Original Article

The Long Head of the Biceps Myotendinous Junction Is Located 1.14 Centimeters Distal to the Proximal Border of the Pectoralis Major Tendon: An Anatomic Study

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Purpose: To describe the proportional anatomic relationship of the long head of the biceps tendon (LHBT) myotendinous junction (MTJ) to pectoralis major tendon (PMT) and to provide an up-to-date review of the current literature. **Methods:** Ten fresh frozen cadaveric specimens were used. A deltopectoral approach was used for exposure and anatomical location of the MTJ as well as the proximal and distal borders of the PMT were identified by 2 fellowship-trained shoulder and elbow surgeons. The longitudinal length of the PMT, the distance from the long head of the biceps (LHB) MTJ to the proximal border of the PMT (pMTJ), and the distance from the LHB MTJ to the distal border of the PMT (dMTJ) were recorded. The relationship between the pMTJ and the PMT length was then reported as a ratio. **Results:** The PMT was found to have a length of 5.16 ± 0.64 cm (4.1-6.1 cm). The pMTJ was 1.14 ± 0.52 cm (0.5-1.9 cm), and the dMTJ was 4.02 ± 0.91 cm (2.5-5.3 cm). The pMTJ/PMT ratio was 0.23 ± 0.11 (0.10-0.39). **Conclusions:** We found the average length of the PMT footprint to be 5.16 cm with the LHB MTJ beginning 1.14 cm distal to its proximal border. **Clinical Relevance:** It is important to understand the LHBT and its relationship to surgically relevant surrounding anatomy to allow for appropriate tensioning and improved patient outcomes in the treatment of LHBT shoulder pathology.

Long head of the biceps tendon (LHBT) pathology is a well-documented source of proximal shoulder pain, with common treatment strategies involving tenotomy with or without tenodesis.[1-8] Previous studies have found similar outcomes between the 2 procedures[2,9-11]; however, tendon tensioning during tenodesis has lacked standardization.[2,12-14] A tenodesis is believed to help prevent biceps ptosis, commonly referred to as the "Popeye" deformity associated with distal muscle belly migration and cramping commonly associated with a tenotomy.[15]

In an effort to avoid cosmetic deformity and improve patient pain and function, tenodesis of the long head of the biceps (LHB) is becoming increasingly more common, with a particular focus on accurately restoring anatomic tendon location and its impact on appropriate tensioning. Previous authors have reported increased or persistent pain in patients who undergo proximal tenodesis where the tendon remains within the bicipital groove.[8,12-14,16,17] This pain may be in part due to over tensioning of the LHB, suggested to occur during arthroscopic suprapectoral tenodesis.[18] Comparatively, pain and even reoperation rates can be improved when using a more distal epipectoral tenodesis.[12-14,17,19-21] Therefore, it is important to understand the LHBT and its relationship to surgically relevant surrounding anatomy to allow for appropriate tensioning and improved patient outcomes.

The LHB myotendinous junction (MTJ) and its relation to the pectoralis major tendon (PMT) is a commonly used tenodesis landmark. Cadaveric and magnetic resonance imaging (MRI) studies have described the proximal extent of the MTJ to range from an average of 0.6 to 5.7 cm distal to the proximal border

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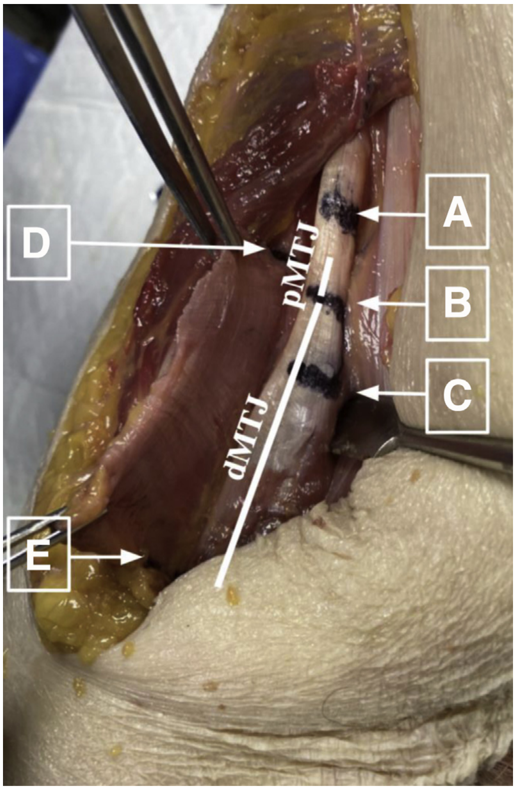

