Biceps Detachment Alters Joint Function and Tendon Mechanical Properties in a Chronic Massive Rotator Cuff Tear Rat Model

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Introduction:

Lesions of the long head of the biceps tendon are often associated with massive rotator cuff tears (MRCT) and may be responsible for shoulder pain and dysfunction.[1] As a palliative treatment, biceps tenotomy is sometimes recommended for pain relief and improvement in joint function.[2] Our previous study indicated that simultaneous detachment of the long head of the biceps tendon in the presence of a MRCT resulted in improved shoulder function and reduced damage to the joint.[3] However, the effect of biceps tenotomy on the surrounding tissues in a chronic condition remains unknown. Therefore, the objective of this study was to define the impact of surgical detachment of the biceps tendon as a potential treatment in a chronic MRCT rat model. We hypothesized that biceps tenotomy would result in improved mechanical and histological properties of the intact subscapularis tendon and improved in vivo shoulder function.

Methods:

Study Design: In 25 male Sprague-Dawley rats (464 ± 24 g; IACUC approved), the supraspinatus and infraspinatus tendons were detached to create a MRCT followed by 4 weeks of cage activity. Animals were then randomly divided into groups that received a surgical biceps tenotomy (BT, n = 11) or a sham surgery (SS, n = 14).

Mechanics: Upper and lower bands of the subscapularis tendon were mechanically tested independently, 4 weeks after the second surgery.[4] Stain lines were used to track optical strain. Cross-sectional area was measured using a custom laser device.[5] Stiffness was calculated as the slope of the linear region of the load-displacement curve during a ramp to failure at 0.3%/s. Modulus was calculated as slope of the linear region of the stress-strain curve. Stress relaxation (%) was calculated from a 300s stress-relaxation test at 6% strain.

Histology: Subscapularis tendon sections were stained with hematoxylin and eosin and images were graded for cell density and cell shape.[7]

Quantitative ambulation: To assess in vivo shoulder joint function, forelimb gait and ground reaction forces were recorded using an instrumented walkway 1 day before the first detachment surgery (baseline), as well as 1 day before, and 3, 7, 10, 14, and 28 days after the second biceps tenotomy/sham surgery.[6]

Statistics: Ambulation data was assessed using a two- way ANOVA with multiple imputations (for ~13% of missing data). Tendon mechanical properties were compared using t-tests. Histology grades were compared using a Mann-Whitney test. Significance was set at $p < 0.05$ and trends at $p \leq 0.1$.

Results:

Decreased stress relaxation and increased tendon stiffness, along with a decrease in insertion site modulus, were exhibited in the lower band of the subscapularis tendon in the BT group. A trend of decreased stress relaxation was observed in the upper band in the BT group with no changes in any other mechanical parameters (Figure 1). A trend of increased

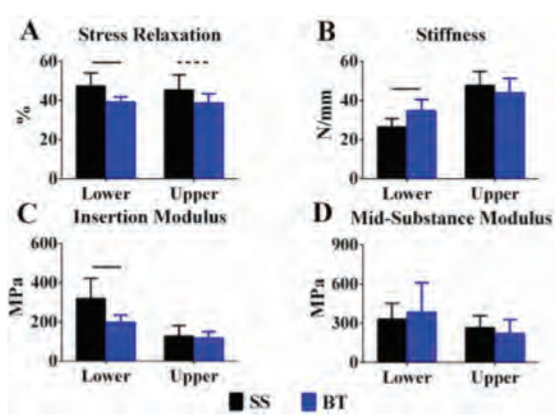

Figure 1. Mechanical properties. Lower subscapularis tendon in the BT group showed **(A)** decreased percent stress relaxation and **(B)** increased stiffness, but **(C)** insertion site modulus was decreased. **(A)** Upper subscapularis tendon in the BT group showed a trend of decreased percent stress relaxation.

cellularity was noted in the insertion area of the lower band in the BT group with no differences in the upper band (Figure 2). Consistently decreased lateral stride width following the second surgery was observed in rats in the BT group (Figure 3). Increased vertical force and rate of loading in the operated limb and increased speed of the contralateral limb were noted in animals with biceps tenotomy.

