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Case Report of a Unilateral Sternalis Muscle: Integrating Historical Perspectives, Literature Review, and Clinical Significance

Reporte de Caso de un Músculo Esternal Unilateral: Integración de Perspectivas Históricas, Revisión de la Literatura y Significado Clínico

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SUMMARY: The sternalis muscle, an anatomical variant situated superficial to the pectoralis major muscle, has long been a subject of anatomical curiosity due to its sporadic occurrence and unsettled characteristics, including its embryological lineage and functional role. Therefore, in light of a case of unilateral sternalis, we inspected the existing literature, emphasizing this variant's importance from an embryologic and clinical standpoint, as well as the muscle's background, source of innervation, and classification. A unilateral sternalis muscle was observed in a 97-year-old male cadaver during routine dissections for educational purposes, displaying distinctive attachments to the sternum and the 4th rib. The variation was photographed, and a digital caliper utilized with a measurement range of 0 to150 mm and an accuracy of 0.02 mm. The muscle was left unilateral and positioned between the upper margin of the 2nd rib and lower margin of the 4th rib, lateral to the sternum and superficial to the pectoralis major muscle. Examining this variation from an embryologic and clinical standpoint, as well as learning about its background, prevalence, innervation, and classification, is critical for both anatomists and clinicians, given the variant's ability to simulate pathological entities on diagnostic imaging and influence surgical planning.

KEY WORDS: Anterior thoracic wall; Anatomical variation; Embryology; Sternalis muscle; Muscular variation.

INTRODUCTON

Musculus sternalis is an anatomical variation that is placed superficial to the m. pectoralis major, has diverse shapes and sizes, and is frequently a unilateral muscle (Waldeyer & Mayet, 1979). This muscle has garnered intermittent attention, with diverse descriptions scattered across anatomical, surgical, and radiological publications (Asghar *et al*., 2022). Despite its well-documented existence, the sternalis muscle remains obscure due to its infrequent presentation and ongoing debate regarding its embryological origin, function, and innervation (Snosek *et al*., 2014). It has been labeled with various names at different times which causes challenges in establishing a universally accepted nomenclature (Arraez-Aybar *et al*., 2003; Snosek *et al*., 2014; Asghar *et al*., 2022). These names are shown in Table I. Its diverse shape, homology, and clinical relevance have prompted a rise in research aimed at better understanding its properties (Snosek *et al*., 2014).

Considering the hypotheses regarding the origin and insertion of the muscles, it has been suggested that it might help elevate the ribcage by acting as an accessory muscle of inspiration (Arraez-Aybar *et al*., 2003). In 1925, Kirk reported his observations that this muscle contracted during trunk flexion and arm adduction in a living male (Kirk, 1925). Some researchers have suggested that the sternalis muscle may have a proprioceptive function that serves to detect movements of the anterior thoracic wall, but the proprioceptive function of the sternalis muscle is not proven (Ram *et al*., 2018). It is also thought that the sternalis muscle may enhance the pectoralis muscle's function, which primarily supports the

Table I. The different names that are used among publications to describe sternalis muscle (Arraez-Aybar *et al*., 2003; Snosek *et al*., 2014; Asghar *et al*., 2022).

Names
Episternalis
Presternalis
Parasternalis
Rectus sternalis
Rectus sterni
Rectus thoracis
Rectus thoracicus superficialis
Superficial rectus abdominis
Sternalis brutorum
Sternalis japonicas
Sternalis thoracicus

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shoulder joint; however, the exact function of the sternalis muscle is still unknown (Scott-Conner & Al-Jurf, 2002; Young Lee *et al*., 2006).

Recent advancements in surgical methods and imaging in medicine have brought renewed attention to the sternalis muscle, particularly regarding its role in mimicking focal density areas on a mammography of the medial breast (Snosek *et al*., 2014). Its detection, or lack thereof, prior to surgical interventions can significantly impact operative outcomes, highlighting the critical importance of comprehensive anatomical knowledge and meticulous preoperative assessments (Harish & Gopinath, 2003). It is critical for a clinician to be knowledgeable about this muscular variant because it can prevent needless invasive procedures and lessen patient stress (Snosek *et al*., 2014). Despite its rarity, the sternalis muscle holds profound consequences for breast and thoracic surgery (Wynn *et al*., 2023).

