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Unusual anatomical variation of the sternal foramen: morphology morphometry

Variação anatômica incomum do forame esternal: morfologia e morfometria

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Abstract

The sternum bone may present anatomical variations acquired during its formation (i.e., from embryonic development to the beginning of adult life). These variations do not impair function but may leave the individual susceptible to injuries and complications. The present study aimed to report a foramen found in an unusual location in the sternum and discuss the main clinical implications when this anatomical variation is unknown.

Keywords: Anatomic variation; Anatomy; Sternum; Surgery; Measurement equipment.

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Resumo

O osso esterno pode apresentar variações anatômicas adquiridas durante o seu processo de formação, que vai desde o desenvolvimento embrionário até o início da vida adulta. Essas variações morfológicas não causam prejuízo da função, mas podem deixar o indivíduo susceptível a várias lesões e complicações. O presente estudo tem como objetivo relatar um forame encontrado numa localização não usual no osso esterno e discorrer, através de uma breve revisão da literatura, sobre as principais implicações clínicas quando essa variação anatômica é desconhecida.

Palavras-chaves: Anatomia; Esterno; Equipamentos de medição; Variação anatômica.

INTRODUCTION

Anatomical structures may present morphology variations during the embryonic development and formation process.[1] These variations differ from what is observed in most individuals, but they do not impair function; they are compatible with life.[1] The sternum is a bone located in the anterior wall of the chest, directly articulated with the clavicles and costal cartilages of the first seven ribs, overlapping the mediastinum region and protecting the viscera in this region.[2] The sternum presents several cartilages since intrauterine life. In the juvenile phase, the ossification centers divide the bone into the manubrium, sternal body, and xiphoid process.[2] Some failures may occur during the development, such as the appearance of a hole (i.e., foramen) in some region of the sternum bone, mainly in its distal portion.[3]

Clinically, the sternum is easily accessible and has a porous and compact composition, facilitating some practices, such as spinal puncture and acupuncture.[4-5] The sternal foramen is filled with connective tissue, hindering its palpation during a procedure. In addition, this foramen may be confused with pathological processes during radiological examination.[4] Therefore, ignoring the existence of the sternal foramen may lead to misdiagnosis and iatrogenesis, justifying the importance of recognizing this anatomical variation.[3,5]

The present study aimed to report a case of an unusual location of the sternal foramen and address the main clinical implications of this anatomical variation.

CASE REPORT

This research was conducted at the Forensic Anthropology and Osteology Laboratory of the Federal University of Pernambuco. During routine washing and drying of the skeletons for storage, a foramen was observed in the upper third of the sternum. The bone belonged to a male individual aged about 28 years old. Regarding morphology, the foramen was medially located and presented an elliptical shape with its largest diameter in the longitudinal direction. The sternal foramen was located between the second and third intercostal space, specifically at the level of

the sternocostal joint of the third costal cartilage. Regarding morphometry, the sternum was measured using a digital caliper (Figure 1A), while diameters (vertical and horizontal) were measured using a Castroviejo-type curved dry point compass (Figure 1B).

