

A Comprehensive Study of Sternal Foramen in a Pakistani Cohort: Prevalence and Morphometric Analysis

Maria Tasleem¹, Iram Atta², Mohtasham Hina³, Raafia Tafweez⁴, Ayesha Yousaf⁵

1. Assistant Professor, Rawalpindi Medical University. 2. Assistant Professor (Ex-Demonstrator KEMU). Services Institute of Medical Sciences. 3. Associate Professor, Rawalpindi Medical University. 4. Professor (Ex-Professor KEMU) King Edward Medical University. 5. Professor, Rawalpindi Medical University.

Corresponding author: Dr Maria Tasleem, marriahnouman@gmail.com

Abstract

Objective: This study aims to find the prevalence and morphometry of sternal foramen in the Pakistani population to prevent any potential cardiac complications and radiological or medicolegal misinterpretations.

Methods: This study was conducted on 178 dry human sternum bones of unknown sex and age available at the bone bank of King Edward Medical University Lahore, Pakistan. All the bones were grossly inspected for the presence of foramen. To describe the exact location of the foramen, its distance from the right and left sternal border was measured. For the size of the foramen, its vertical and transverse diameters were taken.

Results: The prevalence of foramen was found to be 7.3%. The foramina were round (53.8%) in shape, median (53.8%) in position and were located on body (61.5%). The average transverse diameter was found to be 3.08mm and the average vertical diameter was 2.83mm.

Conclusion: This study provides valuable insights for cardiac surgeons, acupuncture specialists, forensic experts, and radiologists, helping them avoid potential complications that may arise from the lack of awareness of the sternal foramen.

Keywords: Sternal Foramen, Medico-legal Significance, Acupuncture, Bone marrow biopsies

Introduction

The sternum is a part of the axial skeleton. It is a flat bone which forms the anterior midline of the thoracic cage.¹ Structurally, it comprises three parts: manubrium, body and xiphoid process. The location of the sternum is quite indispensable as it lies adjacent to the pericardial cavity, pleural cavity and great vessels of the thoracic cavity.² In addition to this, the importance of the sternum lies in the fact that it lodges hematopoietic bone marrow, containing highly vascular trabecular bone enclosed by a compact layer that is thickest in the manubrium.³ Embryogenesis of the sternum starts in the 6th week of intrauterine life through the longitudinal fusion of the mesenchyme located on both sides of the chest wall. These mesenchymal condensations later undergo chondrification and begin to fuse in the midline in a craniocaudal fashion, laying down a cartilaginous model of bone.⁴ Any variation in this midline fusion can result in a defect in the sternum that manifests itself as a sternal foramen. A sternal foramen could be a round, oval or irregular defect which can be located anywhere in the sternum, but usually, it is found at its lower end.⁵ Although it is asymptomatic, mostly diagnosed incidentally in imaging studies, postmortem examinations or intraoperatively during Coronary Artery Bypass Grafts (CABG),⁶ knowledge regarding its prevalence and likely anatomic locations is essential for the surgeons, pathologists, radiologists and forensic experts.

Review began 04/12/2024

Review ended 01/02/2025

Published 31/03/2025

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How to cite this article: Tasleem M, Atta I, Hina M, Tafweez R, Yousaf A. A Comprehensive Study of Sternal Foramen in a Pakistani Cohort: Prevalence and Morphometric Analysis. JRMC. 2025 Mar. 29;29(1). <https://doi.org/10.37939/jrmc.v29i1.2789>

Since the sternum contains bone marrow, it serves as a common site for bone marrow aspirations. During procedures such as bone marrow biopsies or acupuncture, the sternal foramen could be inadvertently penetrated, potentially leading to serious complications, including cardiac tamponade or even death.^{7,8} Furthermore, for radiologists and medico-legal experts, awareness of the prevalence of the sternal foramen is crucial, as its presence may be mistaken for other pathologies, such as gunshot wounds, fractures, or lytic bone lesions.^{9,10} For cardiac surgeons, recognizing the foramen is essential, as it may pose specific challenges during sternal closure following procedures like sternotomy. Given these clinical and surgical considerations, this study was designed to evaluate the incidence and morphometric characteristics of the sternal foramen in the Pakistani population.

Materials And Methods

This was a descriptive cross-sectional study that was conducted on 178 dry human sternum bones of unknown sex and age from January 2024 to March 2024, available at the bone bank of King Edward Medical University Lahore, Pakistan. All intact, clean bones were included in the study, while the broken ones were excluded. All the bones were grossly inspected for the presence of foramen. In the case where foramen was found, its location, shape, size and number were recorded. To describe the exact location of the foramen, its distance from the right and left sternal border was measured. The size of the foramen, its vertical and transverse diameter, was taken. All the measurements were taken using a digital vernier calliper, which was calibrated using a standard reference to ensure accuracy. The measurements were recorded in millimetres. Statistical data was then entered in Microsoft Excel.

Results

Out of 178 bones, sternal foramen was found in 13 bones, making an incidence of 7.3%. The morphological and morphometric data are given in Table 1. In the present study most of the foramina were round (53.8%) in shape, median (53.8%) in position and were located on the body (61.5%). The average transverse diameter was found to be 3.08mm and the average vertical diameter was 2.83mm.

