Radiologic and Histologic Evaluation of Proximal Bicep Pathology in Patients With Chronic Biceps Tendinopathy Undergoing Open Subpectoral Biceps Tenodesis

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Purpose: To correlate preoperative magnetic resonance imaging (MRI) and intraoperative anatomic findings within the proximal long head biceps tendon to histologic evaluation of 3 separate zones of the tendon in patients with chronic biceps tendinopathy.

Methods: Sixteen patients with chronic biceps tendinopathy were treated with open subpectoral biceps tenodesis. Preoperative MRI tendon grading was as follows: normal tendon, increased signal, tendon splitting, incomplete/complete tear. The removed portion of the biceps tendon was split into 3 segments: zone 1, 0-3.5 cm from the labral insertion; zone 2, 3.5-6.5 cm; and zone 3, 6.5-9 cm, and was histologically evaluated using the Bonar score. Tenosynovium adjacent to the tendon was assessed histologically using the Osteoarthritis Research Society International score. CD31, CD3, and CD79a immunohistochemistries were conducted to determine vascularization, T-cell infiltrates, and B-cell infiltrates, respectively. Analysis of variance and Pearson correlations were performed for statistical analysis.

Results: Preoperative MRI showed no significant differences in tendon appearance between zones 1-3. Intraoperative findings included nonspecific degenerative SLAP tears or mild/moderate biceps tenosynovitis in all cases. Significantly (P < .001) higher Bonar scores were noted for tendon in zones 1 (7.9 ± 1.8) and 2 (7.3 ± 1.5) compared with zone 3 (5.0 ± 1.1). Cell morphology scores in zone 1 (1.9 ± 0.4) and zone 2 (1.5 ± 0.6) were significantly higher than that in zone 3 (0.8 ± 0.3) (P < .05). Inflammatory tenosynovium showed weak correlation with tendon changes in zone 1 (r = 0.08), zone 2 (r = 0.03), or zone 3 (r = 0.1).

Conclusions: In patients with chronic long head biceps tendinopathy who underwent open subpectoral tenodesis, MRI and intraoperative assessment did not show significant structural abnormalities within the tendon despite significant histopathologic changes. Severity of tendon histopathology was more pronounced in the proximal and mid-portions of the tendon. Clinical Relevance: Proximal versus distal biceps tenodesis is a subject of frequent debate. This study contributes to the ongoing evaluation of the characteristics of the proximal biceps in this type of pathologic condition.

The proximal aspect of the long head of the biceps (LHB) tendon is frequently a pain generator in the shoulder, but no single effective treatment method has been delineated to date. Pathology of the LHB has been attributed to numerous anatomical considerations, from stress caused by concurrent labral or rotator cuff tearing to abnormal tendon tracking within the bicipital groove.1,2 Operative treatment may be indicated in cases of primary or secondary tendinopathy after failure of conservative treatment or in cases of instability, pending from Arthrex and Zimmer. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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partial rupture, entrapment of the LHB, or anterior shoulder pain with associated rotator cuff tear.3-6 Biceps tenodesis has been shown to be an effective treatment option for refractory biceps tendinopathy.7-12 The anatomic location of tenodesis (proximal, distal, or within the bicipital groove) and method of fixation (screw fixation, cortical button fixation, or soft tissue suturing) remain highly controversial. Studies have shown difficulty in fully evaluating the entire biceps tendon arthroscopically, and as such distal tenodesis techniques have an advantage of removing the LHB biceps tendon from a potentially inflammatory extra-articular environment, either within the bicipital groove or closer to the musculotendinous junction.9,13-23 Previous studies have evaluated the histopathology of the LHB in patients with concurrent rotator cuff tears or impingement syndrome, but there is limited data correlating intraoperative and magnetic resonance imaging (MRI) findings to histopathology in separate biceps sections in patients with chronic biceps tenosynovitis.24-26

The purpose of this study was to correlate preoperative MRI and intraoperative anatomic findings within the proximal LHB tendon to histologic evaluation of 3 separate zones of the tendon in patients with chronic biceps tendinopathy. We hypothesized that the appearance of the biceps on MRI and intraoperative inspection would not correlate with histologic severity and that higher levels of inflammatory markers and histopathologic changes would be present in the proximal portions of the tendon.

