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RESEARCH ARTICLE

'Superior biceps aponeurosis'—Morphological characteristics of the origin of the short head of the biceps brachii muscle☆

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ABSTRACT

Purpose: Our aim was to characterize the morphology of the proximal attachment of the biceps brachii short head. We hypothesize that it has an aponeurotic component that may affect shoulder joint biomechanics.
Methods: The coracoacromial region and the biceps brachii muscle were dissected in 30 cadaveric shoulders. The course and dimensions of the tendon and aponeurosis were evaluated. The cross-sectional area of the belly of the short head and the length of the whole muscle were measured. Correlations between the aponeurosis and dimensions of the muscle were tested with the Spearman's rank correlation coefficient.
Results: Aponeurosis was present in all specimens, although in 10 cases it was vestigial. The aponeurotic part of the muscle (mean length 90.7 ± 16.3 mm, mean width 12.5 ± 2.9 mm) branched off laterally and traveled to the acromion, blending with the coracoacromial ligament creating the aponeurotic membrane. We named this structure the "superior biceps aponeurosis". The mean length of the biceps brachii was 31.3 ± 2.1 cm and the mean cross-sectional area of the short head was 210.7 ± 54.3 mm^2. The dimensions of the "superior biceps aponeurosis" correlated positively with the cross-sectional area of the muscle (R^2 from 0.37 to 0.52, p from 0.014 to 0.001).
Conclusion: The origin of the short head of the biceps brachii muscle has a varied aponeurotic component combining the aponeurotic part of the muscle and the aponeurotic membrane. Together, they create the "superior biceps aponeurosis".
Clinical relevance: The morphology of the origin of the biceps brachii short head is relevant in Bristow/Latarjet procedures. This aponeurotic component may affect the shoulder joint biomechanics after the coracoid process transfer.

1. Introduction

The biceps brachii muscle consists of a long head and a short head, which have two different origins and one common insertion. Although numerous studies have examined the insertion of the muscle to the radial tuberosity (Athwal et al., 2007; Champlin et al., 2017) and the origin of the long head from the supraglenoid tubercle (Bicos, 2008; Taylor and O'Brien, 2016; Werner et al., 2000), less attention has been paid to the morphology of the origin of the short head of the biceps brachii at the coracoid process (Mohammed et al., 2016). Nevertheless, with increasing popularity of surgical procedures in this region, particularly Latarjet coracoid process transfer, the detailed anatomy of this region should be studied.

According to Crichton and Funk (2009), the origin of the short head of the biceps brachii muscle is not a typical tendon but it also comprises an aponeurosis covering its anterior surface. We partially agree with these authors; however, our hypothesis is that the aponeurotic component is a more complex structure that extends to the acromion.

The aim of this study was to characterize the morphology of the origin of the biceps brachii short head in context of its aponeurotic component.

☆ Institutional Review Board: The bioethical committee of Medical University of Lodz (protocol number: RNN/241/16/KE).

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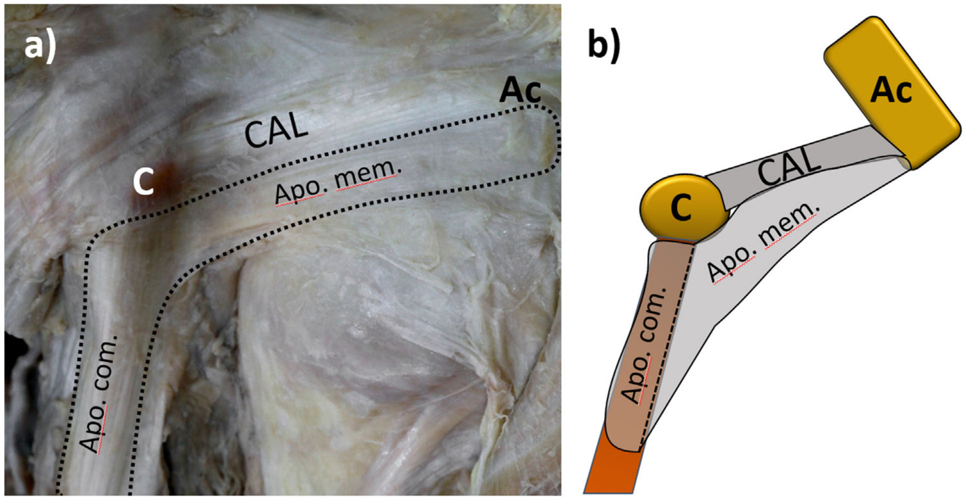

