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ORIGINAL ARTICLE

Accessory thoracic muscles in human fetuses

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ABSTRACT

Background: Typically, the anterior thoracic wall musculature is composed of the pectoralis major and pectoralis minor. Embryologically, these two muscles are originated from a common pectoral muscle mass; therefore, disruption of the normal development and differentiation could give rise to an aberrant or accessory muscle. The main aim of this study is to demonstrate and classify the accessory muscles of the pectoralis region in human fetuses.

Material and methods: Fifty spontaneously aborted human fetuses (25 male and 25 female, 100 sides) aged 18-38 weeks of gestation at death, and fixed in 10% formalin solution were examined. Following parental approval, the fetuses were donated to the Medical University anatomy program. The pectoralis major and minor muscle's morphology, the possible occurrence of accessory muscles of pectoral region and its morphology, their origins, and insertions, as well as the morphometric details, were assessed.

Results: The pectoralis major and minor were bilaterally found in all fetuses (100 cases). The accessory muscles of pectoral region were found in 16 cases (16%), and four types were

differentiated. The Pectoralis Quartus muscle was the most common type of accessory muscles found in this study and occurred in 8 cases. The axillary arch muscle was observed in 3 cases. The chondrocoracoideus muscle was observed in 3 cases. The sternalis muscle occurred in 2 cases, and one of them was bifurcated.

Conclusions: The thoracic region is characterized by a large amount of morphological variations, which are observed not only in adult population, but also among human fetuses. The pectoralis quartus was the most frequent variation in this study. Accessory structures like sternalis muscle, chondrocoracoideus muscle, pectoralis quartus muscle, or axillary arch muscle may have clinical implications, and knowledge about them is very useful for clinicians, especially plastic surgeons, thoracic surgeons, and orthopedics.

Keywords: pectoral region, pectoralis major muscle, pectoralis minor muscle, sternalis muscle, chondrocoracoideus muscle, pectoralis quartus muscle, axillary arch muscle, human fetuses

INTRODUCTION

Typically, the anterior thoracic wall musculature is composed of the pectoralis major (PM) and pectoralis minor (PMi). Embryologically, these two muscles are originated from a common pectoral muscle mass; therefore, disruption of the normal development and differentiation could give rise to an aberrant or accessory muscle [16]. The accessory thoracic muscles (ATM) could be identified with great morphological variability and the most observed ones are the sternalis muscle, the axillary arch (of Langer’s), the pectoralis quartus, the chondrocoracoideus (of Wood), the pectoralis intermedius and the pectoralis minimus (of Gruber) [3]. The morphological variability is high enough that even recently, unreported variations could be found [23].

Several studies have been investigating the prevalence and morphology of the abovementioned variations, while few of them have been studied for over two hundred years [2]. For example, sternalis muscle pooled prevalence was estimated at 5.96% (adult cadavers) and was classified in eight different morphological types [2]. Interestingly, the coexistence of accessory thoracic muscles have also been reported, complicating even more the thoracic wall typical anatomy [6].

Except of the great anatomical interest, these variants present with great clinical significance. Accessory muscles of the thoracic wall and axilla should be kept in mind by surgeons performing axillary lymphadenectomy to avoid iatrogenic lesions, while accessory structures are closely related to potential compression sites [13].

Although, the thoracic region is morphologically variable, in the available literature there is not a general study carried out among human fetuses. As these morphological variations may be associated with embryological development, the main aim of this study is to investigate ATM in human fetuses.

MATERIALS AND METHODS

Fifty spontaneously aborted human fetuses (25 male and 25 female, 100 sides) aged 18–38 weeks of gestation at death, and fixed in 10% formalin solution were examined. Following parental approval, the fetuses were donated to the Medical University anatomy program. Their ages were calculated using head and craniosacral measurements. The thoracic wall, abdomen, shoulder region, and anterior and medial regions of the arm were the first areas of the dissection to have their skin and superficial fascia removed. In order to visualize muscles of pectoral region, the subcutaneous tissue had to be removed [22]. If there are no accessory structures, then proximal attachments and the subcutaneous tissue of the PM had to be removed. The PMi structure as a whole was the meticulously cleaned. Following dissection, the morphological and morphometric characteristics of ATM were evaluated as follows:

- the PM, and PMi morphology,
- the possible occurrence of ATM,
- the morphometric measurements of ATM.

