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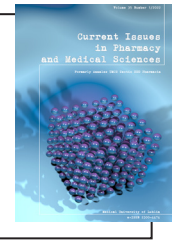

Sternalis muscle, a rare anatomical variation with clinical implications

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ABSTRACT

The sternalis muscle is a rare variant of the anterior chest wall musculature. Although its frequency in general population worldwide has been reported from 2% to 8%, its prevalence depends on regions and populations. The aim of this paper is to describe one of the first cases of sternalis muscle found in Central Europe. An anterior chest wall of 64-year-old white male was dissected during a regular anatomy class at Department of Human Anatomy. A right unilateral sternalis muscle was revealed and described. The unilateral sternalis muscle laid between the pectoral and the superficial thoracic fascia. The muscle was long and wide. In addition, it had a massive tendon. According to the Snosek *et al*. Classification, it was a "simple unilateral" type. This report presents another case of the sternalis muscle among humans. Although the sternalis muscle serves a minor role in body movement, its occurrence gives several clinical implications. The awareness of variability in the thoracic region is important during diagnostic and treatment processes or in surgical operation planning.

INTRODUCTION

The sternalis muscle (SM) is a rare variant of the anterior chest wall musculature. Its incidence ranges from 2% to 8%, but prevalence depends on regions and populations [1]. It can be located unilaterally or bilaterally, along the sternum or parasternal, in the vicinity of the pectoralis major muscle [2].

The prevalence of SM has been evaluated by many anatomists. SM predominance is higher among men than women – 8.4% and 6.7%, respectively. The incidence of this muscle varies widely depending on the race. It ranges from 4% to 7% in the white population, 8.4% in the African population and 11.5% in the Asian population. In some populations, such as the Taiwanese, it may be lower than 1%, while in the Northern Chinese population, it may be as high as 23.5%. In the European population, its incidence is 4.4 % [3]. This muscle frequently appears in people with a congenital absence of the pectoralis major muscle [4]. In these cases, it achieves a significant size [5].

The SM is one important variant of the panniculus carnosus (PC) remnants – a superficial muscle layer in the thoracic region typical for lower mammals. In contrast to humans, the PC skeletal muscle layer is well developed and sits immediately beneath the skin of most mammalian animal species, including marsupial (*Macropus bennetti*), mice, rats, cavia and rabbits, cats and dogs, pigs, horses, dolphins and skin areas of some higher primates. In most of these, the PC covers the dorsal, ventral and lateral surfaces of the body trunk and extends down to the upper part of the limbs [6]. In those with it, it is possible to visualize the SM after exercise only in individuals with very strongly developed skeletal muscles.

It consists of longitudinal muscle fibers of varying length and width running parallel to the sternum. It has a band-like appearance. In a typical position, SM connects to: the attachments of the rectus abdominis muscle, the external oblique abdominal aponeurosis and the sternocostal joint of ribs of the thoracic cage. The simultaneous stimulation of SM and the pectoralis major muscle causes the skin covering the chest to wrinkle, which on a living person is visible as a longitudinal fold of skin on the chest [2,3]. SM is relatively small, therefore it does not have a significant physiological function and does not play an important role in thoracic cage movement [4]. Researchers suggest that it may have an accessory role in elevating the lower chest

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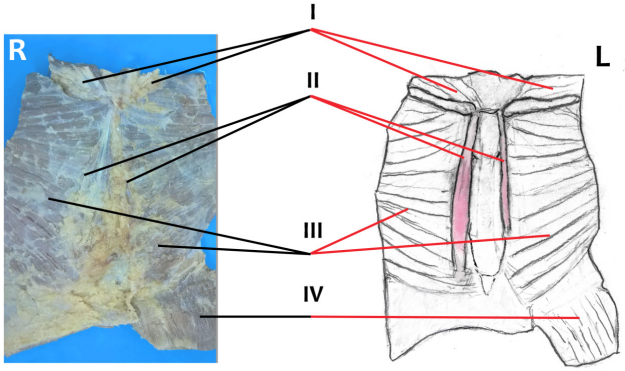
wall and participates in respiratory process in cooperation with pectoralis major muscle [2,7].

The SM was first described by Cabrolius in 1604 [3]. However, to date, the origin, innervation and vascular supply of this rare variant is still being discussed. According to Snosek *et al*. [3], it has unclear embryological origin and innervation. In the literature, it has been referred to by numerous alternative names deriving from its morphology, embryological origin and location [3,8]. Some anatomists hold the view that SM, like the muscular axillary arch or the torso part of the pectoralis major muscle, can arise from an incomplete division of the muscular primordia of the torso, irregular shifts within these primordia or the remnants of ancestral development [2,3,5]. SM is supplied mainly from perforating branches of the internal thoracic artery, as well as the pectoral branch of the thoracoacromial artery [3].