**Methods**

**Study Population**

In this institutional review board-approved study, 20 patients from December 2014 through April 2016 with symptomatic chronic refractory biceps tendinopathy were identified. Four patients were excluded based on failing exclusion criteria on intraoperative evaluation, resulting in 16 patients for final evaluation. Study patients met the following inclusion criteria: ≥30 years of age, anterior shoulder pain with positive biceps physical examination findings, and failure of conservative treatment. Physical examination required positive tenderness when directly palpating the LHB tendon in the bicipital groove and a positive Speed’s test.27 Instability tests were always negative. The exclusion criteria included patients with inflammatory arthritis or significant glenohumeral osteoarthritis—or those requiring concomitant reparative or reconstructive procedures (including rotator cuff or SLAP). Conservative treatment typically consisted of 3 or more months of activity modification, oral anti-inflammatories, physical therapy, and a cortisone injection, if the patient consented to it. Surgical intervention was indicated in patients who failed conservative management and showed persistent anterior shoulder pain and dysfunction, suggesting LHB pathology. All patients underwent a shoulder arthroscopy followed by a subpectoral biceps tenodesis. Patient demographics are documented in Table 1.

**MRI Evaluation**

All patients had preoperative shoulder MRIs evaluated by a musculoskeletal radiologist who was blinded to clinical findings. MRI was performed using a dedicated shoulder coil on a 1.5 T GE Optima 450 Scanner (GE Healthcare, Waukesha, WI). Coronal oblique T2FS images, sagittal oblique PDFS images, and axial PDFS images were evaluated. LHB tendon appearance was separated into 1 of 4 categories: 0 = normal, 1 = increased signal, 2 = tendon splitting, and 3 = tendon tearing, and, if present, pathology was assessed based on the area of abnormality: 1 = proximal to the groove, 2 = distal to the groove, 3 = entire tendon involvement28 (Fig 1).

**Table 1. Patient Demographics**

<table>
<thead>
<tr>
<th>Average age</th>
<th>44.25 (range: 32-52)</th>
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<tr>
<td>Gender</td>
<td>Male: 12 patients; female: 4 patients</td>
</tr>
<tr>
<td>Average body mass index</td>
<td>29.4 (range: 21-39)</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td>Nontraumatic: 10 patients; traumatic: 6 patients</td>
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<tr>
<td>Average duration of symptoms</td>
<td>30 mo (0.5-60 mo)</td>
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Intraoperative Technique

All study patients were treated with open subpectoral biceps tenodesis. The biceps groove itself was opened manually by palpation in all cases. Intraoperative anatomic findings from both arthroscopic and open visualization were recorded. The proximal biceps tendon and also the surrounding tenosynovium adjacent to the tendon were removed and collected for analysis. All tissue specimens were placed into biohazard containers in the operating room with normal saline and transported immediately to the laboratory for analysis after surgery. Patient information was coded and stored confidentially throughout the duration of the study.

Histopathology

The removed portion of the biceps tendon was placed in neutral-buffered 10% formalin solution for approximately 24 hours. After formalin fixation, each tendon was split into 3 segments based on previous studies evaluating the separate zones of the biceps tendon: zone 1 (proximal), 0-3.5 cm from the labral insertion; zone 2 (mid), 3.5-6.5 cm; and zone 3 (distal), 6.5-9 cm (Fig 2). Specimens were histologically processed and 5 μm sections were obtained. Both the removed portion of the biceps tendon sections and surrounding tenosynovium sections adjacent to the tendon were stained with H&E and evaluated histologically using the Bonar score for tendon pathology and the Osteoarthritis Research Society International score for synovium pathology, respectively. In addition, Masson’s trichome, staining, picrosirius red staining, Verhoeff’s elastin staining, and immunohistochemistry staining for CD31, an endothelial marker (Dako, M0823 dilution 1:40); CD3, a T-cell marker (Dako, A0452 dilution 1:400); and CD79a, a B-cell marker (Diagnostic BioSystems, Mob118 dilution 1:100) were performed (Fig 3). Statistical analysis was performed using analysis of variance to determine differences among zones with respect to the Bonar score. When significant differences among zones were obtained, the Tukey test procedure was selected as post hoc analysis to determine which zones were different. Pearson correlations were used to determine correlation of histopathologic changes among these 3 zones. Significance was set at $P < .05$.