When dissecting the PM and PMi:

- special attention should be paid when removing the fascia, as some accessory muscle could be present in the area.

A digital caliper (Mitutoyo Corporation, Kawasaki-shi, Kanagawa, Japan) with an accuracy of up to 0.01 mm was used for all measurements. The same researcher conducted each measurement twice, recording the mean value of the two measurements or calculating the interobserver error. The fetuses belonged to the Department of Anatomical Dissection and

Donation at the Medical University of Lodz, Poland, and the study protocol was approved by the Bioethics Committee (resolution RNN/137/20/KE).

RESULTS

The PM and PMi were found bilaterally in 50 fetuses (25 male, 25 female), which means 100 sides (50 R, 50 L). During anatomical dissection, 16 ATM were found (16%). Four different types of ATM were differentiated based on their course. Morphometric measurements of all accessory muscles are listed in Table 1.

Pectoralis quartus muscle — this type of ATM was identified in 8% of studied cases (50% of observed ATM; 4 F, 4 M, 3 R, 5 L). In all cases the point of origin was 5th or 6th rib. Five cases were distally attached to the bicipital grove located on the humerus, and three cases were fused with fascia of the upper limb — Fig. 1.

Axillary arch muscle — this type of ATM was identified in 3% of studied cases (18.75% of observed ATM; 1 F, 2 M, 2 R, 1 L). All cases originating from latissimus dorsi muscle were distally fused with the PM — Fig. 2.

Chondrocoracoideus muscle — this type of ATM was identified in 3% of studied cases (18.75% of observed ATM; 1 F, 2 M, 1 R, 2 L). All cases originated from 6th or 7th rib and rectus sheath as a muscle belly. Two cases were distally fused as a tendinous structure with the shorth head of the biceps brachii and attached to the coracoid process. One case was distally attached as a tendinous structure directly to the coracoid process — Fig. 3.

Sternalis muscle — this type of ATM was identified in 2% of studied cases (12.5% of observed ATM; 1 F, 1 M, 1 R, 1 L). The first case originated from the body of sternum at level of 2nd intercostal space as a single muscular band and inserted to the 5th rib — Fig. 4a. The second case originated from distal part of sternocleoidomastoid muscle and sternum, as bifurcated muscle belly distally merged into one belly attaching to the 6th and 7th ribs Fig. 4b.

Table 1. Morphometric measurements of ATM

	Sex	Side	P.A. width [mm]	P.A. thickness [mm]	M.B. lenghth [mm]	M.J. width [mm]	M.J. thickness [mm]	T. lenghth [mm]	D.A. width [mm]	D.A. thickness [mm]

Pecotalis quartus muscle — 8 cases										
1.	M	L	1.32	0.17	16.84				0.91	0.08
2.	M	L	1.66	0.14	18.59				0.53	0.19
3.	F	L	1.52	0.49	13.77				0.30	0.08
4.	F	R	1.80	0.28	10.39				1.30	0.39
5.	F	R	2.60	0.45	18.16				2.13	0.56
6.	F	L	6.11	0.73	11.13				3.29	0.62
7.	M	R	3.09	0.40	17.82				3.49	0.54
8.	M	L	2.88	0.59	17.36				0.85	0.28
Axillary arch muscle — 3 cases										
1.	M	L	0.63	0.33	8.64				3.44	0.61
2.	M	R	1.02	0.37	7.59				3.71	0.38
3.	F	R	1.61	0.14	12.59				2.94	0.45
Chondrocoracoideus — 3 cases										
1.	F	R	5.36	0.27	19.38	3.17	0.98	5.62	3.31	0.37
2.	M	L	0.67	0.33	23.48	0.46	0.27	6.45	0.45	0.23
3.	M	L	0.68	0.02	16.13	1.13	0.13	6.59	1.47	0.19
Sternalis muscle — 2 cases										
1.	M	R	3.52	0.25	11.21				3.86	0.46
2.	F	L	1.86	0.30	17.03				2.77	0.52