CASE REPORT

The dissections were performed in the dissection laboratory of the Department of Anatomy, Faculty of Medicine, Bahcesehir University. This study was approved by Bahcesehir University Board of Scientific Research and Publishing Ethics at the meeting numbered 2024/05 on May 29, 2024, in accordance with the Declaration of Helsinki.

During routine dissections of anterior thoracic wall for educational purposes one unilateral accessory muscle was encountered, on the anterior thoracic wall belonging to a 97-year-old male (Fig. 1). The cadaver showed no evidence of previous trauma, skeletal disorder or signs of surgical interventions of the related area. This unilateral muscle was attached superiorly to the left margin of sternum via multiple tendons and was attached inferiorly to the left 4th rib via one large tendinous attachment (Fig. 1). This muscle was a left musculus sternalis, as it was positioned superficial to the left pectoralis major muscle, between the upper margin of the 2nd rib and lower margin of the 4th rib, lateral to the sternum. The length and width of the muscle belly was 57,29 mm and 29,13 mm respectively. The length from superior-most attachment (shown as tendon 2 in Fig. 1.A) to the inferior-most attachment was 102,19 mm. The length and width of the proximal tendons are shown in Table II. There was no adipose tissue encountered macroscopically between the sternalis muscle and the pectoralis major muscle. The digital caliper utilized has a measurement range of 0 to150 mm and an accuracy of 0.02 mm.

Table II. Measurements of the proximal tendons (1, 2 and 3) of the musculus sternalis.

Proximal Tendons	1	2	3
Length	10,2 mm	22,29 mm	12,68 mm
Width	2,77 mm	3,03 mm	3,98 mm

DISCUSSION

Identification of our case: Although our laboratory has conducted cadaver dissections for many years, this was the first case of the m. sternalis we encountered. The prevalence of the muscle is reported to be between 0.5 % and 23.5 %, with an average of 7.8 % (Snosek *et al*., 2014). It more often appears as a unilateral structure on the right side (67 %-64