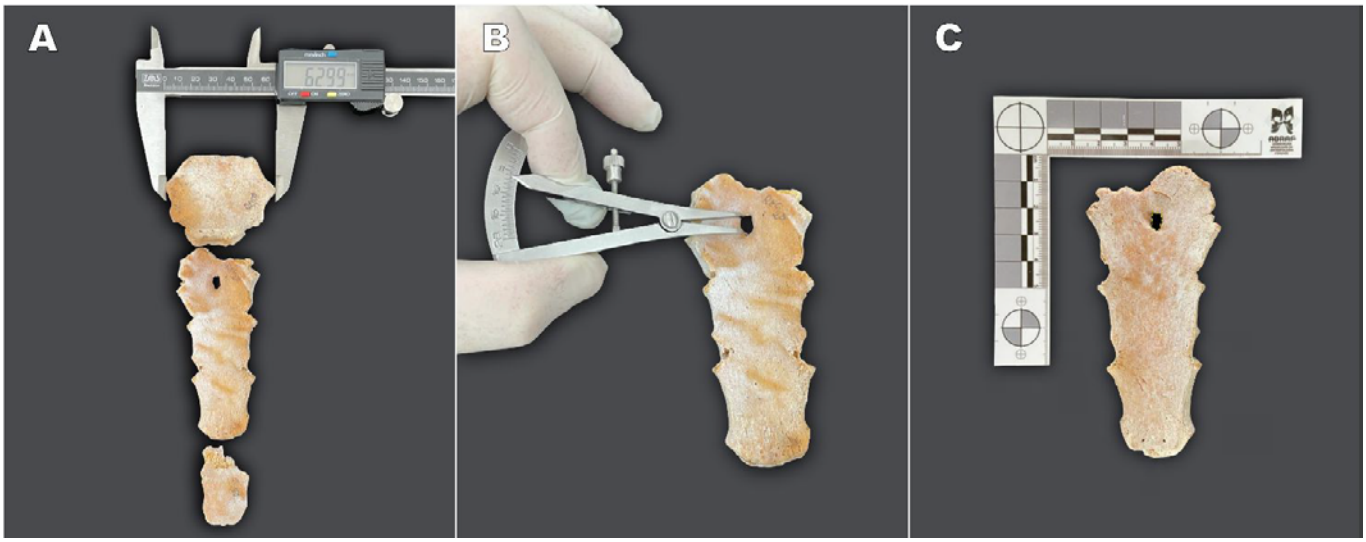

Figure 1. Measurement method and instruments for morphometry of the sternum bone. **A:** Measurement of the sternum bone and its parts using a digital caliper; **B:** Measurement of the diameters of the sternal foramen using a curved dry point compass; and **C:** Measurement of the sternal foramen area using the ImageJ and ABFO ruler nº 2.

The maximum length (height) of the sternum and the height and width of the manubrium, body, and xiphoid process were measured (Figure 2). The maximum length of the sternum bone was 201.19 mm. The width and height of the manubrium were 62.99 mm and 56.41 mm, respectively. The body height was 105.70 mm, and the width was 48.54 mm, 31.06 mm, and 25.92 mm in the upper, middle, and lower thirds, respectively. The width and height of the xiphoid process were 24.89 mm and 39.08 mm, respectively. The sternal foramen had a height and width of 0.65 mm and 0.4 mm, respectively, and was 17.95 mm distanced from the angle of Louis.