Fig 1. Cadaveric shoulder illustrating the long head of the biceps (LHBT) myotendinous junction (MTJ) and its relationship to the pectoralis major tendon (PMT). (A) Visible LHBT before PMT reflection. (B) LHB MTJ. (C) Mid-substance of the MTJ. (D) Superior border of the PMT. (E) Inferior border of the PMT. (dMTJ, distance from the proximal aspect of the long head of the biceps myotendinous junction to the inferior border of the pectoralis major tendon; pMTJ, distance from the proximal aspect of the long head of the biceps myotendinous junction to the superior border of the pectoralis major tendon.)

of the PMT. The same reports found the average length of the PMT to range from 2.8 to 7.7 cm.[2,22-26] Given the wide range of reported proximal MTJ locations and PMT lengths, single-value recommendations for this relationship can provide for LHB tension variations, as differences as small as 1.37 cm in tenodesis positioning significantly impact average load to failure.[18] Rather, a patient-specific proportional value between the location of the LHB MTJ and PMT length may be beneficial in defining this relationship.

The purpose of this study was to describe the proportional anatomic relationship of the LHB MTJ to PMT and to provide an up-to-date review of the current literature. We hypothesized that the MTJ would consistently be localized to the proximal 50% of the PMT regardless of length.

Methods

Ten fresh frozen cadaveric specimens were included in this study. All specimens were with attached scapula and extended distally to include the hand. A deltopectoral approach was used to expose the PMT. A tenotomy of PMT was performed with a cuff of tendon left attached to its humeral footprint. Once free, the PMT was reflected, and the LHBT was gently mobilized to allow for localization of MTJ. The location of the most proximal extent of the MTJ as well as the proximal and distal borders of the PMT were agreed upon between 2 fellowship-trained shoulder and elbow specialists. The length of the PMT from its proximal to distal humeral insertion, the distance from the LHB MTJ to the proximal border of the PMT (pMTJ), and the distance from the LHB MTJ to the distal border of the PMT (dMTJ) were recorded (Fig 1). Using previously published methodology, all measurements were collected with the humerus aligned to 40° in relation to the medial border of the scapula.[2] The elbow was flexed to 90° and the forearm was held in neutral rotation. All measurements are reported as a mean, standard deviation, and range. The relationship between the pMTJ and the PMT length was then reported as a ratio in which pMTJ was divided by PMT length. A literature review was conducted of all cadaveric and MRI studies documenting the aforementioned parameters. If not explicitly stated, the aforementioned values were calculated if the data were made available.

Results

The PMT was found to have a length of 5.16 ± 0.64 cm (4.1-6.1 cm). The pMTJ was 1.14 ± 0.52 cm (0.5-1.9 cm), and the dMTJ was 4.02 ± 0.91 cm (2.5-5.3 cm). The pMTJ/PMT ratio was 0.23 ± 0.11 (0.10-0.39). Data from a review of the current available literature are summarized on Table 1.

Discussion

We found the LHB MTJ to be positioned 1.14 ± 0.52 cm distal to the proximal border of the PMT and found within the proximal 10% to 40% of the PMT longitudinal length. These results are consistent with the previously published literature on this relationship whose sMTJ/PMT ratios were calculated to range from 0.21 to 0.55. There does appear to be variability in these landmarks and using a patient-specific relative relationship may help avoid the over- or undertensioning that may be associated with using a single-value recommendation.

In our review of the literature, the average length of the PMT varied from 2.8 cm to 7.7 cm.[2,26] We intended to supplement currently available literature describing the length of the PMT and its relationship to patient specific factors such as sex, age, height, humeral length, or muscle atrophy. These factors may contribute to the variations in the reported tendon length as differences in the subscapularis footprint between male and female patients has been previously described in a cadaveric analysis by Ide et al.[27] In their study, the authors also

Table 1. Review of Anatomic and MRI Studies Describing the Relationship Between the PMT and LHB MTJ