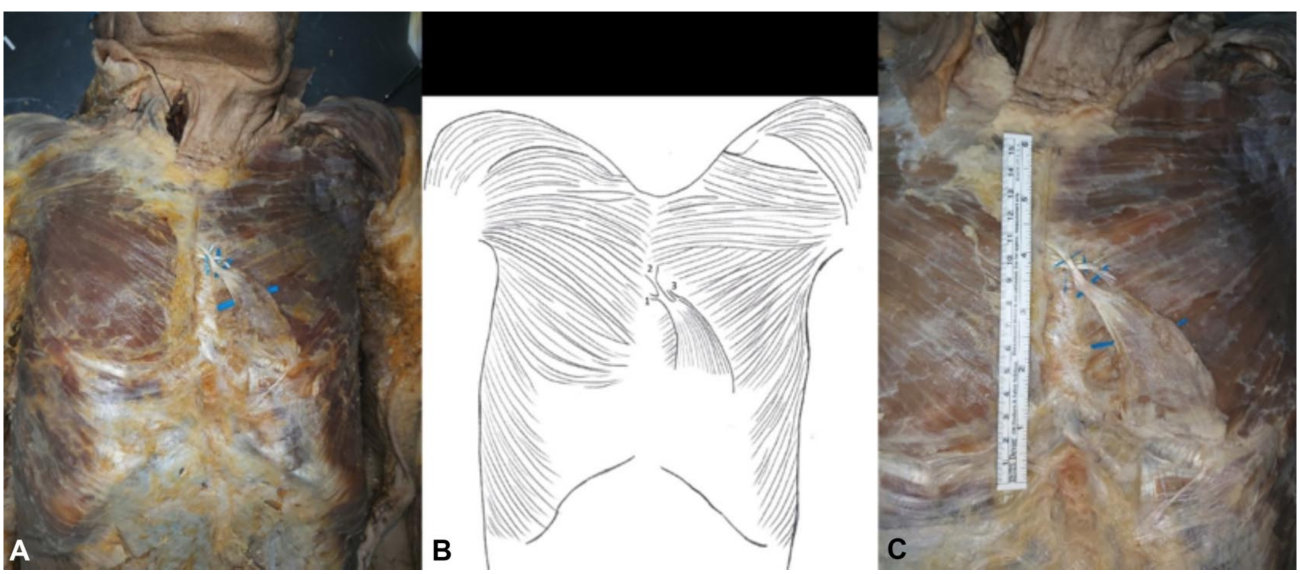

Fig. 1. A. Sternalis muscle on the left anterior thoracic wall of a male cadaver. B. 1, 2 and 3 are the proximal tendons C. a close-up image.

%) rather than bilaterally (33 %) and is most frequently found on the right side (64 % of cases) (Snosek *et al*., 2014). Our case was also unilateral, however it was on the left side.

Background, Prevalence and Classification. Many researchers have investigated the prevalence, source of innervation, and embryological origin of the sternalis muscle. In 1867, W.M. Turner stated that Cabrolius (aka Cabrolio) was the first to observe this muscle in 1604 (Cabrolio, 1604; Turner, 1867). In the same article, he also published the results based on their dissections and gave a prevalence of 3 % (21 sternalis muscle out of 650 specimens) (Turner, 1867). Table III represents some of the early studies from 17th-19th century including anatomists, year of publication, and the key aspects described.

A variety of attachments and connections in the form of the sternalis muscle were drawn schematically by Turner in that very detailed article (Fig. 2).

According to a meta-analysis by Ashgar *et al*., the prevalence of the sternalis muscle among adults is 6 % (5-7 %), with no significant difference reported across sex (Barlow, 1935; Asghar *et al*., 2022). Dissection-based studies reveal a higher prevalence of the sternalis muscle than other methods of examinations, such as computed tomography (CT), mammography, surgery (Snosek *et al*., 2014). Additionally, mammography and surgery appear to have a lower rate of detecting sternalis muscle than multidetector computed tomography (MDCT) (Snosek *et al*., 2014; Asghar *et al*., 2022).

The sternalis muscle is quite varied in shape. Due to this feature, there are several classifications in literature. Jelev *et al*. (2001) proposed a classification of the sternalis muscle into 2 main types and 4 subgroups within each main type. Raikos *et al*., offered an update to Jelev *et al*. (2001) classification and introduced a new subtype of muscle (Raikos *et al*., 2011b). Ge *et al*., recommended 3 types and 9 subtypes of the sternalis muscle based on their MDCT findings (Ge *et al*., 2014). In 2014, Snosek *et al*. (2014) proposed a new classification similar to Ge *et al*. (2014) by categorizing variations into three groups: simple, mixed, and other. Furthermore in 2019, Prall *et al*. (2019) suggested a modification of Snosek *et al*. (2014) classification by describing a new variant. Table IV shows these classifications, as well as the fundamental aspects of each.

Table III. A part of the history of the sternalis muscle.

Author	Year of publication	Important features
Cabrolio (ius)	1604	Sternalis muscle has been observed for the first time (Cabrolio, 1604; Turner, 1867).
Du Puy	1726	Connections and relations of the sternalis have been described in detail for the first time (Du Puy, 1726; Turner, 1867).
Weitbrecht	1729	(Turner, 1867).
Albinus	1734	Drew attention to the connection between the rectus and sternalis muscles (Turner, 1867).
De la Faye	1736	(Turner, 1867).
Wilde	1740	(Turner, 1867).
Kaau Boerhaave	1751	Explained the sternalis muscle with 2 different cases, including one case where the rectus abdominis ascended beneath pectoralis major, until the level of the 3rd rib (Turner, 1867).
Sandifort	1783	Used the name *Thoracicus* based on the findings of Boerhaave (Turner, 1867).
Halbertsma	1861	Explained the muscle that is continuous with rectus abdominis is suggested to be named as *Musculus accessorius ad rectum* (Turner, 1867).
Hallett	1848	Claimed that sternalis would appear to belong to the same muscle class that includes platysma, and as a result, it is a development of the large dermal muscle (Turner, 1867).
Abraham	1883	Stated that the sternalis muscle is correlated with fetal anomalies, and that in the presence of the sternalis muscle, there is also an abnormality in the pectoralis muscle (Abraham, 1883; Asghar *et al*., 2022).
Testut	1884	Gives a detailed description and comparison of the literature in his renowned book about muscular anomalies, concerns a thoracic extension of the rectus abdominis (Testut, 1884).
Wallace	1886	Worked on the nervous supply of the sternalis (Wallace, 1886; Asghar *et al*., 2022).
Cunningham	1888	Worked on the nervous supply of the sternalis (Cunningham, 1888; Asghar *et al*., 2022).