Fig. 1. Photography (a) and model (b) presenting the "superior biceps aponeurosis" (Apo. com. – aponeurotic component, covering the short head of biceps brachii, Apo. mem. – aponeurotic membrane interweaving with coracoacromial ligament, C – coracoid process, CAL – coracoacromial ligament, Ac – acromion).

2. Materials and methods

Dissection was performed in 30 isolated, formalin-fixed cadaveric shoulders (15 right and 15 left), derived from 14 males and 10 females. The mean age of the donors was 67 years (range 55–77 years).

The coracoacromial region was dissected by removal of the skin with the subcutaneous tissue. Then the deltoid muscle was detached from the deltoid tuberosity and the muscle with its fascia was retracted superiorly. The coracoacromial ligament was exposed and the region was inspected for signs of injury, intervention or chronic bursitis. Then the pectoralis major was detached from the medial insertion and retracted laterally. Loose connective tissue was removed from the surrounding of the coracoid process exposing attachments of the pectoralis minor, coracobrachialis and the short head of the biceps brachii muscle. The dissection was then continued distally to the cubital fossa to visualize the whole length of the biceps brachii muscle with its attachment to the radial tuberosity.

The short head of the biceps brachii was identified. The mediolateral (a) and anterioposterior (b) dimensions of the short head of the biceps brachii were measured in the most bulky part of the muscle belly. Cross-sectional area was calculated according the formula for ellipsoid surface ($0.52 \times a \times b$). The length of the muscle was measured along the course of the short head (from the origin to the distal insertion).

Afterwards, the aponeurosis was evaluated by dividing it into two parts: the aponeurotic component (tendinous aponeurosis) covering the short head of biceps brachii muscle and the aponeurotic membrane that branched off the muscle and travelled superiorly (Fig. 1). We named this whole structure the 'superior biceps aponeurosis'. The maximal length of the aponeurotic component covering the muscle was measured from the tip of the coracoid process to the site of blending with muscle belly. The maximal width of this component was also measured. Then, the aponeurotic membrane was followed from the site where it separates from the muscle belly and travels laterally to the lateral edge of the coracoid process. The membrane was found to interweave with the fascia covering the rotator cuff muscles, and with the lateral edge of the coracoacromial ligament (Fig. 1). Due to its triangular shape and distinct lateral border it could be distinguished from the aforementioned structures. The width and thickness of the aponeurosis at the level of the base of the coracoid process were measured. In addition, the distance between the tip of the coracoid process and the place where the aponeurotic membrane was found to branch off from the fascia covering the muscle belly was also assessed.

Measurements were performed twice by two independent investigators with an electronic digital caliper (Mitutoyo Company, Kawasaki-shi, Kanagawa, Japan) or a measuring tape in the case of the length of the whole muscle belly. The mean results of these two measurements were used in further analyses. In all specimens, none of the muscles, tendons and ligaments in dissected regions had any features of former injuries, which was confirmed during further dissection. The study followed the rules of the Declaration of Helsinki.

Statistical analysis was performed using Statistica 12 software (StatSoft Poland, Cracow, Poland). A P-value <0.05 was considered significant. The normality of the data distribution was assessed with the Shapiro–Wilk test. As the distribution was non-normal, correlation between measured parameters was evaluated with the Spearman's rank correlation coefficient.