SM as imaged on mammography, presents itself as a variably shaped fibroglandular asymmetry in craniocaudal (CC) viewing, that is located in the medial hemisphere at posterior depth [3,9,10,11]. Nevertheless, this presentation is prone to misinterpretation, as it mimics the appearance of a lymph node, skin lesion or other unspecified breast mass.

On magnetic resonance imagining (MRI), the SM shows signal isointense to skeletal muscle. Computer tomography (CT) scans view the SM as a well-defined structure with attenuation values alike those of muscle, and is located anterior to the sternum. Most often, the shape is flat, but can also be oblique or irregular [4]. Encountering the enhancing components on either MRI or CT is not typical for the SM imagining, and should call for further evaluation or tissue sampling [3,9,10].



R - right side, L - left side, I - sternocleidomastoid muscle, II - sternalis muscle, III - pectoralis major muscle, IV - rectus abdominis muscle

Figure 1. Photograph (on the left) and drawing (on the right) of the anterior chest wall musculature with the sternalis muscle – right simple unilateral type. The skin and subcutaneous tissues were removed

MATERIALS AND METHODS

An anterior thoracic wall of formalin fixed male cadaver dissection was conducted during a regularly anatomy class of medical faculty in an autopsy room at the Department of Human Anatomy, Medical University of Lublin, Poland. The skin and subcutaneous tissue were removed. The sternalis muscle was revealed and described.

RESULTS

A right band-like unilateral sternalis muscle (SM) was found during the autopsy performed on a 64-year-old white male. The cadaver weighted 86 kg and was 172 cm height. The unilateral SM occupied a position under the epidermis and the subcutaneous fascia, parallel to the sternum, laid superficial to medial surface of the pectoralis major muscle and the pectoralis fascia and was covered by the anterior thoracic fascia. The SM was composed of one band and its fibers did not cross the sternum (Figure 1). The band, approximately 15 cm long and 5 cm wide at the widest point was clearly visible. A well-marked tendon originated near the medial head of the right sternocleidomastoid muscle, on the surface of the manubrium sterni, anterior of the right sternoclavicular joint. The insertion point merged into the superficial fascia covering the anterior right pectoralis major muscle (the attachment of the 6^{th} and 7^{th} right costal cartilages to the sternum). These fibers extended down and were attached to the rectus abdominis muscle. The innervation and blood supply vessels of the muscle were not identified, due to the dissection technique.

DISCUSSION

This is the first well-described study of SM case in the Polish population, the second SM case in Poland mentioned in the literature and one of the first SM cases in central Europe. The research assessing a variability of the pectoralis major muscle conducted by Department of Normal and Clinical Anatomy, Medical University of Lodz, Poland on 40 cadavers revealed 1 unilateral (left) SM [12]. In our Department, SM was present in 1 out of 70 cadavers (1.43% of specimens) during a 10 year period.

Over the years, few attempts to classify SM have been made. In 2001, Jelev *et al*. [2] defined four conditions that must be fulfilled for a muscle to be categorized as SM: (a) location between the superficial fascia of the anterior thoracic region and the pectoral fascia; (b) originating from the sternum or infraclavicular region; (c) insertion onto the lower ribs, costal cartilages, aponeurosis of the external abdominal oblique muscle or the sheath of rectus abdominis; (d) innervation by the anterior thoracic (pectoral) and/or intercostal nerve. However this classification has been rarely used in literature, due to the existence of many SM variations and a strict approach to the assessment.

According to the classification put forward by Jelev *et al*. [2], the SM described in this research should be classified as a "I1" type [3,13]. However, due to a newly found "double belted-midline crossing SM", Raikos *et al*. [13] advanced a next system based on the work of Jelev *et al*. [2] that included this new SM type. Nevertheless, this systematization has not gathered big interest in literature [3,13].

Two most recent systems were proposed in 2014 and they categorized all SM types comprehensively. In these systems, each hemi-thorax is investigated separately, and the grading is based on the morphology of muscle bands. The previous classification according to Ge *et al*. [1], divided SM into 3 types: Type I or single-banded, Type II or multi-headed and Type III or multi-banded. In contrast, Snosek

et al. [3] differentiate the sternalis muscles into three types: "simple type", "mixed type" and "other" with 15 subtypes [1]. According to the latter classification, the muscle from this research can be classified as a "simple unilateral" type.

Although SM has been encountered many times since it was first described in the 17th century, its very presence has been a conundrum for many anatomists. Many of them believed that SM is a variant of the adjacent muscles such as the pectoralis major muscle, the rectus abdominis muscle, the external oblique abdominis muscle, the subcutaneous panniculus carnosus muscle, or the sternocleidomastoid muscle. Turner defined SM as a result of atavism of the fascicles of the pectoralis cutaneous muscle of lower animals, while Sadler interpreted SM as part of a ventral, longitudinal column of muscle arising at the ventral tips of the hypomeres [2,5]. Ruge and Barlow claimed that SM is a vestige of the panniculus carnosus, which in most mammals is highly developed and serves as a subcutaneous muscle for prominent movements in e.g. defense against insects [3].