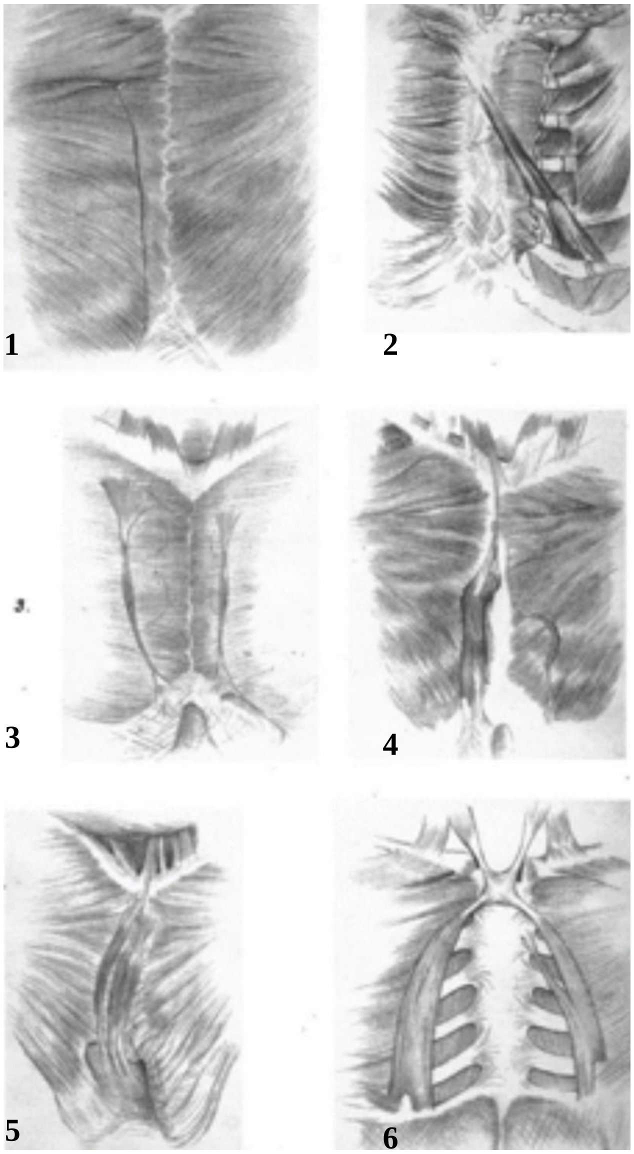

Fig. 2. The drawings of Turner 1867 regarding the variety of Sternalis muscle 1:The right sternalis muscle, slender in form, is seen originating from the decussating tendinous fibers located in front of the lower end of the sternum, with its insertion into the front of the manubrium. A rounded slip joins this muscle to the upper fibers of the pectoralis major. 2: The sternalis muscle is shown originating from the 5th and 6th left costal cartilages and the 6th rib. It traverses obliquely upwards and inwards across the front of the sternum, with insertion into the strong fibrous aponeurosis over the right pectoralis major, opposite the 2nd right costal cartilage. 3: A double sternalis muscle is depicted, originating from the 5th and 6th costal cartilages and inserting into the aponeurosis covering the greater pectoral muscles. 4: The double sternalis is described, with the right side being significantly larger than the left. The right muscle extends from the aponeurosis covering the rectus to the right sterno-mastoid, while the left muscle inserts into the aponeurosis covering the manubrium sterni. 5: The right sternalis muscle is observed arising from the aponeurosis covering the rectus, subdivided into various bundles. The external bundle ascends to the sterno-mastoid, and the internal bundle inserts into the manubrium, close to the sternal fibers of the left pectoralis major's origin. 6: Double sternalis muscle is seen, inserted mostly into sterno-mastoids, with defective sternal origins of pectoralis major. Some fibers of the left sternalis is attached to manubrium of sternum.