D.A. — distal attachment; M.B. — muscle belly; M.J. — myotendinous junction; P.A. — proximal attachment; T. — tendon

DISCUSSION

The pectoralis region is characterized by high morphological variability, and the main cause of it is the abnormal development of pectoral muscle mass [3]. The PM and PMi originate from the same pre-muscle mass in the first embryonic stage (5-week embryo), which is derived from the proximal part of the humerus and the second rib. There are two layers in this pre-muscle mass: a superficial layer for the development of the PM and a deep layer for the development of the PMi and subclavius. The pre-muscle structure of the pectoral mass grows inferiorly during the early stages of embryogenesis. In an 11 mm embryo, PM and PMi are represented by a common mass attached to the humerus, clavicle, and CP. In a 14 mm embryo, the caudal portion of this structure extends to the tip of the fifth rib. At that point, the distal connection is still merged, but the proximal portion splits into the PM (insertion to humerus) and Pm (insertion to the CP) [5, 10]. These two muscles are separated in a 16 mm embryo. Interestingly, one piece of information found in the literature that is currently available states that the PM is separated into three bellies during embryological development [10].

The disrupted process of embryological development seems to be the best explanation for occurrence of different morphological variants. What is interesting, frequency of muscular variations in thoracic region is significantly higher than in any other regions [7].

Standard muscles, like PM and PMi may be variable because of various insertion's location or place and level of proximal attachment [2]. The results of some studies [21, 23] showed that the PM and PMi may be divided into types, based on number and course of bellies, and these differences are observed already in the embryonic stage [20].

It is interesting to note that the PM or PMi may not exist at all. However, there are situations where the PM or PMi is double [3]. A large group of morphological variations within the chest are additional muscles. The pectoralis quartus, the pectoralis intermedius, the pectoralis minimus, the chondrofascialis, the sternohumeralis, the sternochondrocoracoideus, the axillary arch muscle, the pectoralis tertius, the chondroepitrochlearis, and the chonrocoracoideus muscles are included to this group. There is an immense amount of confusion because these muscular variances are referred to by a variety of names [3].

In the present study the PM and PMi were found bilaterally in all fetuses, and the ATM were observed in 16% of studied cases. The most common type of ATM were pectoralis quartus muscle, which occurred in 50% of fetuses with ATM. Usually the pectoralis quartus originates from the 5^{th} or 6^{th} rib, and the lateral border of the PM, or the rectus sheath. It may inserts into

the bicipital groove of humerus or fascia of the upper arm [3]. In the present study in all cases the point of origin was 5th or 6th rib. Five cases were distally attached to the bicipital grove located on the humerus, and three cases were fused with fascia of the upper limb. The prevalence of this muscle in available literature is various. For example Natsis et al. [3] found the pectoralis quartus in 2.8% of studied cases, in turn, Bonastre et al. [6] found rates as high as 11% to 16%. The results of our study, showed that prevalence of the pectoralis quartus is closer to the results obtained by Bonastre et al. [6]., who also described a coexistence of a pectoralis quartus muscle with an unusual axillary arch muscle, and the pectoralis quartus originating from the rectus sheath, were fused with the inferior medial border of the axillary arch band, at the point of lateral part of the PM [6]. What is interesting, not only Bonastre et al. [6] described the pectoralis quartus coexisting with another variation. Arican et al. [1] described the pectoralis quartus muscle (originating from the 5th and 6th ribs, forming a long flat band inserted into the intertubercular groove of the humerus and tendon of the shorth head of the biceps brachii), coexisting with pectoralis intermedius muscle [1].