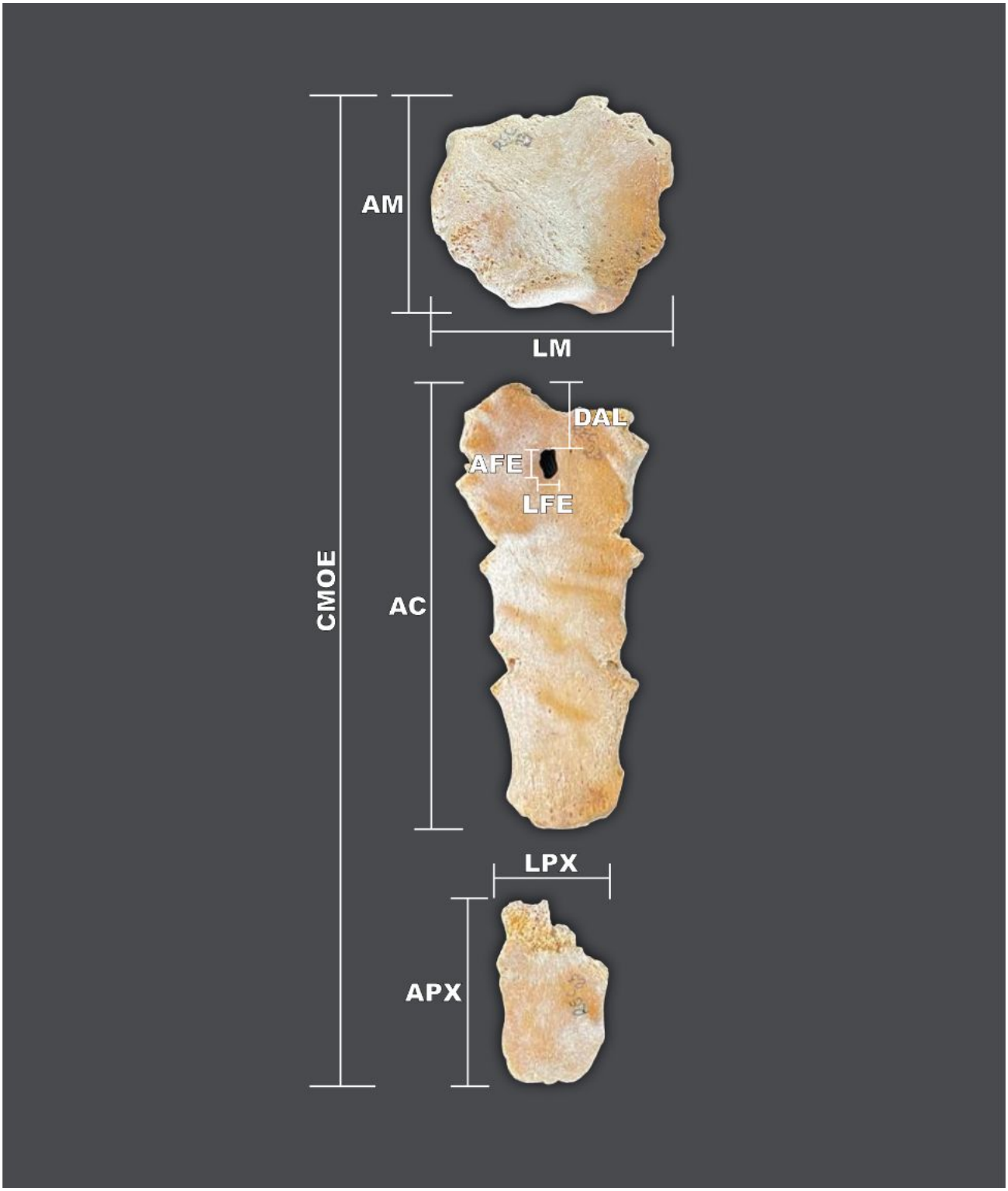

Figure 2. Measurements of the sternum bone and its parts. Maximum sternum bone length (CMOE); manubrium height (AM); manubrium width (LM); body height (AC); xiphoid process height (APX); xiphoid process width (LPX); sternal foramen height (SFA); sternal foramen width (LFE); and distance from the sternal foramen to the angle of Louis (DAL).

Then, the sternal foramen was photographed with a camera positioned at a 30-cm height of the specimen. The sternum bone was positioned on a flat surface, parallel to the ground, with the ventral surface facing upwards and downwards. The camera was positioned to form an imaginary line from the lens to the anatomical variation as perpendicular as possible. A ruler with a millimeter scale was positioned next to the anatomical piece (American Board of Forensic Odontology [ABFO] ruler nº 2, Crime Scene, Phoenix, Arizona, USA) to demonstrate the parallelism of the lens concerning the anatomical variation. In this way, the foramen area was measured using ImageJ (National Institutes of Health, USA). The software was calibrated by drawing a one-millimeter straight line on the ABFO nº 2 rulers next to the sternum bone. After calibration, morphometry was performed with a cursor, completely contouring the foramen, with the area expressed in square millimeters (mm2). The area of the sternal foramen was 0.264 mm2 (Figure 1C).

