the LHBT exhibits increased proteoglycan and collagen type III [9] which may in part explain the signal changes observed in cases of biceps tendinopathy.

Yet despite a multitude of studies addressing MRI-arthroscopy

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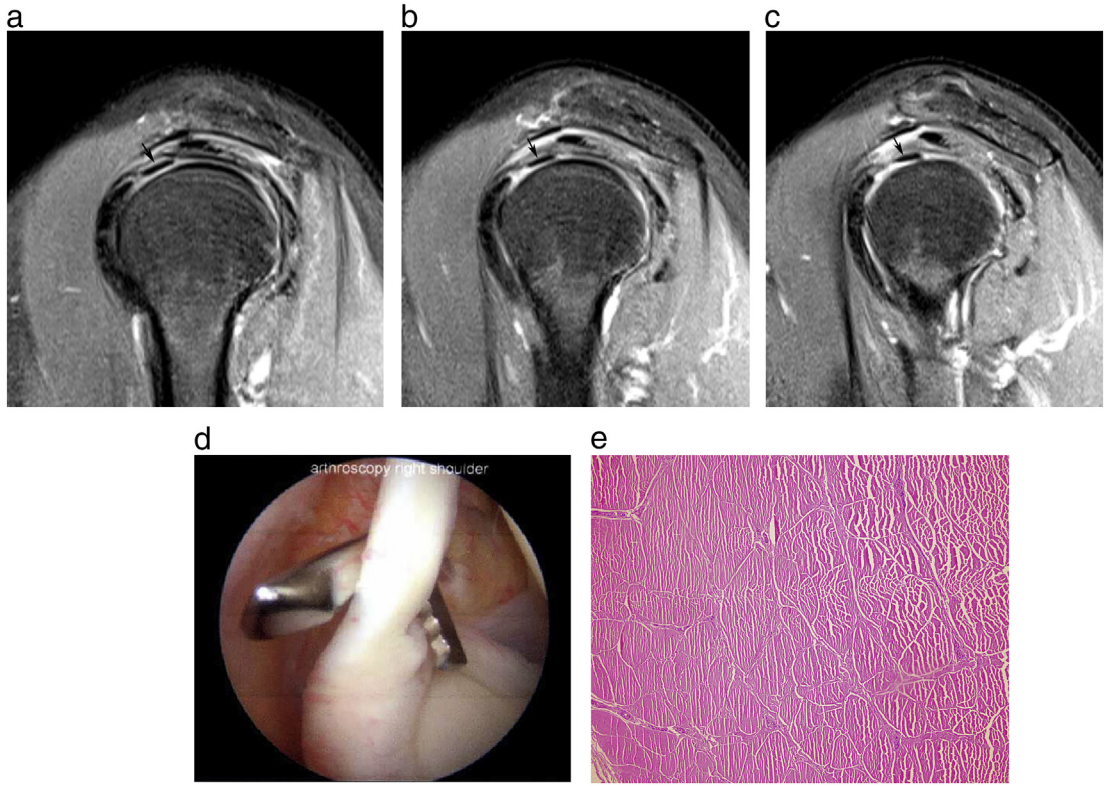

Fig. 1. 42 year old female with shoulder pain prior to biceps tenodesis. (a–c) Sequential Sagittal PD FS images (TR 2950/TE 42) prior to biceps tenodesis read as normal appearances of the long head of biceps by both readers. White arrows depict the intra-articular course of the tendon. (d) Corresponding arthroscopic image and histopathology slide (e) with H&E staining at 4× magnification demonstrating normal morphology showing bundles of fibroconnective tissue with thin fibrovascular septae which are not thickened as seen in cases with fibrosis.

[6,12,16,19,20], arthroscopy-pathological [11,13] and cadaveric MRI-histopathology [4] correlation, there is limited specific data regarding the direct in vivo comparison of all three together, particularly in the context of the radiologically normal or near normal tendon.

The purpose of this study was to see how LHBT MRI findings compared to examination during surgery and histologic analysis in the normal appearing tendon to characterize those changes below the limit of current clinical techniques. In other words, to determine what findings might be below the resolution of routine clinical MRI techniques. We hypothesized that low grade LHBT degenerative and inflammatory changes seen during surgery or histologic analysis could be poorly conspicuous on MRI.