The currently held view is that the original occurring cutaneous muscle (*panniculus carnosus*) in humans became redundant and disappeared, and its remnant only appears individually and infrequently [3]. Such a remnant is probably best deemed a muscular axillary arch. This is a band of muscle that runs from the pectoralis major muscle to the latissimus dorsi muscle, crossing the neurovascular bundle of the axillary fossa and the coracobrachialis muscle. In addition, the side of the pectoralis major muscle adjacent to the rectus abdominis muscle is considered a remnant of the torso muscles since their muscle bands run a similar course which sometimes merges with the axillary arch. The third vestige of the torso muscles is considered to be an SM [3,5,14].

The sternalis muscle is innervated by branches of the pectoralis nerves (medial and lateral, leaving the supraclavicular part of the brachial plexus) and the upper intercostal nerves (thoracic nerves I-VI) [2,3,5,15]. According to Shinohara, this dual innervation may be caused by: migration, separation or fusion. In accordance with the law of migration, the nerve is the route along which the muscle mass migrates to other anatomical locations. The diaphragm is an example which originates in the III-V cervical myotome, and with the heart, migrated into the chest. According to the law of separation, when one muscle splits into two different muscles, each of the two muscles will be innervated by a different nerve (e.g. common muscle mass for the sternocleidomastoid and trapezius muscles). As per the law of fusion, two muscles can merge, with each innervated being by a different nerve (e.g. the external oblique abdominis muscle, which is innervated both from the external and internal surfaces) [16].

Sonne supported a hypothesis that SM derives developmentally from pectoral musculature. Typically, the medial pectoral nerve does not convey sensory afferent fibers, but, rather, somatic efferent fibers from the C8 and T1 spinal nerves of brachial plexus. The nerve innervates the major and the minor pectoralis muscles and the chondrocoracoideus muscle. It is also conceivable that some fibers may extend and supply SM. The anterior intercostal nerves, which lead mostly sensory afferent fibers, are visible on the border of sternum and they penetrate the medial margin of the SM or travel along its border. A more thorough dissection may reveal that the intercostal nerves do not supply SM, but, instead, supply the skin of the anterior thoracic wall. It should be noted that the delicate fibers from the medial pectoral nerves to SM travel in the deep fascia and may be easily overlooked in surrounding connective tissue during a dissection. Therefore dissection does not always indicate the innervation from intercostal nerves, but from branches of the medial pectoral nerve [7].

Due to the limited diagnostics that can be used on a cadaver, multitude of variations and the fact that tiny nerves can be easily overlooked and destroyed during a dissection, the mechanism by which SM is created is difficult to explain [7,15]. It is possible that new techniques may answer this question in the near future.

Although SM serves a minor role in body motion, its occurrence gives some clinical implications. Among others, it can be accidentally detected during a radiology examination, and these findings can be misinterpreted as pathological lesions, anterior chest wall tumors, breast nodules or pectoralis major hernia and may result in unnecessary diagnostic procedures (e.g. biopsy) in patients. In addition, the occurrence of SM can lead to delays during urgent surgical operations. However, if the muscle has been detected preoperatively, it can be applied in plastic and reconstructive surgeries of head, neck and breast as a muscular flap [2,3,14]. Of note, during modified radical mastectomy, all breast tissue with pectoralis fascia must be removed, but removal of SM in this type of operation should be considered individually, depending on the location of SM, its proximity to the tumor and lymphatic vessels and the stage of neoplastic invasion [3].

The presence of SM may also be associated with a sternalis syndrome condition. Herein, a dull myofascial pain does not occur during chest wall movement, but only at palpation of the anterior chest wall in the sternum region. This state should be also considered in the differential diagnosis of cardiac diseases [2,7,17]. Diagnostic process of the sternalis syndrome should involve electromyography and anesthetic or corticosteroid injection made into the SM. In physiotherapeutic practice, SM may cause difficult recovery of anterior chest wall pain [7]. For the reasons stated above not only physical therapists, but also radiologists, surgeons and other physicians should be aware of SM occurrence in general population.

CONCLUSION

Familiarity with SM is not purely theoretical knowledge, but carries with it serious clinical consequences. Diagnostic methods such as mammography, MRI and CT scans are now standard procedures if breast cancer is suspected, or during its treatment. A mistakenly diagnosed irregular structure in the image, located in the medial part of the chest, may expose the patient to unnecessary frustration and additional medical procedures.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ETHICS APPROVAL

The donors agreed to provide bodies for anatomy classes in the Department of Human Anatomy. The research was conducted in accordance with ethical standards and 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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