DISCUSSION

Anatomical variations of the sternum occur when the bone presents an incomplete closure during its formation. They are divided into clefts, sternal foramina, or supernumerary xiphoid process.[5,6]

The appearance of the sternal foramen is caused by a developmental defect in the midline of the sternum due to incomplete fusion of the ossification centers.[5] This defect happens during embryonic development when mesenchymal cells group to form the pre-cartilage; then, they fuse in the midline to form the cartilage of the sternum.[7,8] The ossification process begins from the fifth intrauterine month and completes its development, forming the manubrium and the xiphoid process after birth.[7,8]

Sternal foramina are generally found accidentally during imaging exams and, more commonly, post-mortem.[6,7] Furthermore, some studies are similar when analyzing the characteristics of the sternal foramen according to ancestry, biological sex, location, and age. In these studies, the foramen was more prevalent in individuals of African descent, and more in males than females. A higher incidence was also observed in individuals from South American individuals than in North American and European populations. Furthermore, this foramen is more common between puberty and the beginning of adulthood because the ossification process is completed in this phase.[5,8,9,10,11]

Furthermore, a study conducted at the Center for Studies in Forensic Anthropology of the Faculty of Dentistry of the University of Pernambuco (CEAF/FOP/UPE) with 126 skeletons found that 13 (10.3%) had the sternal foramen; 9 (7.1%) in the lower part of the sternal body and 4 (3.1%) in the xiphoid process.[5] Furthermore, a meta-analysis (n = 35 studies; 16,666 individuals) on the prevalence and morphometry of the sternal foramen found a higher prevalence in the lower region of the sternal (6.5%) than in the xiphoid process (2.9%).[9]In the first study, the prevalence of the sternal foramen was 10.3%.[5] However, the meta-analysis demonstrated an oscillation from

0.2% to 57.8%, suggesting that the prevalence changes according to the population studied.[9]

Previous studies did not report the presence of the foramen in the upper third of the body of the sternum, as described in the present study. This anatomical variation is typically observed only in the lower third or the xiphoid process (or both). Regarding morphometry, in a study conducted at the CEAF/FOP/UPE, a foramen presented a longitudinal dimension with a mean size of 0.6 cm and a vertical dimension of 0.5 cm. On the other hand, a meta-analysis revealed a prevalence of 4.7 mm in transverse diameter and 5.6 mm in vertical diameter.[9]

In this sense, the presence of anatomical variations deserves special attention because they may resemble gunshot wounds or osteolytic lesions. Furthermore, these variations may harm the pericardium and adjacent soft tissues in some procedures (e.g., acupuncture and bone marrow puncture), causing serious clinical implications for the patient.[4,5,10] For this reason, the sternal foramen has been associated with several risks, including injury to the pericardium, resulting in cardiac tamponade, decreased chest resistance, increased infections after heart surgery, and a greater likelihood of fracture associated with osteoporosis. Moreover, this foramen may harm vital organs due to perforation of the heart chambers, mainly in the right ventricle and the lungs.[6,9,10,11]

In this context, healthcare professionals must be aware of the existence of this anatomical variation. This awareness would make it possible to consider an early examination of the sternal region before any clinical procedures, preventing accidents and undesirable complications.[5,10,11]

Last, the literature regarding the epidemiology, morphology, and morphometry of the sternal foramen is scarce, especially about the Brazilian population.

Considering the importance of this topic in clinical procedures, further studies must encompass the Brazilian population and consider variables such as age, biological sex, ancestry, and height. Moreover, morphological and morphometric aspects often present variations between different populations and regions within the same country, according to the ethnic groups. Therefore, additional studies are needed to comprehensively understand this anatomical landmark and its variations in the Brazilian population.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest

AUTHOR CONTRIBUTIONS

Pacífico FA: conceptualization, data curation, investigation, methodology, project administration, resources, supervision, writing of the original draft writing, and writing (review and editing); **Gonçalves AAIS**: writing of the original draft; **Maia ER**: writing of the original draft; **Lages DB**: writing of the original draft; **Lima PHL**: resources and writing of the original draft; **Campina RCF**: resources, supervision, and writing (review and editing). All authors approved the final version.

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