2. Material and methods

2.1. Patient selection

The study was approved by the Institutional Review Board (IRB). An initial pool of consecutive 139 LHBT pathology reports were obtained from the pathology database between 2013 and 2016. 62 of which had corresponding pre-operative MRI imaging. Cases without preoperative imaging, missing arthroscopy details or pathology specimens were excluded. MR Arthrogram studies were included as well as routine non-contrast examinations and outside MRI studies were also included. The MRI studies were reviewed on our department's PACS system (Philips ISite, Intellispace, Netherlands).

2.2. MRI shoulder protocol

Scans obtained at our institution were performed using either 3 Tesla scanners: Biograph, Magnetom, Skyra, Prisma, Verio, (Siemens, Erlangen, Germany), Discovery MR750 (GE Healthcare, WI, USA) or 1.5 Tesla scanners: Signa Excite (GE Healthcare, WI, USA), Magnetom Aera, Espree, Symphony, Sonata, or Avanto (Siemens, Erlangen, Germany). The routine shoulder protocol at our institution includes the following sequences: Axial PD FS, Coronal T2 FS and PD, Sagittal T2 FS and PD sequences. The MR arthrogram protocol at our institution consists of the following sequences: Coronal T1 FS and T2 FS, Sagittal T1 FS, Axial T1 FS and Axial T1 FS ABER.

2.3. Primary MR imaging analysis

The 62 MRI studies meeting the inclusion criteria were independently reviewed by two fellowship trained musculoskeletal radiologists with 5 and 7 years of experience (Reader 1 and Reader 2, respectively) who were blinded to the results of arthroscopic and histologic evaluation. The region of proximal biceps tendon subsequently excised at tenodesis was evaluated including the intra-articular and proximal extra-articular tendon. MR imaging findings were classified as: normal appearances, mild/moderate/severe tendinosis, split tearing, fraying, and/or tenosynovitis. Only LHBTs with normal or mild increased intrasubstance signal (not contacting the tendon surface) as established by the more senior reader were included for further analysis. The sagittal oblique was the primary sequence utilized to evaluate the LHBT in combination with the coronal oblique and axial images (Figs. 1–3). This primary interpretation was performed independently, anonymously and the analysis kept for subsequent comparison. Cases with more pronounced abnormalities such as caliber changes or moderate to severe intrasubstance signal change were excluded. Long TE weighted sequences were preferentially used to analyze the biceps tendon to avoid magic angle artifact in both the non-arthrographic and arthrographic studies.