Axillary Arch Muscle is an another interesting type [23] of ATM found in the present study, and its prevalence was 18.75%, which was significantly higher than in previous studies. For example, Rizk and Harbaugh [14] assessed its frequency on 4.3%, Bertone et al. [4] on 11.5%, and Karanlik et al. [9] on 1.2%. The axillary arch muscle, firstly described by Bugnone in 1783 [4] usually originates from the latissimus dorsi muscle, and its insertion is fused with the PM, and in the present study proximal and distal attachments were the same in all cases. However, this structure can also be variable. All cases described by mentioned Rizk and Harbaugh [14] arose from the latissimus dorsi muscle, and its insertion was located on the intertubercular groove. In the other study, there were some cases distally attached to the aponeurosis level of the coracobrachialis muscle [4]. In the literature there are also descriptions of axillary arch muscle distally attached to the PM, PMi and coracoid process [11] or short head of the biceps brachii [17].

The chondrocoracoideus muscle (sometimes called the costocoracoideus or muscle of Wood) [21] is another example of ATM observed in the present case, which was identified in 3% of studied As is mentioned above, all cases originated from 6th or 7th rib and rectus sheath. Two cases were distally fused with the shorth head of the biceps brachii and attached to the coracoid process. One case was distally attached as a tendinous structure directly to the coracoid process cases. It is a very rare variation, so in the literature, there is not a lot of described cases. One of them is the chondrocoracoideus muscle originating as three distinct

slips from the 6th to 8th ribs and external oblique aponeurosis. Its distal attachment was represented as a small fusion with the tendon of the shorth head of the biceps brachii and as a common junction was inserted to the coracoid process [18]. Another case was about chondrocoracoideus originating from the 6th to 8th ribs and the external oblique muscle aponeurosis, and distally attached to the coracoid process, as a small fusion with the short head of the biceps brachii [8].

Another interesting variation is sternalis muscle, observed in 2% of studied cases. The first case originated from the body of sternum at level of 2nd intercostal space as a single muscular band, and inserted to the 5th rib. The second case originated from distal part of sternocleoidomastoid muscle and sternum, as bifurcated muscle belly distally merged into one belly attaching to the 6th and 7th ribs. Snosek et al. [15] created classification system of this muscle, and divided it into three categories: “Simple Type”, “Mixed Type”, and “Other”. The simple type was divided into six subtypes: single, double, bicipital diverging, bicipital converging, single midline crossing and double midline crossing. In the mixed type we can find a lot of variations, for example double sternalis with single midline cross, double with single bicipital converging, bicipital diverging with double cross and others. And the last one category named “Other” contains all variants not previously described [15]. Looking for some similarity between mentioned classification and the present study, the first case originated from the body of sternum at level of 2nd intercostal space as a single muscular band, and inserted to the 5th rib, may be classified as a right single sternalis muscle. In turn, the second case may be name left bicipital converging type, however its bifurcated proximal attachment arising from the distal part of the sternocleoidomastoid muscle, and distally merge into one belly. Mori et al. [12] also carried out a study about the sternalis, and found this muscle in about 10.0% of the bodies, and it appears more frequently in the right than in the left. The classification system divided the sternalis muscle into six types based on its morphology [12].

Summing up, the results of the present study, the statement that muscles of thoracic region characterized by large amount of morphological variations was confirmed. Knowledge about possible accessory muscles, bellies or different origins and insertions is important for surgeons, especially for plastic surgeons, orthopedics, or thoracic surgeons. For example, the sternalis muscle may be observed during mastectomy. Some accessory structures may be located in close relation to axillary vessels and the brachial plexus. This may result in in neurovascular compression, for example leading to pectoralis minor syndrome [19]. On the

other hand, accessory structures may be used as a graft material during some reconstructions.

CONCLUSIONS

The thoracic region is characterized by a large amount of morphological variations, which are observed not only in adult population, but also among human fetuses. The pectoralis quartus was the most frequent variation in this study. Accessory structures like sternalis muscle, chondrocoracoideus muscle, pectoralis quartus muscle, or axillary arch muscle may have clinical implications, and knowledge about them is very useful for clinicians, especially plastic surgeons, thoracic surgeons, and orthopedics.