3. Results

The "superior biceps aponeurosis" was present in all cases (Fig. 2), although in 10 specimens it was vestigial: a thin membrane was covering only the proximal part of the muscle, and did not reach the acromion after branching off, blending with the coracoacromial ligament (Fig. 3). There was a trend for the vestigial form to be present more often in limbs taken from female subjects ($n = 6$) than males ($n = 4$) and in limbs with shorter biceps with a mean length of 29.3 ± 3.3 cm for the whole muscle (compared to 30.7 ± 2.7 cm for normal length muscles); however, these differences were not statistically significant ($p = 0.1928$ and 0.2452, respectively).

In the remaining 20 cases, the mean length of the aponeurotic portion covering the biceps brachii muscle was 90.7 mm ($\pm$16.3 mm) and its width 12.5 mm ($\pm$2.9 mm). The mean cross-sectional area of the short head was 210.7 mm^2 ($\pm$54.3 mm^2) and the mean length of the whole muscle 31.3 cm ($\pm$2.1 cm). The aponeurotic membrane began a mean distance of 23 mm ($\pm$11 mm) from the tip of the coracoid process, with a mean width and thickness of 7.7 mm ($\pm$4.1 mm) and 1.5 mm ($\pm$1.7 mm), respectively.

Significant correlations were found between the dimensions of the aponeurotic membrane and the length and the width of the aponeurotic component, and with the cross-sectional area of the short head of the biceps brachii muscle (Table 1). The dimensions of the aponeurotic component also correlated with the diameter of the cross-sectional area. In addition, the length of the whole muscle

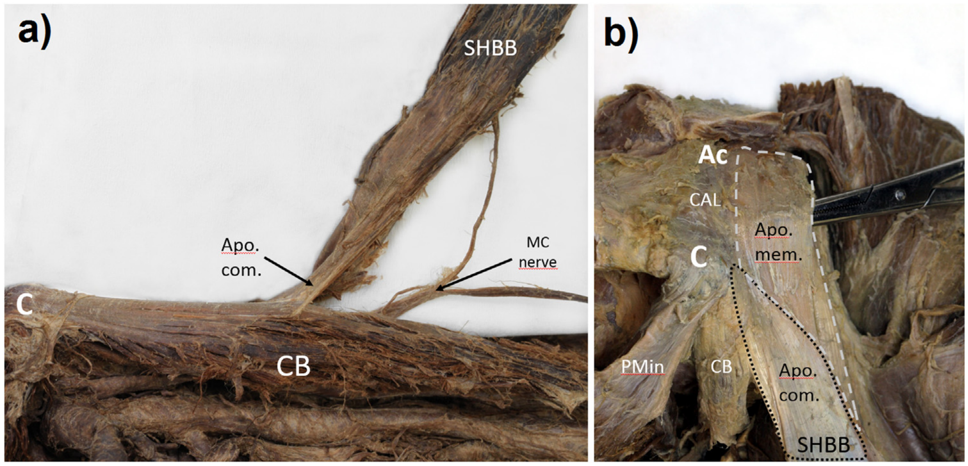

Fig. 2. Photographs presenting the "superior biceps aponeurosis" after reflecting the short head of the biceps brachii muscle, medial (a) and anterior (b) view (Apo. com. – aponeurotic component, Apo. mem. – aponeurotic membrane, SHBB – short head of biceps brachii muscle, CB – coracobrachialis muscle, MC nerve – musculocutaneous nerve, C – coracoid process, CAL – coracoacromial ligament, Pmin – pectoralis minor muscle, Ac – acromion).

Table 1
Correlations between dimensions of the superior biceps aponeurosis and the short head of biceps brachii.

		Aponeurotic component of the biceps brachii muscle				Short head of biceps brachii			
		Length [mm]		Width [mm]		Area [mm^2]		Length [cm]	
		R^2	P	R^2	P	R^2	P	R^2	P
Aponeurotic membrane width [mm]		0.55	0.001	0.43	0.016	0.52	0.002	0.09	0.421
Aponeurotic membrane thickness [mm]		0.41	0.022	0.32	0.027	0.37	0.016	0.11	0.348
Distance from the tip of the coracoid process to the beginning of the aponeurotic membrane [mm]		0.57	0.001	0.36	0.012	0.66	0.001	0.24	0.073
Aponeurotic component of the biceps brachii muscle [mm]	Length				–	0.41	0.014	0.26	0.184
	Width		0.52	0.008	0.17	0.231			

R^2 – Spearman's rank correlation coefficient; P – P-value.