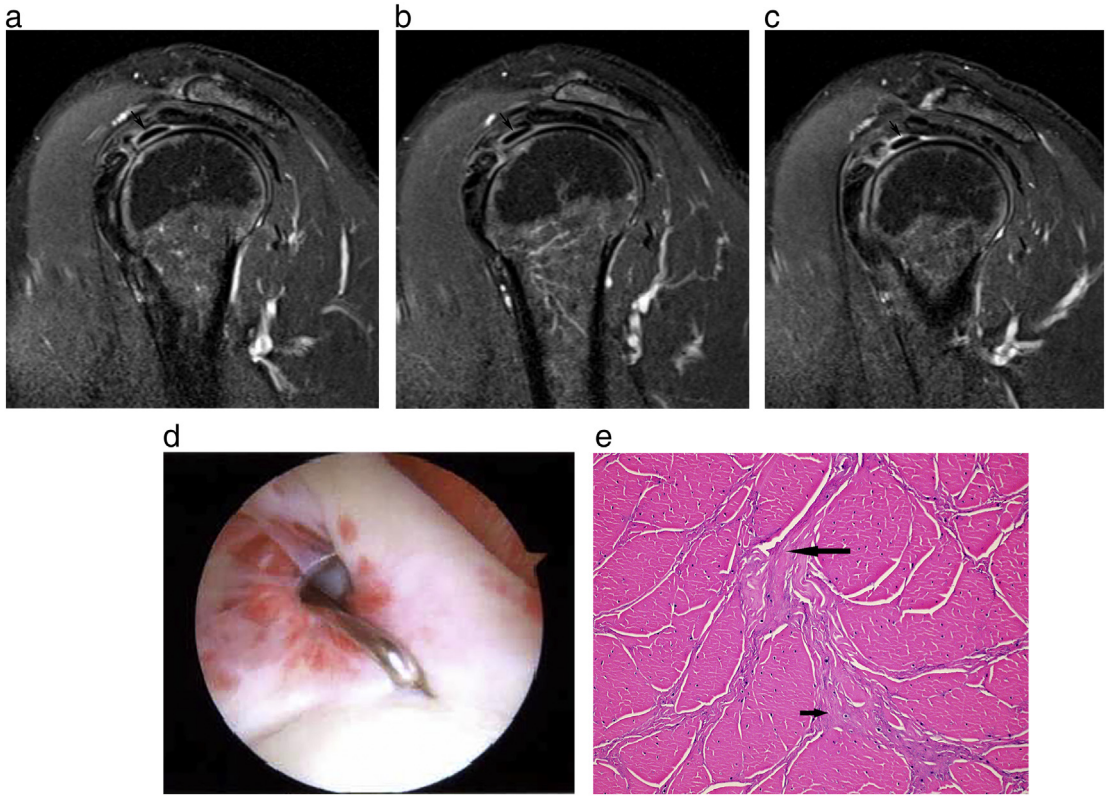

Fig. 2. 47 year old female with shoulder pain prior to biceps tenodesis. (a–c) Sequential Sagittal T2 FS images (TR 4210/TE 48) prior to biceps tenodesis read as normal appearances of the long head of biceps by both readers. White arrows depict the intra-articular course of the tendon. (d) Arthroscopic image demonstrating tenosynovitis and erythema of the intra-articular biceps tendon close to the biceps anchor. (e) Corresponding histologic slide of the resected biceps tendon specimen with H&E staining at 20× magnification demonstrating fibrotic bands with intermingled blue-ish degenerative changes seen in myxoid degeneration (arrows show areas of both changes intermingled).

2.4. Intra-operative arthroscopic analysis

The indication for surgery was SLAP tear in all cases. Biceps tendinopathy was suspected pre-operatively in only 6 patients. Arthroscopic findings and pathology specimens were reviewed by an orthopedic surgeon and specialized musculoskeletal pathologist, respectively. Review of arthroscopic findings was performed for the following features: normal, tear (split or partial), fraying, or erythema (tenosynovitis) or a combination of the aforementioned. The operative report in the electronic medical record (EPIC, Verona, Wisconsin) was also reviewed. The term tenosynovitis was used to describe changes affecting the extra-articular LHBT, also making the basis of the so-called "lipstick" sign on arthroscopy [8].

2.5. Histopathological analysis

Histologic slides were analyzed for features of myxoid degeneration, fibrosis, acute and chronic inflammation, vascular congestion, focal ossification and dystrophic calcification as previously described by Murthi et al. [13]. One biceps tendon sample was not available for histopathological re-evaluation so the original pathologic interpretation was used.

2.6. Statistical analysis

Statistical analysis including inter-rater reliability was performed to assess the degree of agreement between radiologists and well as the specificity of the radiologist and surgeon, using SPSS version 24 (IBM, Armonk NY). Inter-rater reliability analysis using Cohen's kappa was performed to determine agreement between the two radiologists. Any single or multiple histopathologic finding was assumed to be an abnormal result and histopathologic diagnosis was considered the gold standard for the calculation of MRI and arthroscopic sensitivity and specificity. Further, any single or multiple MRI or arthroscopic findings was assumed to constitute a positive screening test for the purpose of statistical analysis. The level of agreement was interpreted as poor when kappa (K) was less than zero, as slight when $0 \leq K \leq 0.2$, as fair when $0.2 < K \leq 0.4$, as moderate when $0.4 < K \leq 0.6$ and as substantial when $K > 0.6$ [24].

3. Results

There were a total of 23 biceps tenodesis specimens in 23 patients (14 male/9 female; mean age 44.5 range 30–69 years) demonstrating normal appearances or mildly increased intrasubstance signal within the proximal LHBT with arthroscopic correlation. Fourteen were obtained from the right shoulder and 9 from the left. Fifteen shoulder MRI examinations were performed at our institution whereas 8 studies were performed at outside institutions. Examinations were performed at 3 T (n = 13) and 1.5 T (n = 10). Twenty examinations were routine MR shoulder studies (Figs. 1–2) and 3 were direct MR arthrograms (Fig. 3). The mean time between MR imaging examination and arthroscopic resection was 133 days. The MR imaging, surgical and corresponding histopathologic analysis of the resection specimens are displayed in Table 1.