Fig 2. Illustration depicting classification of the proximal long head biceps tendon in a right shoulder into 3 separate zones: zone 1 = proximal/purple, zone 2 = middle/green, zone 3 = distal/blue. (© 2018. The Curators of the University of Missouri.)

Fig 3. H&E staining of biceps tendon specimens. (A) Zone 3/distal: roughly 30% of the area is infiltrated and replaced by adipocytes. Mild mucoid changes particularly at near/in tendon sheath are present, with tendon sheath edema. (B) Zone 2/middle: roughly 40% of the area/bundles exhibit mucoid and fibrous changes with tendon sheath edema. (C) Zone 1 (proximal): roughly 75% of the area/bundles exhibit mucoid and fibrous changes with increased vascularity and pallor, frequent chondrocytic differentiation/chondrometaplasia, and occasional shredded bundles with separation.
Results

MRI evaluation revealed normal biceps appearance in 38% of patients, increased signal in 50% of patients, and splitting in 12% of patients. In patients with an abnormal tendon by MRI criteria, the region of abnormality extended from the anchor to biceps groove in 50% of patients and involved most of the tendon in 12% of patients. The biceps size was noted to be normal in 81% of patients, increased in 13% of patients, and decreased in 6% of patients. Overall, preoperative MRI showed no significant differences in tendon appearance between zones 1-3.

Intraoperative findings included nonspecific degenerative SLAP (type 1) tears or mild/moderate bicep tendinositis in all cases. A simplified classification system from a prior study was used to describe the LHB. All tendons were type 0 (normal appearing) or type 1 (tendinitis) tendons. There were no type II (debrillated), type III (tendon tear ≤50% of tendon width), or type IV tendons (tendon tear >50% of tendon width) evident on visual evaluation. All LHB were located within the bicipital groove, with no cases of subluxation or dislocation present.

Significantly (*P* < 0.001) higher Bonar scores were noted for tendon in zones 1 (7.9 ± 1.8) and 2 (7.3 ± 1.5) compared with zone 3 (5.0 ± 1.1) (Fig 4). Among variables evaluated by the Bonar score, cell morphology scores in zone 1 (1.9 ± 0.4) and zone 2 (1.5 ± 0.6) were significantly higher than that in zone 3 (0.8 ± 0.3) (*P* < 0.05); ground substance scores in zone 1 (1.5 ± 0.9) and zone 2 (1.3 ± 0.7) were significantly higher than that in zone 3 (0.4 ± 0.5) (*P* < 0.05); and collagen arrangement scores in zone 1 (1.8 ± 0.5) and zone 2 (1.6 ± 0.4) were significantly higher than that in zone 3 (0.8 ± 0.3) (*P* < 0.005), whereas vascularity scores as evaluated using H&E-stained sections and CD31 immunohistochemistry were not different among these 3 zones (zone 1: 2.4 ± 0.7, zone 2: 2.8 ± 0.5, and zone 3: 2.8 ± 0.4). There was a significant (*P* = 0.005) and moderately strong correlation of the Bonar score between zone 1 and zone 2 (*r* = 0.66) and a significant (*P* = 0.04) and moderately strong correlation between zone 2 and zone 3 (*r* = 0.51). Interestingly, intratendinous fatty infiltrates not included in the Bonar score variables were only seen in 1 case in zone 1 (6.2%), whereas fatty infiltrates were seen in 9 zone 2 specimens (56%) and 13 zone 3 specimens (81%). Surrounding biopsied tenosynovium occasionally had synovial hypertrophy, hyperplasia, and subintimal edema, but typically had no overt inflammation, with an average Osteoarthritis Research Society International score of 1.0 (ranging from 0 to 7 out of total 18 points). Tenosynovium scores showed weak correlation with tendon changes in zone 1 (*r* = 0.08), zone 2 (*r* = 0.03), or zone 3 (*r* = 0.1). Results are shown in Table 2.