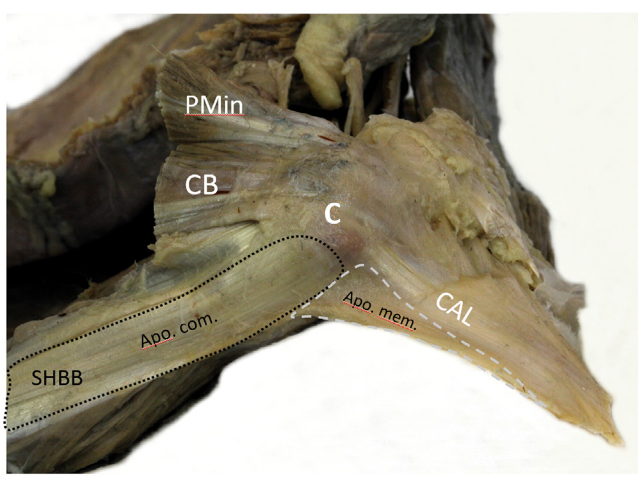

Fig. 3. Photograph presenting the vestigial form of the "superior biceps aponeurosis" from a lateral view. The coracobrachialis (CB) and pectoralis minor (PMin) muscles were cut off. (Apo. com. – aponeurotic component, Apo. mem. – aponeurotic membrane, SHBB – short head of biceps brachii muscle, C – coracoid process, CAL – coracoacromial ligament).

did not correlate with the dimensions of the aponeurotic component of the muscle, nor with the dimensions of the aponeurotic membrane.

4. Discussion

Our work presents a new insight into the anatomy of the short head of the biceps brachii muscle. It shows a detailed anatomical relationship between the coracoacromial ligament and the aponeurotic structures derived from the short head of biceps brachii. Therefore, we propose the term "superior biceps aponeurosis" for the aponeurotic component of the short head of biceps brachii muscle and the connection between its membranous extension and the coracoacromial ligament (so called 'aponeurotic membrane').

By definition, aponeurosis is a ribbon-like tendinous expansion. Bicipital aponeurosis is well defined in the distal part of the muscle where it branches from the distal biceps tendon and covers the cubital fossa. However, aponeurosis may be present in a different form, covering the part of muscle gradually collecting the muscle fibers to finally create the attachment. This kind of aponeurosis is present in the insertion of the triceps brachii muscle (Kawakami et al., 1993), the insertion of the distal part of the gastrocnemius (Blitz and Eliot, 2007), the origin of the spinal part of the deltoid muscle or, as presented in this study, in the origin of the short head of the biceps brachii muscle. Although the existence of this aponeurotic component has already been proposed by Crichton and Funk (Funk and Crichton, 2009), they report this structure as being present in only five specimens and do not describe the connection of the aponeurosis with the coracoacromial ligament. In our opinion, the "superior biceps aponeurosis" is a structure of a greater complexity, as it branches off on its lateral edge as an aponeurotic membrane, blends with the coracoacromial ligament and may insert to the tip of the acromion.

This bundle (aponeurotic membrane) running between the short head of the biceps brachii muscle and the coracoacromial ligament has also been described by Birnbaum et al.(1998) and defined as "coracoid aponeurosis". The authors suggest that this structure may contribute to the gliding mechanism of the subacromial bursa and shoulder joint capsule on the basis of a tension band wiring effect. However, the aforementioned study does not address the aponeurotic character of the short head of the biceps brachii muscle. Although no biomechanical testing was performed in the present study, it is possible that the superior biceps aponeurosis may act as a band that compresses the subacromial/subdeltoid bursae supporting the gliding mechanism of the supraspinatus tendon through the subacromial space. If so, this band may transfer the force more effectively when branching from the aponeurotic component of the muscle, as it was found in our morphological observations.