3.1. MRI findings

Reader 1 reported 15 tendons as normal on MRI and 8 as demonstrating mild increased intrasubstance signal, whereas Reader 2 reported 14 tendons as normal and 9 with mild increased intrasubstance signal (see Figs. 1–3). The MRI features reported by the two radiologists

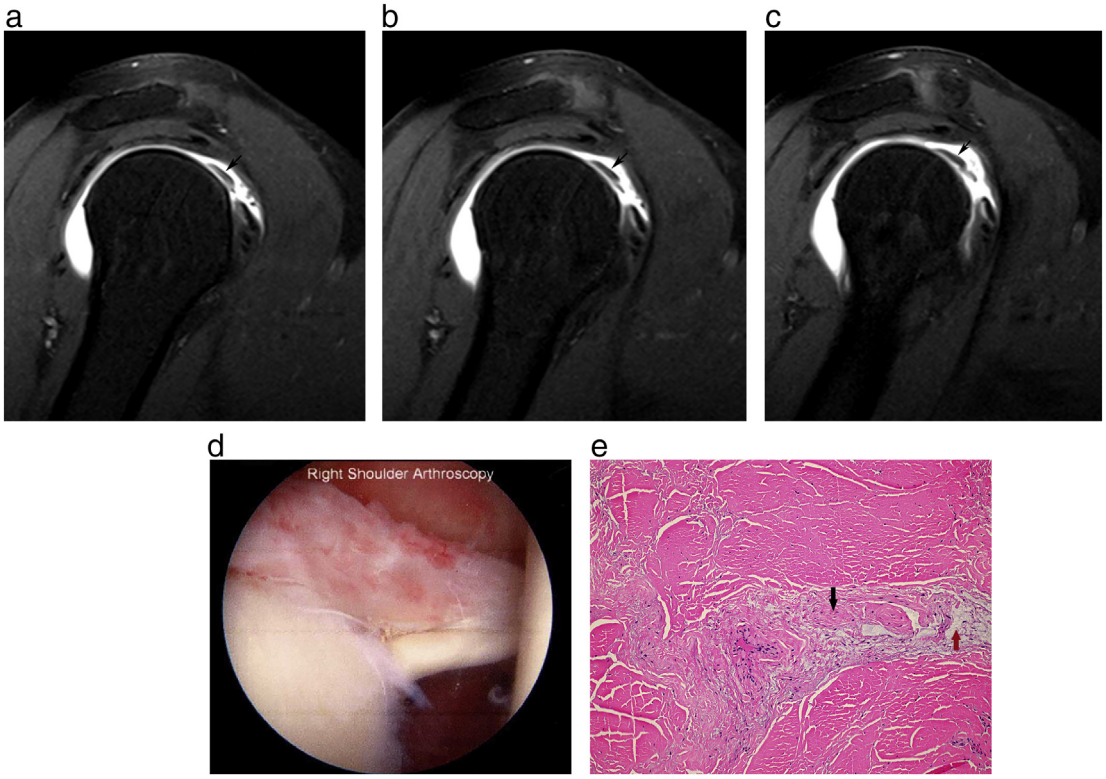

Fig. 3. 45 year old male with shoulder pain. (a–c) Sequential Sagittal T1 FS (TR 540 TE 14) arthrogram images prior to biceps tenodesis read as normal by Reader 1 and mild increased intrasubstance signal by Reader 2. Note that this is a short TE sequence therefore introducing the possibility of magic angle artifact. Black arrows depict the intra-articular course of the tendon. (d) Arthroscopic image demonstrating tearing, fraying and erythema of the intra-articular tendon. Corresponding histopathology slide (e) with H&E staining at 20× magnification demonstrating prominent myxoid degeneration (red arrow) and areas of banding fibrosis (black arrow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

are displayed in Table 2. Reader 1 demonstrated a sensitivity of 35.0%, specificity of 66.7%, positive predictive value of 87.5%, and negative predictive value of 13.3%. Reader 2 demonstrated a sensitivity of 42.9%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 14.3%. 11/14 (78.6%) cases, read as completely normal by the more experienced reader, demonstrated a histopathologic abnormality (Tables 1 and 4). According to Cohen's kappa, there was a moderate agreement between the two radiologists' readings, $\kappa = 0.534$ (95% CI, 0.177 to 0.891), $p = 0.01$. There was no significant difference in the detection of pathological changes when comparing 1.5 T versus 3 T studies.