Discussion

The results of the study showed that preoperative MRI showed no significant differences in proximal LHB tendon appearance between zones 1-3 despite significantly higher histopathologic scores in the proximal zones (zones 1 and 2). Biceps tendon pathology can result from numerous causes, but the understanding of the full extent of the changes within the LHB tendon itself is the subject of an ongoing study and debate. Given these findings, we accept our hypotheses that the appearance of the biceps on MRI and intraoperative inspection did not correlate with histologic severity and that higher levels of inflammatory markers and histopathologic changes were present in the proximal portions of the tendon.

Various studies have elucidated the accuracy of detecting biceps pathology using MRI. Ultrasound is also a useful tool for evaluating biceps pathology and is frequently used at our institution, both diagnostically and for biceps sheath-guided injections, but more extensive research and baseline characteristics for comparison from the literature have been performed using MRI. Jung et al. found no significant differences between indirect and direct magnetic resonance arthrography for identifying LHB tendon tears, with sensitivities of 67% to 78% and 78% to 89%, respectively. Similarly, Tadros et al. found that MRI and magnetic resonance arthrography did not differ significantly in the diagnosis of biceps tendinosis or frank tears. In this study, there was evidence of biceps splitting on the MRI results in 2 patients, but no

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**Table 2. Results**

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<th>Bonar Score</th>
<th>Cell Morphology</th>
<th>Tenosynovium Correlation</th>
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<tr>
<td>Zone 1</td>
<td>7.9 ± 1.8</td>
<td>1.9 ± 0.4</td>
<td><em>r</em> = 0.08</td>
</tr>
<tr>
<td>Zone 2</td>
<td>7.3 ± 1.5</td>
<td>1.5 ± 0.6</td>
<td><em>r</em> = 0.03</td>
</tr>
<tr>
<td>Zone 3</td>
<td>5.0 ± 1.1</td>
<td>0.8 ± 0.3</td>
<td><em>r</em> = 0.1</td>
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evidence of frank tendon tears in any study patients intraoperatively. This exemplifies the difficulty in completely accurate detection of biceps pathology with this modality. Although the definitive accuracy of MRI in detecting biceps lesions varies widely in the literature, it is nonetheless routinely used in the work-up of anterior shoulder pain. This study provides evidence that MRI, although still helpful to rule out other shoulder pathologies, may show suboptimal detection of biceps pathology in this patient population.

Taylor et al.21 reported on the clinical importance of the extra-articular segment of tendon and its fibro-osseous “bicpital tunnel.” They showed in a cadaveric study that standard diagnostic arthroscopy using a probe pull test only visualizes 55% of the LHB tendon relative to the proximal margin of the pectoralis major. They then found that 47% of 277 patients with chronic refractory biceps tendinitis had extra-articular lesions affecting the biceps tendon that remained hidden from view during standard diagnostic arthroscopy. Similarly, Gilmer et al.22 evaluated arthroscopic versus open comparison of LHB tendon pathology in patients requiring tenodesis and found that arthroscopic examination visualizes only 32% of the tendon and may underestimate pathology. Taylor et al.23 in a second study then divided the biceps into 3 distinct and anatomic zones: zone 1 extending from the articular margin to the margin of the subscapularis tendon, zone 2 within the bicipital area extending from the margin of the subscapularis tendon to the proximal margin of the pectoralis major, and zone 3 extending from the subpectoral region to the musculotendinous junction. Using these reference zones, we sectioned study specimens into 3 segments and evaluated each segment independently. Similar to their findings, our study showed a significant amount of pathology within zone 2 (middle third) of the biceps tendon. Both zone 1 (proximal) and zone 2 had significantly higher scores than zone 3. This provides evidence that higher levels of inflammation may occur in the more proximal two-thirds of the tendon, despite no major intraoperative visual differences. This finding would potentially support removal of at least the proximal two-thirds of the LHB when performing a procedure for chronic biceps tendinopathy.