Study	Characteristics	PMT Length and MTJ Relationship	pMTJ/PMT
Jarrett et al., 2011[22]	12 cadaveric specimens; 3 M, 9 F; average age 84 (69-98) y	PMT: 5.32 cm pMTJ: 2.20 cm dMTJ: 3.38 cm	0.41
Denard et al., 2012[23]	21 cadaveric specimens; 11 M, 10 F; average age 60.9 ± 11.5 y	PMT: 4.46 cm* pMTJ: 2.47 cm* dMTJ: 1.99 cm*	0.55
Lafrance et al., 2013[2]	10 cadaveric specimens; 9 M 1 F; average age 66.5 y	PMT: 7.7 ± 1.2 cm pMTJ: 3.2 ± 1.4 cm dMTJ: 4.5 cm*	0.42
Kovack et al., 2014[24]	20 cadaveric specimens; 10 M, 10 F; age range 57-61 y	PMT: 5.55 cm* pMTJ: 2.38 cm dMTJ: 3.17 cm	0.42
Hussain et al., 2015[25]	43 cadaveric specimens; 20 M, 23 F; average age 76.3 ± 10.2 (57-95) y	PMT: Not available pMTJ: 5.7 cm dMTJ: Not available	Not available
Ek et al., 2021[26]	MRI evaluation of 45 patients; 33 M, 12 F; average age 37 ± 13 (18-59) y	PMT: 2.8 ± 0.73 cm pMTJ: 0.59 ± 1.08 cm dMTJ: 2.21 cm*	0.21

dMTJ, distance from the proximal aspect of the long head of the biceps myotendinous junction to the inferior border of the pectoralis major tendon; F, female; M, male; MRI, magnetic resonance imaging; PMT, pectoralis major tendon; pMTJ, distance from the proximal aspect of the long head of the biceps myotendinous junction to the superior border of the pectoralis major tendon.

*Calculated based on data provided in manuscript.

found the diameter of the humeral head correlated with longitudinal insertional length. Similar relationships may be true of the PMT and humeral length.[25] We found the PMT footprint to be 5.16 cm in length, which is similar to that found by Jarrett et al.[22] and Kovac et al.[24]

There also appears to be variation in the reported proximal origin of the LHB MTJ in relation to the proximal border of the PMT. In their MRI review of 45 patients presenting for an evaluation of shoulder pain, Ek et al.[26] found an average pMTJ of 0.59 cm. This is compared with more distal values of 2.2 to 5.7 cm found in cadaveric studies.[2,22-25] The authors suggest this difference may be attributed to the younger patient population included in their study compared with cadaveric studies, as increasing age may influence bicep muscle bulk and LHB MTJ positioning relative to the PMT. This was supported by a correlation nearing statistical significance that pMTJ may become more distal with increasing patient age.[26] The wide discrepancies in the location of the pMTJ are of clinical importance, as this is often used as a reference point for location of the biceps tenodesis. Ideally, the location of the MTJ nears its native relationship with the PMT to allow for appropriate tensioning with the goal of improving patient pain and function. Furthermore, differences less than 1.5 cm in LHB tensioning have been shown to change load to failure.[18] Our review of the literature found an average pMTJ difference of over 5 cm between the minimum and maximum reported values. These values would result in variations in tendon tensioning depending on distance used.

PMT length and the location of the proximal origin of the LHB MTJ appear to be patient specific and related to demographics and pathology as these values vary widely in the literature. These differences may lead to clinically significant tensioning variations if a uniform tenodesis location is used for all patients based on pMTJ distance alone. Instead, a ratio pMTJ/PMT provides surgeons the ability to guide LHB tension to individual patients. In our study, we found this value to be 0.23 ± 0.11 and 0.21 to 0.55 when calculated for the previous studies (Table 1). Using this ratio, all studies found the LHB MTJ to be localized proximally relative to the PMT footprint, roughly within 20% to 50% of its longitudinal length. Providers can use preoperative MRI or intraoperative PMT measurements to calculate a patient-specific tenodesis range. Knowing these individualized values will allow for a likely acceptable range of tenodesis localization that can help prevent significant over or under tensioning of the LHBT. We believe that this ratio gives a reliable and reproducible intraoperative landmark for surgeons to use during biceps tenodesis surgery. Our literature review demonstrates that great variability exists with absolute landmark measurements, and that if used it could lead to either overtensioning or undertensioning by affixing the long head of the biceps tenodesis in a nonanatomic site. Based on the findings of our current study and our literature review, we recommend that the long head of the biceps myotendinous junction be placed at the junction of the proximal one-third and distal two-thirds of the PMT.

Limitations

The main limitation for this study was that only 10 cadaveric shoulder specimens were used during the investigation and final analysis.

Conclusions

We found the average length of the PMT footprint to be 5.16 cm with the LHB MTJ beginning 1.14 cm distal to its proximal border.

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