This hypothesis is supported by the results of our statistical analysis. Firstly, the dimensions of the aponeurotic component correlate with the dimensions of the aponeurotic membrane and secondly, the dimensions of both of these structures correlated with the cross-sectional area of the short head of biceps brachii muscle. This may suggest that the morphology of 'superior biceps aponeurosis' is closely associated with the morphology of the muscle, potentially creating a functional complex. These findings should be confirmed in further biomechanical studies; however, based on the morphology, the term 'coracoid aponeurosis', proposed by Birnbaum et al. (1998), does not fully account for its true anatomic relations. Therefore, we propose the term 'superior biceps aponeurosis'.

The morphogenesis of the biceps brachii muscle also seems to support our hypothesis. Both the long and short head of the biceps brachii muscle develop from the same myotome antecedent to the development of the scapula (Birnbaum et al., 1998). Initially the origins of the biceps brachii muscle are separated, though they are closely united (Tiwana and Varacallo, 2018). Then they become separated again into two apparent origins by the development of the scapula. Hence, some of the fibers of the short head of biceps brachii may remain on the path of its course to the coracoid process, blending with the coracoacromial ligament.

Variations in the morphology of the 'superior biceps aponeurosis' and the existence of aponeurosis in the form of a vestigial structure are not unexpected, as the whole muscle is characterized by many anatomical diversities. The contribution of the short and long head of the biceps brachii to the bicipital aponeurosis (in the cubital region) seems to be highly variable (Blitz and Eliot, 2007). Moreover, its maximal length ranges from 5.8 to 10.4 cm (Snoeck et al., 2014). The number of muscle heads may also vary from three (Nasr and Hussein, 2013) to five (Hyman and Warren, 2001). The origin of the long head of biceps brachii also demonstrates great variation (Bicos, 2008; Taylor and O'Brien, 2016).

Our work has potentially important clinical implications. Firstly, it may contribute to an explanation of the phenomenon that, on the contrary to the long head of the biceps brachii, the short head is rarely affected with acute and chronic overload injures. The reason would be that the "superior biceps aponeurosis" may dissipate some of the load away from its enthesis. Secondly, it may be important for shoulder surgeons. Bristow or Latarjet (Nourissat et al., 2016) surgeries are open or arthroscopic procedures performed to prevent anterior instability in the context of a significant glenohumeral bone defect. In these procedures, the coracoid process is transferred, with the conjoined tendon of the short head of biceps brachii and coracobrachialis muscle, to the neck of the scapula at the anterior glenoid rim. Current literature does not provide information about the soft tissue implications of various coracoid osteotomy sites (Dolan et al., 2011). Nevertheless, as the short head of the biceps brachii muscle is transferred in all these cases, the aponeurotic connection with the coracoacromial ligament is dissected or stretched. The influence of this transposition remains unclear and should be further investigated in the context of supraspinatus impingement, which may occur due to the loss of gliding support provided by the aponeurosis, in the case of the aponeurotic membrane being cut, or due to increased friction created by the stretched aponeurotic membrane.

The limitation of our study is that the true function of the 'superior biceps aponeurosis' is only speculation. However, this can be confirmed in further biomechanical studies.

5. Conclusion

The origin of the short head of the biceps brachii muscle has a more complex morphology than commonly described. It comprises the aponeurotic component covering the muscle belly and the aponeurotic membrane, extending to the coracoacromial ligament. Therefore, we propose to name the whole structure the "superior biceps aponeurosis".

Ethical approval and consent to participate

The anatomical protocol of the study was accepted by the Bioethics Committee of the Medical University of Lodz (resolution RNN/241/16/KE). The cadavers belong to the Department of Normal and Clinical Anatomy of the Medical University of Lodz. This article does not contain any studies with human participants or animals performed by any of the authors.

Consent to publish

Not applicable.

Availability of data and materials

Please contact authors for data requests (Łukasz Olewnik, Ph.D – email address: lukasz.olewnik@umed.lodz.pl).

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