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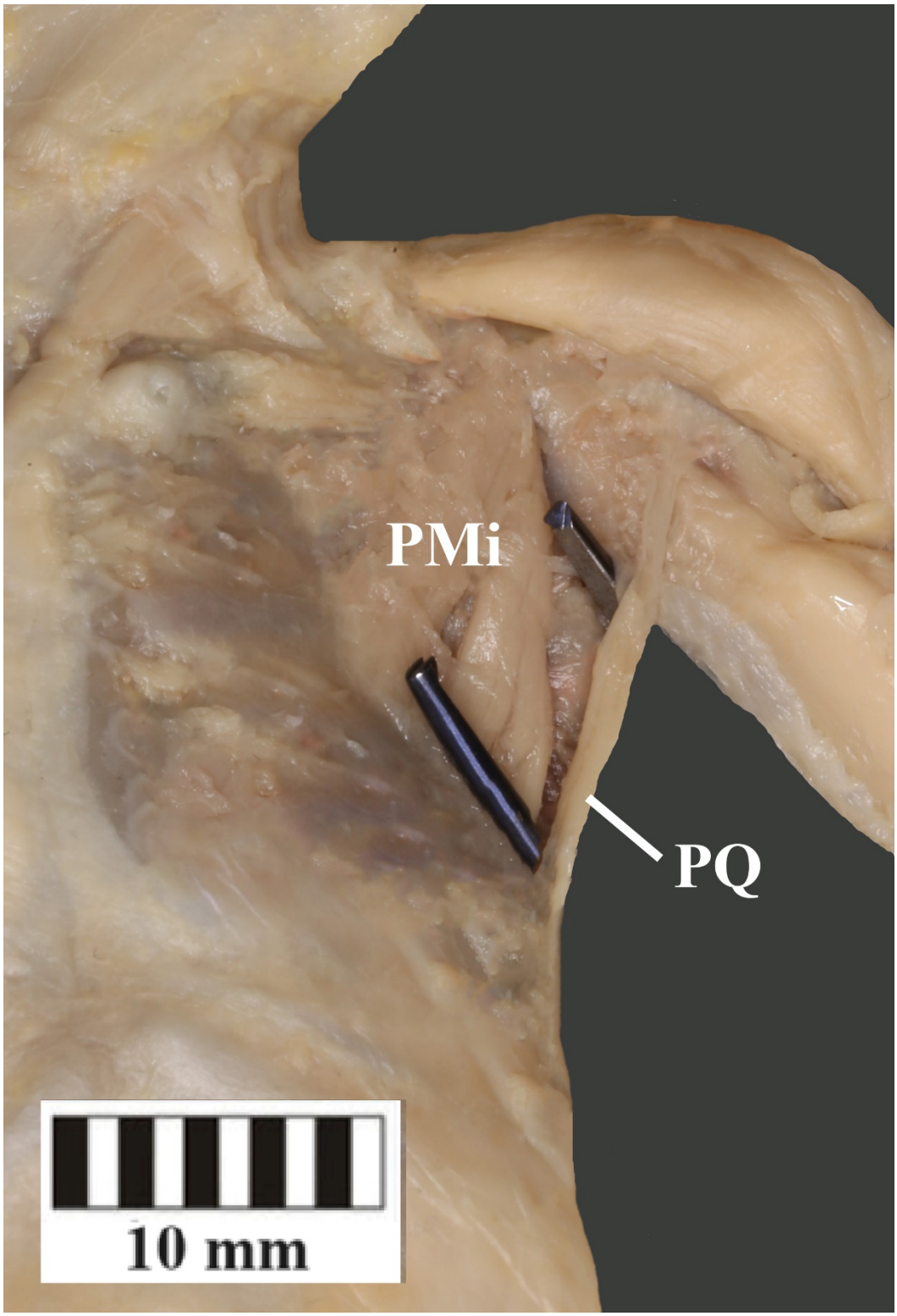

Figure 1. Pectoralis quartus muscle. PMI — pectoralis minor muscle; PQ — pectoralis quartus muscle.