3.2. Arthroscopic findings

One of the cases was converted to an open procedure before arthroscopic images were documented, thus there was no arthroscopic description of this tendon which was excluded and the remaining 22 cases were reviewed. 7/22 (31.8%) cases demonstrated an arthroscopic abnormality and 15/22 (68.2%) were reported as normal in appearance. The most common arthroscopic abnormality was fraying 4/22 (18.2%) and erythema 3/22 (13.6%). 16/22 (72.7%) LHBTs demonstrated a concurrent SLAP tear diagnosed at the time of arthroscopy and 21/22 (95.5%) documented labral pathology. 7/22 (31.8%) of tendons with a normal appearance or low-grade signal change demonstrated an abnormal arthroscopic appearance. The orthopedic surgeon demonstrated a sensitivity of 31.6%, specificity of 66.6%, positive predictive value 85.7%, and negative predictive value of 13.3%. The arthroscopic findings are presented in Table 3.

3.3. Histologic findings

23 resected LHBT samples fixed using hemotoxylin and eosin stains were analyzed (Figs. 1–2). The histologic findings in the resected specimens are presented in Table 4. 20/23 (87.0%) of cases demonstrated an abnormal histologic appearance. The most common reported histopathology finding was myxoid degeneration 17/23 (73.9%) and fibrosis 12/23 (52.2%). There were 11 cases where the tendon was considered normal on MRI by both readers without any signal abnormality, of which 2 (18%) were confirmed as normal on histopathology.

3.4. Other surgical findings

21/22 (95.5%) demonstrated labral pathology and specifically 16/22 (72.7%) LHBTs demonstrated a concurrent SLAP tear diagnosed at the time of arthroscopy. The length of clinical follow up range was 1–26 months (mean = 9.6 months). There were no surgical complications encountered in any of the 23 patients evaluated. One patient required a subsequent surgery for release of adhesions, rotator cuff and labral debridement as well as revision subacromial decompression.

4. Discussion

This study sought to determine what findings might be below the resolution of MRI in the normal appearing proximal LHBT, using histopathological correlation as the gold standard. Half of all patients with histopathological abnormalities, most commonly myxoid degeneration and fibrosis, demonstrate a normal appearance on clinical MRI. Furthermore, only 13% of tendons considered normal or with mild signal abnormality on MR evaluation were considered histologically normal and 31.8% demonstrated an abnormal arthroscopic appearance.

Table 1
Demographics, pre-operative indication, type of biceps intervention, arthroscopic labral and biceps findings with histopathological appearances of the resected specimens. N = Normal, I = Mild increased signal.