Innervation and Embryology. The innervation of the sternalis muscle has been stated to originate from nervus pectoralis medialis and lateralis, ventral branches of thoracic nerves, or both (Waldeyer & Mayet, 1979). The source of this muscle's innervation is still debated; different nerves have been indicated by various studies (Snosek *et al*., 2014). In 1935, Barlow reported thirty-three new cases exhibiting thirty-eight sternalis muscles that were found in 535 cadavers at the Department of Anatomy, Washington University School of Medicine (Barlow, 1935). The pooled data from the literature indicated that anterior thoracic innervation of the sternalis muscle was reported more than three times as often as intercostal nerve supply (Barlow,1935). However, the author's findings reversed this ratio in favor of intercostal innervation (Barlow, 1935). Recently, a meta-analysis of 369 dissected specimens from diverse research studies reported that 44 % of the sternalis muscles were innervated by pectoral nerves, 37 % by intercostal nerves, and 4 % had dual innervation (Asghar *et al*., 2022).

Several ideas about the embryonic origin of the sternalis muscle have been proposed based on its attachment sites and innervation patterns. Also a number of investigations have stated that this muscle originates from nearby muscles such as the sternocleidomastoid, rectus abdominis, pectoralis major, and external oblique abdominal muscles or their blastema's, or ventrolateral parts of the diaphragm (Blees, 1968; O'Neill & Folan-Curran, 1998; Novakov *et al*., 2008; Raikos *et al*., 2011b). Furthermore, it has been suggested that the sternalis muscle may be an atavistic anomaly of the pectoralis major muscle (Wahl *et al*., 2022). Some researchers have also suggested that the sternalis is a remnant of the panniculus carnosus muscle and that its function is to cause the skin of the chest to twitch to ward off insects which is a derivative of thoracic cuticular muscle (Turner, 1867; Huntington, 1904; Barlow, 1935; Arraez-Aybar *et al*., 2003; Naldaiz-Gastesi *et al*., 2018). Additionally, if it develops from the rectus abdominis sheath, it is suggested that it is a derivative of the hypaxial myotome/dermomyotome, from which the ventral and lateral body wall muscles of the thorax and abdomen develop (Raikos *et al*., 2011a,b). Therefore, a malfunction in the patterning of the ventral wall muscle could be the cause of the sternalis variation (Raikos *et al*., 2011b). If the sternalis muscle develops from the pectoralis major muscle, this variation could be the result of faulty myogenic precursor migration and/or defective patterning (Raikos *et al*., 2011b). In addition, Saddler interpreted it as part of the ventral longitudinal muscle column arising from the ventral lips of hypomeres (Sadler, 1995; Vaithianathan *et al*., 2011). The sternalis muscle is thought to have formed as a result of abnormal clockwise rotation of certain fibers during the movement of the prepectoral mass, which is where the pectoralis major

Table IV. Key notes for several classification systems presented by various authors (Jelev *et al*., 2001; Raikos *et al*., 2011b; Ge *et al*., 2014; Snosek *et al*., 2014).

Author and year of publication	Classification	Parameters used for classification
Jelev *et al.*, 2001	Type I (Unilateral) - Type I 1 - Type I 2 - Type I 3 - Type I 4 Type II (Bilateral) - Type II 1 - Type II 2 - Type II 3 - Type II 4	Type I Muscles are classified based on the number of muscular bellies, whether they cross the median line, and whether they connect to another muscle. Type II Whether the muscles are symmetrical or asymmetrical, connection type with the pectoralis major muscle
Raikos *et al.*, 2011	Type A, B, C, D, E and F	They represented a classification for unilateral sternalis muscle. Type E shows their finding, bicipital sternalis that crosses midline.
Ge *et al.*, 2014	Type I (single head, single belly) - Type I A - Type I B - Type I C Type II (double headed or multi headed) - Type II A - Type II B - Type II C Type III (double bellied or multi bellied) - Type III A - Type III B - Type III C	This classification is made by using MDCT views. The three primary classes are determined by the number of muscle heads and muscular bellies. Subgroups are determined by looking at muscular heads/bellies being on the same hemi thorax, connecting with the sternocleidomastoid muscle (SCM), crossing the midline, and connecting with the contralateral SCM.
Snosek *et al.*, 2014	Simple type (includes 6 variations) Mixed type (shows most common 6 types) Other types (crisscrossed, midsagittal converging from right, right-left bicipital converging with right cross)	The illustrations of their article show the right hemi-thorax, but they recommend that all the variations can also be adapted to the left side.