Discussion:

This study investigated the role of biceps tenotomy in the presence of a chronic massive rotator cuff tear. The resulting increase in overall lower band tendon stiffness and decrease in both upper and lower bands stress relaxation can be attributed to a rebalance of the transverse force couple as previously reported.[7] In the absence of biceps tenotomy, the unbalanced anteriorly directed force of the biceps tendon on the humeral head could decrease loading to the subscapularis tendon, resulting in reduced stiffness of the lower band. This is supported by an increased stride width in the SS group at later time points, as the intact biceps may prevent internal rotation in that group. Furthermore, the decrease in insertion site modulus of the lower band in the BT group indicates a return toward baseline subscapularis material properties (unpublished data). The increases in cellularity in the lower band of the BT group could indicate remodeling in response to biceps detachment and support these mechanical differences. Further studies will investigate the effects of biceps tenotomy on other joint tissues such as articular cartilage to more thoroughly quantify joint health. Overall, results suggest biceps tenotomy in the presence of chronic massive rotator cuff tears partially preserves in vivo shoulder function and potentially restores subscapularis tendon health, consistent with our previous study and supported by clinical outcomes.[3,8]

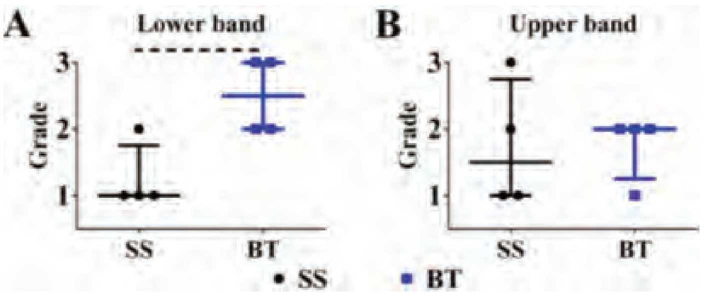

Figure 2. Histology. **(A)** Lower subscapularis tendons in the BT group showed a trend of increased cellularity in the insertion area. **(B)** No difference was noted in the upper subscapularis tendons.

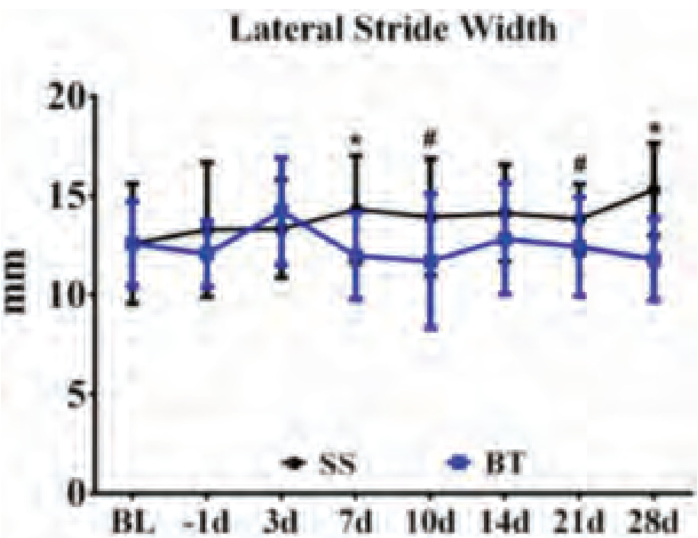

Figure 3. Ambulation. Rats in the BT group showed decreased lateral stride width from 7 days after the biceps tenotomy / sham surgery. (* $p < 0.05$, # $p < 0.10$)

Significance:

This study demonstrates that biceps tenotomy results in largely protective effects to various parts of the shoulder joint in chronic massive rotator cuff tears in a rat model. Further investigation of the role of biceps tenotomy on overall shoulder joint health is needed.

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