Age	Sex	Clinically suspected biceps tendinopathy	Field strength (Tesla)	Arthrogram (Y/N)	Reader 1	Reader 2	Surgical procedure	Labrum at arthroscopy	LHBT at arthroscopy	Pathological appearances
69	F	Y	3	N	I	I	Tenodesis	Minimal fraying	Unremarkable	Myxoid degeneration
55	M	N	3	N	I	I	Converted to open tenodesis	No correlation	No correlation	Not available
52	M	N	3	N	N	I	Tenodesis	Type II SLAP	Unremarkable	Myxoid degeneration
49	M	N	3	N	N	I	Tenodesis	Type II SLAP	Unremarkable	Myxoid degeneration and fibrosis
67	F	N	3	N	I	I	Tenodesis	Type II SLAP	Unremarkable	Myxoid degeneration and fibrosis
47	F	N	1.5	N	N	N	Tenodesis	SLAP degeneration	Tenosynovitis/erythema	Myxoid degeneration and fibrosis (see Fig. 2)
48	F	N	1.5	N	N	N	Tenodesis	Type II SLAP	Tear	Fibrosis
38	F	N	1.5	N	N	N	Tenodesis	Type II SLAP	Unremarkable	Myxoid degeneration
38	M	N	1.5	N	N	N	Tenodesis	Extension of SLAP tear posteriorly	Unremarkable	Normal
34	M	N	3	N	I	N	Tenodesis	SLAP	Fraying	Myxoid degeneration
54	F	Y	3	N	N	N	Tenodesis	Type II SLAP	Unremarkable	Myxoid degeneration
47	F	Y	3	N	N	N	Tenodesis	Type II SLAP (unstable)	Unremarkable	Myxoid degeneration
45	F	N	1.5	N	I	I	Tenodesis	Degenerative tear of superior labrum	Fraying	Chronic inflammation, fibrosis and myxoid degeneration
45	M	N	1.5	Y	N	I	Tenodesis	Posterior tear of labrum	Tear, tenosynovitis/erythema and fraying	Myxoid degeneration and fibrosis
44	M	Y	1.5	N	N	N	Tenodesis	Type II SLAP	Unremarkable	Myxoid degeneration and fibrosis
43	M	Y	3	N	N	N	Tenodesis	Type II SLAP	Unremarkable	Fibrosis
30	M	N	3	N	1	N	Tenodesis	Type II SLAP	Unremarkable	Myxoid degeneration and fibrosis
31	M	N	1.5	Y	N	I	Tenodesis	Extension of SLAP tear posteriorly	Unremarkable	Myxoid degeneration and fibrosis
33	M	N	3	Y	I	N	Tenodesis	Extension of SLAP tear posteriorly	Fraying	Normal
46	M	Y	3	N	I	I	Tenodesis	Type II SLAP	Tenosynovitis/erythema	Myxoid degeneration, fibrosis, vascular congestion
36	M	N	1.5	N	N	N	Tenodesis	Type II SLAP	Unremarkable	Myxoid degeneration, vascular congestion, focal ossification
30	M	N	1.5	N	N	N	Tenodesis	Type II SLAP	Unremarkable	Myxoid degeneration and fibrosis
42	F	N	3	N	N	N	Tenodesis	Posterosuperior labral tear	Unremarkable	Normal (see Fig. 1)

Table 2
MRI features reported by the two musculoskeletal radiologists.

Reader	#1	#2
Normal	15	14
Mild increased signal	8	9
TOTAL	23	
Additional findings		
Split tear	1	4
Fraying	0	0
Tenosynovitis	5	7

Table 3
Long head of biceps arthroscopic findings.

Normal	15
Tear	1
Fraying	3
Tenosynovitis/erythema	2
Tear, tenosynovitis/erythema, fraying	1
TOTAL	22

Table 4
Histopathological findings in the resected LHBT specimens.

Normal	3
Myxoid degeneration	17
Fibrosis	12
Acute inflammation	0
Chronic inflammation	1
Vascular congestion	2
Focal ossification	1
Dystrophic calcification	0

There were 11 cases where the tendon was considered normal on MRI by both readers without any signal abnormality, of which only 2 (18%) were confirmed as normal on histopathology.

4.1. Arthroscopy-histology correlation

The correlation of arthroscopic and histopathological findings in LHBT disease is well established. Murthi et al. compared findings of LHBTs in association with rotator cuff tears and evaluated seven histologic components of the tendon including normal tendon, chronic inflammation, fibrosis, mucinous degeneration, vascular congestion, dystrophic calcification and acute inflammation [13]. Streit and colleagues demonstrated in a cohort of patients following open subpectoral biceps tenodesis for anterior shoulder pain that the histologic findings of the extra-articular portion of the LHBT and synovial sheath are similar to the pathologic findings in de Quervain tenosynovitis at the wrist, including abundant ground substance, collagen bundle changes, and increased vascularization likely due to a chronic degenerative process. They identified tenocyte enlargement and proliferation, characterized by increased roundness and size of the cell and nucleus with proteoglycan matrix expansion and myxoid degenerative changes, in all specimens [23]. In a further study evaluating the histological and molecular analysis of the LHBT post-tenotomy, Joseph and colleagues noted that the intra-articular LHBT exhibited significantly greater histological evidence of tendinopathy inclusive of increased proteoglycan and decreased organization as measured by polarized light microscopy, compared to the extra-articular LHBT. The proximal LHBT also had significantly increased expression of collagen type III and of MMP-1 and 3. These histopathologic changes would explain the increased signal seen on MRI [9] identified as most typical for mucoid degeneration [4]. It is important to note that magic angle artifact can play a large role in the assessment of tendinosis of the long biceps tendon, in which case the TE is important. For this reason, long TE sequences are most frequently used to analyze the biceps tendon.