and minor muscles share their common genesis during early embryonic development (Kida *et al*., 2000; Raikos *et al*., 2011a,b). The findings based on the assessment of the literature about the heterogeneity of sternalis innervation reveal that the muscle's common origin source is not as consistent as previously thought (Raikos *et al*., 2011b).

According to Huntington (1904), the sternalis muscle and other supernumerary pectoral muscles can be understood as part of a continuous series, all deriving from the pectoralis plane. These muscles share a common origin, supported by consistent innervation patterns and associated deficiencies in the pectoralis major. The development of these variants is linked to abnormal cleavage processes within the pectoral mass, leading to the formation of accessory muscles. While these processes are atypical for primates, they may reflect normal differentiation patterns seen in other mammals. Hence, some of these aberrant human muscles are morphologically homologous with intermediate pectoral elements normally found in lower mammals (Huntington, 1904). Additionally, reversion to a primitive pectoral mass and the migration of the embryonic pro-pectoral mass may contribute to the development of these atypical muscles, such as the sternalis (Huntington, 1904).

As a matter of fact, after more than a century, it is still debated if these muscle fibers have an axial or appendicular embryological origin, or whether they start in the sternocleidomastoid, pectoralis, or rectus abdominis muscles (Tubbs *et al*., 2016).

Clinical Importance. In the literature, sternalis muscle has been demonstrated to be accompanied by additional variations, such as the absence of pectoralis major muscle, vascular variants of the kidney, testis, suprarenal gland, and hepatobiliary system anomalies (O'Neill & Folan-Curran, 1998; Anjamrooz, 2013). In 1893, Windle, B.C., stated that sternalis muscle was found to be 10 times more frequent in anencephalic fetuses than in typical forms (Windle, 1893). In addition, according to Eisler, the sternalis muscle is twelve times more common in anencephalic individuals than in "healthy" ones. This is primarily attributed to the atypical widening of the ventral portions of one or more intercostal spaces, a condition he believes results from hyperplasia of the thymus and the large size of the heart, which leads to abnormal development of the pectoral sheet (Eisler, 1901). This occurrence is further facilitated by the consistent and pronounced lordosis of the cranial segment of the vertebral column in these cases. Eisler (1901) suggests categorizing the sternalis within a distinct group of muscular variations consisting of atypical myological structures that have "become independent". Other researchers also reported similar frequency in anencephaly cases (Abraham, 1883; Shepherd, 1889; Harper, 1936).

Glasser indicated in 1975 that the absence of the pectoralis major muscle could cause some electrocardiographic alterations (Glasser, 1975). It has also been stated that mastectomy surgeries can produce alterations in the electrocardiogram (ECG) (Glasser, 1975). Therefore, the musculus sternalis, as an anterior thoracic wall variant, may be called into doubt if it impacts the ECG (Snosek *et al*., 2014).

According to a case report from Gruber *et al*. (2016) long-term painful swelling in the parasternal region should cause clinicians to consider the existence of a sternalis muscle. Their report depicts a case of painful soft tissue swelling in the anterior thoracic wall caused by a sternalis muscle, which they refer to as symptomatic sternalis (Gruber *et al*., 2016).