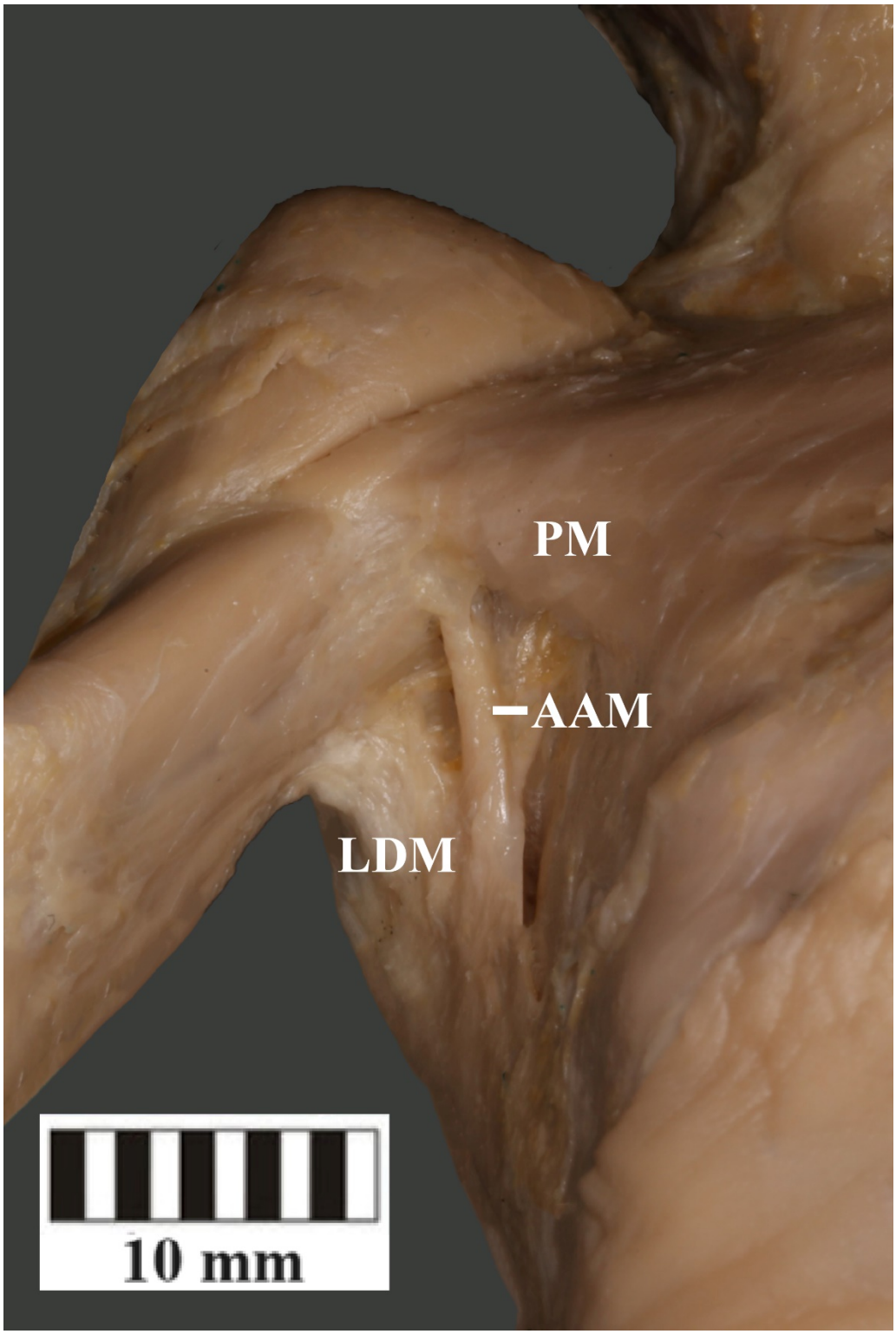

Figure 2. Axillary arch muscle. AAM — Axillary arch muscle; LDM — latissimus dorsi muscle; PM — pectoralis major muscle.