4.2. MRI-arthroscopy correlation

Despite representing the primary modality in the assessment of LHBT pathology, there remains concern regarding the diagnostic accuracy of MRI when compared to arthroscopy [6,12,16,20]. Mohtadi and colleagues questioned the ability of MRI in diagnosing specific pathology in the LHBT, reporting poor arthroscopic-MRI concordance of 37.7% [12]. In their series, using arthroscopy as the gold standard, MRI demonstrated poor to moderate sensitivity for all classifications of biceps tendon pathology, over-diagnosed patients with partial tears of the biceps tendon and underdiagnosed patients with tendon inflammation, seen in 41.5% of cases evaluated [12]. More recently Dubrow et al. reported the sensitivity and specificity of MRI for detecting partial tearing of the LHBT as 27.7% and 84.2%, respectively (positive predictive value = 81.2%, negative predictive value = 32.0%) [6]. Furthermore, Razmjou et al. reported sensitivity and specificity of 0.27 and 0.86 for partial tears of the biceps tendon, respectively [16]. The two readers in this study demonstrated varying sensitivities (35.0% v 42.9%), specificities (66.7% vs 100%), and positive predictive values (87.5% v 100%) with similar negative predicative values (13.3% vs 14.3%). This was similar to arthroscopic assessment, which demonstrated a corresponding sensitivity of 31.6%, specificity of 66.6%, positive predictive value 85.7%, and negative predictive value of 13.3%.

Three of the MRI examinations in this cohort were arthrographic studies. It has been suggested that intraarticular gadolinium may improve the diagnostic performance of MRI to detect intra-articular LHBT pathology, however this remains yet to be determined. Indeed, Tadros and colleagues examined the diagnostic accuracy of unenhanced MRI and direct MR arthrography for evaluation of the intra-articular LHBT using arthroscopy as the gold standard demonstrating no significant difference in the detection of tendinosis and tears [19]. In our series, all 3 arthrographic cases were discordant between the 2 readers.

4.3. Biceps tenodesis

The indication for subpectoral tenodesis was SLAP tear in all cases. LHBT tendinitis requiring tenodesis is generally regarded as a clinical diagnosis that should be made before arthroscopic examination [8]. The topic of biceps tenodesis as an alternative to repair for SLAP tears, particularly in older patients, remains controversial. There is a school of thought that biceps tenodesis, which maintains the length-tension relationship of the LHBT, should be the procedure of choice for patients with isolated type II SLAP lesions [21]. The utility of biceps tenodesis versus primary repair as a viable treatment for certain SLAP lesions, in particular type II and IV SLAP lesions is beyond the scope of this article, however biceps tenodesis has been purported to offer an acceptable, if not better, alternative to primary repair of SLAP lesions, particularly in the context of an evolving body of evidence suggesting unacceptably high failure rates with primary repair of type II SLAP lesions [7].

4.4. Limitations

The study is limited by its retrospective design, small sample size, ability to obtain a complete clinical history and long-term follow-up data. The clinical significance of low grade histopathological LHBT findings in the context of a concurrent SLAP tear is difficult to ascertain as biceps tenodesis is known to represent an effective treatment for labral pathology. Histologic review was performed retrospectively and different regions of the resected intra-articular LHBT could have been analyzed which may be significant given that it is known regional histological differences exist in the LHBT with the greatest pathological changes being seen in the region of the bicipital groove [25]. The pathologist was not aware of what was proximal or distal by means of a stitch or other fiducial marking method (as is sometimes performed)

limiting assessment for the exact distribution of the tendinopathic changes. Eight MRI examinations were performed at outside institutions introducing variability in imaging protocols, and 3 cases were arthographic studies introducing additional heterogeneity. No inter-observer reliability analysis for grading between the two readers and no intra-observer reliability analysis was not performed. The small number of normal studies also makes the specificity performance inaccurate. Finally, there was an average of 133.1 days between the initial MR imaging exam and the arthroscopic resection of the LHBT, thus theoretically allowing the pathological changes of tendinosis to evolve.

5. Conclusions

This is the first direct comparison of preoperative MRI with both arthroscopic and histopathologic findings in the radiologically normal proximal biceps tendon and those with mildly increased signal. A significant number of patients demonstrate histopathological evidence of tendinosis including mainly myxoid degeneration and fibrosis, which are occult on both MRI and arthroscopy, although the clinical significance of this remains unclear.

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