Multiple studies have delineated histopathologic changes within the LHB tendon when in the presence of other concomitant pathologies within the shoulder.24-26,34,35 Singaraju et al.25 evaluated the inflammation, vascularity, and neuronal plasticity present within tenodesis or tenotomy samples in patients with associated chronic rotator cuff tears. They found a moderate correlation between LHB vascularity and pain scores, but no significant differences in calcitonin gene-related peptide or substance P immunostaining testing. They concluded that, in the context of rotator cuff disease, the etiology of anterior shoulder pain, even with changes in the biceps tendon, is likely multifactorial. Mazzocca et al.36 evaluated histomorphologic changes in the LHB tendon in 3 different disease states: instability, tendinosis, and degenerative joint disease, while separating the biceps into proximal (intra-articular) and distal (extra-articular) segments. Their study showed a greater degree of degeneration of the proximal region of the LHB tendon in all pathologic groups. Similar to their study, our findings showed higher levels of pathology within the proximal biceps; however, we sectioned the specimens into 3 sections in an effort to better delineate potential differences within the bicipital groove portion of the tendon from the most proximal and most distal segments.

Wu et al.26 evaluated macroscopic versus microscopic pathology in patients with LHB tendinopathy and chronic rotator cuff tears. They found that the macroscopic grading and symptom duration did not correlate to the severity of histology in the biceps tendon and that the proportion of high-grade histologic LHB changes was significantly increased in patients with massive rotator cuff tears. Similar to their study, we found that visual appearance of the tendons did not correlate to histology severity, with histopathologic changes showing much more evidence of tenosynovitis within the tendon. Our study expands on this research in that we evaluated the LHB in patients with chronic anterior shoulder pain but without concomitant pathologies within the shoulder, which we believe strengthens the validity of the results in evaluating the underlying pathology of the bicep itself. In contrast to the LHB tendons, however, the surrounding tenosynovium did not show significant inflammatory changes, suggesting a more chronic etiology in this patient population. This correlates clinically because these patients had prolonged symptoms and failed extensive conservative management before surgical intervention.

Although isolated LHB tendinopathy without other shoulder pathology is relatively rare, there have been some clinical studies evaluating treatment of this condition.12,37-39 Tahal et al.12 evaluated active patients <45 years old who underwent subpectoral biceps tenodesis for refractory LHB tenosynovitis. Their results showed decreased pain, improved function, high satisfaction, and improved quality of life. Our study expands on these studies in that it incorporates preoperative MRI evaluation, intraoperative findings after biceps tenodesis, and histopathologic findings in patients with LHB tendinopathy.

**Limitations**

First, the study has a limited sample size, primarily related to the rarity of the isolated condition. However, the narrow inclusion criteria—with clear indication for surgery and consistent LHB histopathologic
evaluation—do provide strength to the findings. Second, there was no control group or other treatment group to directly compare the results. Funding constraints limited use of cadaveric tissues as controls for immunohistochemistry testing. However, we believe that evaluating multiple zones within each tendon specimen provides valuable information regarding differences at varying levels of the biceps. The classification scheme for the MRI evaluation was also slightly different than that for the histology. It would be very difficult to consistently identify the exact portions of the tendon that are intra-articular, within the tunnel or distal to the tunnel once it was removed and sent for histology evaluation. Thus, to maintain consistency in tendon evaluation, the histopathologic classifications were performed based on the exact distance. Previous studies have shown these distances to correlate well to the tendon location within the shoulder. 22,23 Finally, we had a selective immunohistologic sampling and other types of testing could provide added histopathologic data.

Conclusions

In patients with chronic LHB tendinopathy who underwent open subpectoral tenodesis, MRI and intraoperative assessment did not show significant structural abnormalities within the tendon despite significant histopathologic changes. Severity of tendon histopathology was more pronounced in the proximal and mid-portions of the tendon.

References