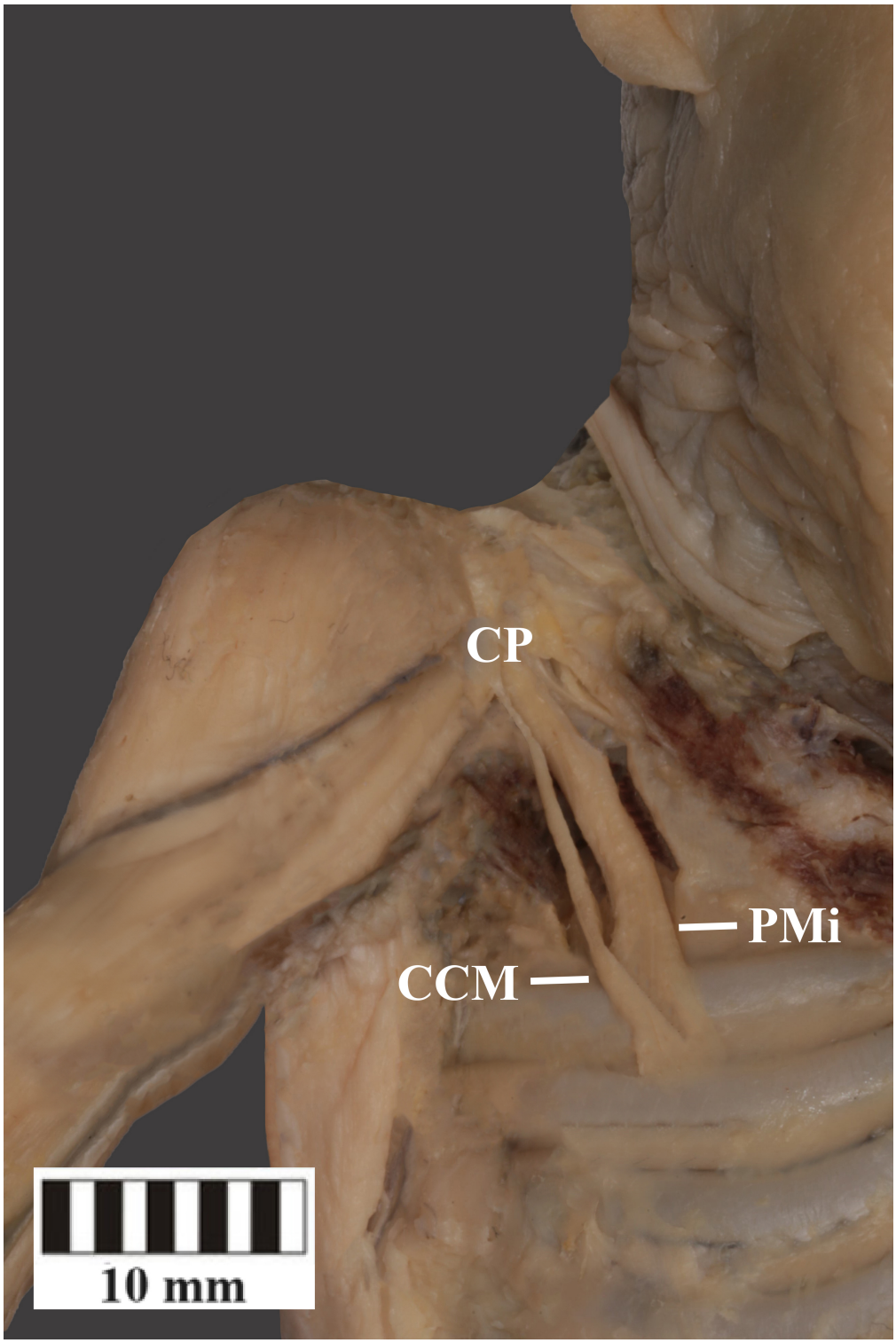

Figure 3. Chondrocoracoideus muscle. CCM — chondrocoracoideus muscle; CP — coracoid process; PMi — pectoralis minor muscle.