Knowing about the sternalis muscle may be important when evaluating radiologic pictures. Mammography now prioritizes patient posture to provide radiographic access to all breast tissue, including the previously overlooked medial section (Bradley *et al*., 1996). In mammographic imaging, the sternalis can be deceptive and concerning since it can appear as a pathologic structure like a mass, hematoma, etc., resulting in additional unneeded diagnostic procedures and, finally, a delay in diagnosis (Demirpolat *et al*., 2010). The appearance of sternalis may also vary on mammographic views, making it difficult to diagnose (Shiotani *et al*., 2012). Thus, it is critical to understand the various forms of this muscle.

The literature also contains multi-detector computerized tomography (MDCT) research on the sternalis muscle. The inconspicuous fat spaces between the sternalis muscle and pectoralis major muscle can make it harder to differentiate the sternalis in CT, and some studies emphasize that MDCT has the limitation of making it difficult to detect precise attachment sites for tendons (Shiotani *et al*., 2012; Ge *et al*., 2014). However, cadaver dissections can yield detailed information regarding muscular attachments.

Encountering the sternalis muscle unexpectedly during surgery, results in longer surgery durations by complicating or altering the surgical strategy (Salval *et al*., 2012). The sternalis may have the potential to be used as a flap too. This muscle can be advantageous as additional muscular coverage since sufficient volume of the flap is required to fill the defects for reconstructive surgeries (Schulman & Chun, 2005; Zhang *et al*., 2020). Schulman & Chun (2005) stated that during reconstructive breast surgery, the multiple muscular insertions of the sternalis muscle may affect the surgical dissections to provide optimum results. Therefore, surgeons may benefit from being aware of different tendinous insertions, including those described here.

Limitations: Unfortunately, due to the nature of the study, this work has certain limitations. First, although this was the first case of a sternalis muscle we encountered in our anatomy dissection classes, we were unable to present it as part of a case series. Additionally, since this specimen was an educational body, we chose not to dissect further or detach the muscle, which prevented us from analyzing the tissue mass. Finally, we acknowledge that there may be other case reports or studies that we were unable to include, as we did not conduct a meta-analysis. We mostly focused primarily on the earliest explanations of the case and studies involving series of cadavers.

CONCLUSION

Anatomists and clinicians may benefit from being aware of the sternalis muscle as an anterior thoracic region variation, given its ability to simulate pathological entities on diagnostic imaging and influence surgical planning, emphasizing the importance of comprehensive preoperative assessments.

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Ethical Approval: This study was approved by Bahcesehir University Board of Scientific Research and Publishing Ethics at the meeting numbered 2024/05 on May 29, 2024, in accordance with the Declaration of Helsinki.

ANACUR, B.; SAVASIR, E.; GUL, Z. & ORTUG, G. Reporte de caso de un músculo esternal unilateral: integración de perspectivas históricas, revisión de la literatura y significado clínico. *Int. J. Morphol., 43(1)*:218-225, 2025.

RESUMEN: El músculo esternal, una variante anatómica situada superficialmente al músculo pectoral mayor, ha sido durante mucho tiempo un tema de curiosidad anatómica debido a su aparición esporádica y características no establecidas, incluido su linaje embriológico y papel funcional. Por lo tanto, a la luz de un caso de músculo esternal unilateral, inspeccionamos la literatura existente, enfatizando la importancia de esta variante desde un punto de vista embriológico y clínico, así como el trasfondo del músculo, la fuente de inervación y la clasificación. Durante disecciones de rutina con fines educativos, se observó un músculo esternal unilateral en un cadáver masculino de 97 años, que mostraba inserciones distintivas en el esternón y la cuarta costilla. Se fotografió la variación y se utilizó un calibrador digital con un rango de medición de 0 a 150 mm y una precisión de 0,02 mm. El músculo se dejó unilateral y se posicionó entre el margen superior de la segunda costilla y el margen inferior de la cuarta costilla, lateral al esternón y superficial al músculo pectoral mayor. Examinar esta variación desde un punto de vista embriológico y clínico, así como aprender sobre sus antecedentes, prevalencia, inervación y clasificación, es fundamental tanto para los anatomistas como para los médicos, dada la capacidad de la variante para simular entidades patológicas en las imágenes diagnósticas e influir en la planificación quirúrgica.

PALABRAS CLAVE: Pared torácica anterior; Variación anatómica; Embriología; Músculo esternal; Variación muscular.

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