Table 1: Prevalence and geometric attributes of Sternal foramina

Number of sternal foramina	Shape	Position (manubrium/ body/ xiphoid or xiphisternal joint)	Location (Median/Lateral)	Distance of foramen from the right sternal border (mm)	Distance of foramen from left sternal border (mm)	Transverse diameter (mm)	Vertical diameter (mm)
1	Round	Body at the level of 5 th intercostal notch	Lateral	9.2	18.7	2.5	3.4
2	Round	Body at the level of 5 th intercostal notch	Median	13.8	13	3.2	4.5
1	Round	Body at the level of 4 th intercostal notch	Median	9	8.3	2.1	1.5
1	Oval	manubrium	Median	14.3	15.1	3.6	4.9
1	Irregular	Body at the level of 5 th intercostal notch	Median	16.5	16.1	2.4	3.9
1	Round	xiphoid	Median	16.1	16.1	4.3	3.1
1	Round	xiphoid	Lateral	5.6	19.4	3.8	2.9
2	Round	xiphoid	Median	13.4	12.9	2.5	3.5
						3.1	1.5
1	Oval	The body at the level of the 6 th intercostal notch	Lateral	8.7	16.2	4.4	1.9
2	Round	Body at the level of 5 th intercostal notch	Median	11.4	11.8	2.6	2.5
						2.1	0.9
1	Oval	xiphisternal joint	Median	16.9	15.8	3.4	1.4
2	Oval	xiphoid	Lateral	5.5	14.6	5.4	2.3
						1.1	3.4
1	Round	The body at the level of the 6 th intercostal notch	Lateral	15.5	5.6	2.9	3.7
1	Oval	Body at the level of 5 th intercostal notch	Lateral	16.8	7.5	4.6	2.3



Figure 1: A single xiphoidal foramen is shown



Figure 2: A single sternal foramen is seen at the junction of the body and xiphoid process



Figure 3: Two sternal foramina are present in the body at the level of the fifth costal notch



Figure 4: A single sternal foramen is seen in the manubrium



Figure 5: Bifurcated xiphoid process showing common stem for the two processes

Table 2: Incidence of SF across different races

Race/Ethnicity	Type of specimen	Incidence of SF (%)
East Africans	Anatomic (Dry Specimens)	13.3
Europeans	Anatomic (Dry Specimens)	4
USA	Cadaveric (X-ray)	6.7
German	Radiologic (CT)	6
Turkish	Radiologic (MDCT)	4.5
Brazilian	Cadaveric (Dry Specimens)	16.6
kenyans	Anatomic (Dry Specimens)	13.8
Japanese	Radiologic (MDCT)	3.1
India	Cadaveric (Dry Specimens)	11.9
Spanish	Radiologic (X-ray)	3.3
Greek	Anatomic (Dry Specimens)	18.3
Uganda	Anatomic (Dry Specimens)	12.9
Australia	Radiologic (MDCT)	16.8
Ethiopian	Anatomic (Dry Specimens)	19.1

Discussion:

Over recent decades, anatomists and clinicians have increasingly emphasized the importance of understanding anatomical variations. These variations are frequently diverse and can differ across ethnic groups. A thorough grasp of human morphology is crucial for accurately interpreting radiological images, making precise diagnoses, and planning medical procedures. This knowledge also plays a vital role in pathology and forensic medicine.² Variations in the anterior thoracic wall, though not uncommon, can present intriguing potential clinical issues. One of these variations encompasses changes in the sternum in the form of foramen, which could be located in any of its parts and could also be in the form of a bifid xiphoid process, often resulting from atypical developmental patterns. Sternal bars develop on the ventrolateral aspects of the body wall and undergo chondrification as they move towards the midline. By the 10th week of development, these bars fuse from cranial to caudal directions in the median plane, forming the cartilaginous structures of the manubrium, sternum, and xiphoid process. Ossification centres appear in the sternum from cranial to caudal before birth, though the xiphoid process typically begins to ossify during childhood.³ As a result of this particular developmental pattern, a foramen may persist in the sternum due to incomplete fusion.

The sternal foramen (SF) is a common anatomical variation often discovered incidentally during radiological imaging, surgical procedures, or postmortem examinations. Although SF is usually asymptomatic, its proximity to vital thoracic structures makes it

crucial for clinicians and acupuncturists to be aware of its existence. During such procedures, the foramen increases the risk of injury to adjacent structures, such as the heart and major blood vessels, especially if the needle is inadvertently directed through the foramen. This could lead to severe complications like cardiac tamponade, bleeding, or even death. Additionally, in acupuncture, the sternal foramen may present challenges in accurately targeting acupuncture points along the chest or sternum, as inadvertent needling through the foramen could cause similar vascular or cardiac injuries.^{4,5,10} Unfortunately, a lack of awareness about SF has been the cause of several serious complications. Therefore, awareness of the SF is essential to minimize the risk of procedural complications and ensure patient safety.

Keeping the above considerations in view, researchers from across the globe have collected and published data on the incidence and morphology of this foramen and a similar study was planned to report prevalence in the Pakistani populace. In our study, the incidence of SF in the Pakistani population was found to be 7.3%. table 2 below shows the incidence in various ethnicities.^{5,9,11}

Conclusions

Although Sternal foramen is an asymptomatic defect, knowledge regarding its prevalence, location and size should be known to cardiac surgeons, radiologists and medicolegal experts to prevent any potential complications. As a cross-sectional study, it provides only a snapshot of the prevalence and morphometry of sternal foramina in the studied cohort. Longitudinal studies could provide more insight into the clinical significance and changes over time.

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Institutional Review Board Approval

112/RC/KEMU

09-02-2018

King Edward Medical University

Conflicts of Interest: None

Financial Support: None to report

Potential Competing Interests: None to report

Contributions:

M.T., - Conception of study

- Experimentation/Study Conduction

M.T, I.A, M.H, R.T, A.Y -

Analysis/Interpretation/Discussion

I.A,- Manuscript Writing

M.H, R.T, M.H, A.Y - Critical Review

All authors approved the final version to be published & agreed to be accountable for all aspects of the work.