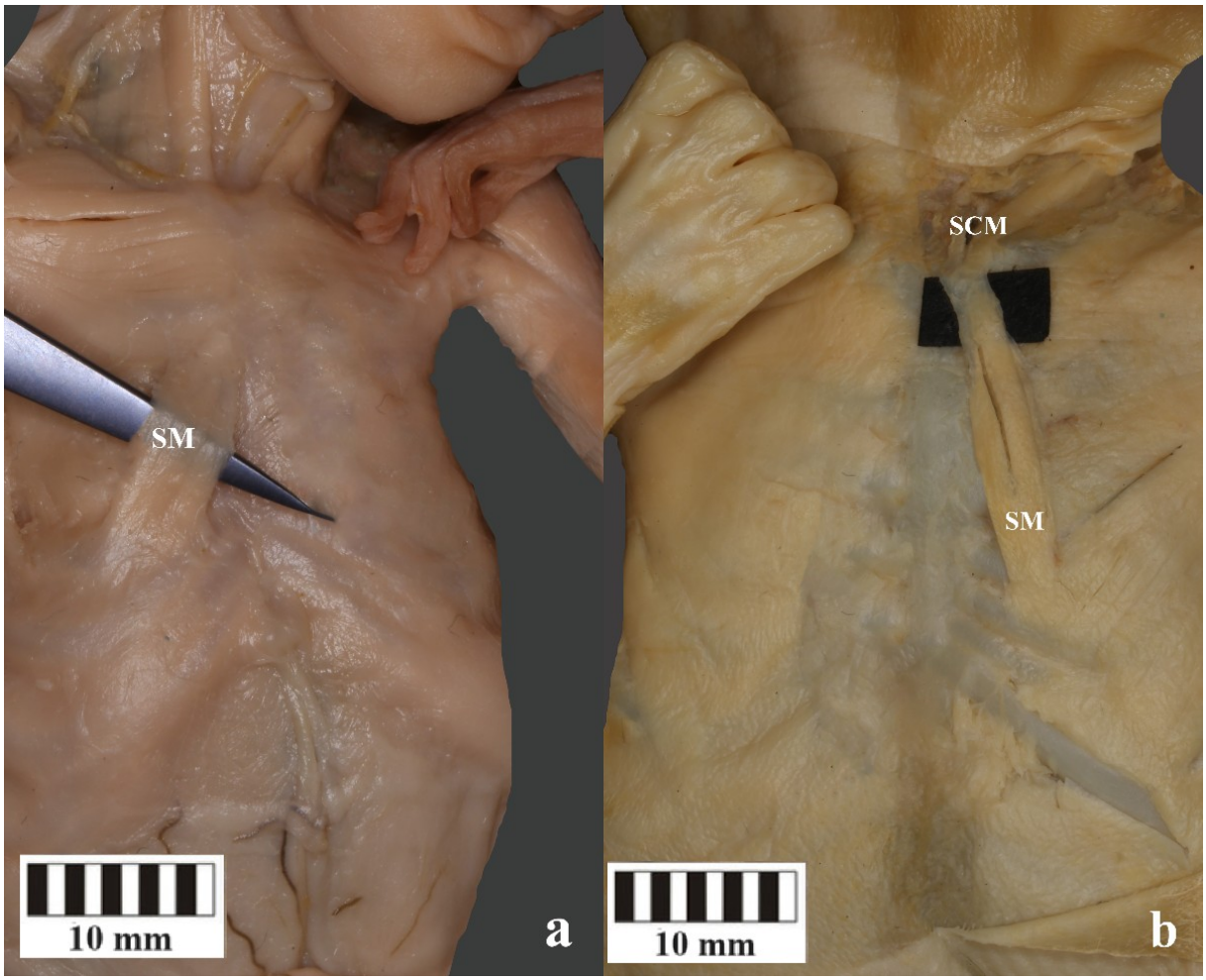

Figure 4. Sternalis muscle. (a) single belly (b) bifurcated belly. SM — sternalis muscle.