



## ANATOMY OF STERNAL FORAMINA AND THEIR CLINICAL SIGNIFICANCE

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### ABSTRACT

The sternum develops from two mesenchymal bars that fuse together in the midline. Any defect in the fusion may result in a sternal foramen. It may pose a great hazard during sternal marrow biopsy, when the needle can cause cardiac or great vessel injury. The present study was conducted on 75 sternal bones to determine the incidence of sternal foramina. The location and size of the foramen were also studied. The foramina were encountered in 6 bones (8%). The average distance measured from the sternal angle was  $7.01 \pm 0.22$  cm. The maximum longitudinal and transverse diameters of the foramen were  $3.48 \pm 1.24$  mm and  $3.13 \pm 1.24$  mm respectively. Prior CT is recommended before any invasive procedure on sternum to avoid complications.

**KEYWORDS :** sternal foramen, pericardial injury, acupuncture.

### INTRODUCTION

The sternum is a flat bone present in the anterior part of thoracic skeleton in the midline. It consists of manubrium, body and xiphoid process. The sternum develops in the parietal layer of lateral plate mesoderm in the ventral body wall. Two sternal bars are formed in the parietal layer of lateral plate mesoderm on either side of the midline, and these later fuse to form cartilaginous models of the manubrium, sternebrae and xiphoid process. Fusion of sternal bars may be incomplete resulting in an oval or circular defect in the sternum, referred to as the sternal foramen. The fusion of the sternal bars may not occur altogether, resulting in complete cleft sternum and ectopia cordis, but this condition is very rare.

Sternal foramen, which is a common finding, is generally asymptomatic. It is commonly encountered as an incidental finding in CT or MRI scans of thorax. However, it may pose a great hazard during sternal marrow biopsy, due to inadvertent pericardial, pleural or great vessel injury. Fatality incidences following this procedure have been widely reported. The risk, though minor, is also involved in acupuncture practice. The foramina may also be misinterpreted as osteolytic lesions during imaging studies of the sternum. In autopsy studies of skeleton, the sternal foramen can be confused with the gunshot wound.

This study highlights the clinical significance of sternal foramina, and their common occurrence in the Indian population. The knowledge of incidence and localization of sternal foramina will be helpful in prevention of complications.

### MATERIALS AND METHODS

A total of 75 dry human sterna (49 M, 26 F) were studied from the bone bank of Department of Anatomy, Maulana Azad Medical College, New Delhi. Broken, incomplete or deformed sterna were excluded from the study. The sterna were inspected for the presence of foramen, and where it was found, its distance from the sternal angle was measured. The relation of the foramina with the costal facets was also noted.

The distance of the lateral edges of the foramen from the left and right sternal borders were measured and analyzed with the aim to determine the median or paramedian location of the foramen.

The maximum longitudinal and the maximum transverse diameters of the foramen were measured, with the aim to determine the exact size of the foramen. All the measurements were made to the nearest 0.01 mm using digital calipers.

### Statistical analysis

Data was analyzed using SPSS version 17.0, and general descriptive statistics were applied to derive means and standard deviations. The paired 't' test was applied to compare the distance of foramen from right and left lateral borders, and a p value of less than 0.05 was considered significant.

### OBSERVATIONS AND RESULTS

#### Incidence of foramina

The foramina were present in 6 sterna (8 %) (4M, 2F). Each of the six bones presented a single foramen in the body. Manubrial and xiphoid foramina were not encountered.

#### Relationship to costal facets

In 5 sterna, the foramen was present around the level of 5<sup>th</sup> costal facet. One sternum presented the foramen just above the level of 7<sup>th</sup> costal facet.

#### Measurements

Average distance from the sternal angle was  $7.01 \pm 0.22$  mm. Average maximum longitudinal and maximum transverse diameters were  $3.48 \pm 1.24$  mm and  $3.13 \pm 1.24$  mm respectively.

The difference in the distance from the right and from the left lateral borders was found significant (p value = 0.65 > 0.05)



Figure 1: Sterna showing foramen in the lower parts of body.



Figure 2: Red arrow showing distance of the foramen from sternal angle.

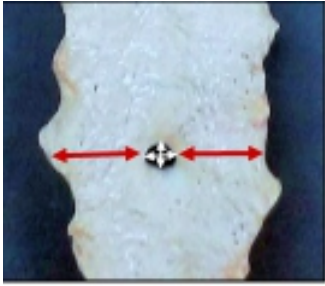


Figure 3: Red arrows showing the distance of the foramen from the lateral borders, white arrows showing the longitudinal and transverse diameters of the foramen.

## DISCUSSION

The sternum develops from the mesenchymal condensation in the lateral plate mesoderm in 6<sup>th</sup> to 9<sup>th</sup> weeks of gestation.<sup>1</sup> The mesenchyme condenses in the anterior thoracic wall to form two sternal bars on either side of midline. By 8<sup>th</sup> week of development, these bars begin to chondrify and fuse with each other in a cranial to caudal direction to form a single midline structure.<sup>2</sup> Ossification centers appear in the fused sternal plates, and the sternum is completely ossified by 25 years of age.<sup>3</sup>

The sternum ossifies from six ossification centers, one for the manubrium, four for the body of sternum, and one for the xiphoid process. The center for the manubrium appears around the 5<sup>th</sup> fetal month. First and second sternebrae ossify from single centers that appear at about the same time. Third and fourth sternebrae ossify from paired centers, which appear at 5<sup>th</sup> month and 6<sup>th</sup> month respectively. The xiphoid process begins to ossify in the third year or later. The union between the mesosternal centers begins at puberty and proceeds from below upwards. By the age of 25 years, they all are united.<sup>3</sup>

Defects in the developmental process lead to various sternal anomalies like bifid xiphoid process, xiphoid foramen, mesosternal foramen and cleft sternum. Various anomalies associated with sternal anomalies include cervicofacial and brain hemangiomas, supraumbilical raphe, diastasis recti, accessory fissures of lung, etc.<sup>4</sup> Malformations of xiphoid process are seen in mice mutant for both HOXC-4 and HOXA-5, and mice mutant for HOXB-2 and HOXB-4 have split sternums.<sup>5</sup>

Author	Study population	Incidence
Stark(on chest CT)	British	4.3%
Cooper(in autopsy cases)	USA	6.7%
Aktan and Savas	Turkish	5.4%
Yekelar	Turkish	4.5%
El-Busaid	Kenyan	13.8%
Yamamura	Brazilian	17.5%
Babinski	Brazilian	16.6%
McCormick	USA	7.7%
Present study	Indian	8.0%

Table 1- Incidence of sternal foramina in different studies.

Incidence of sternal foramina is higher in Negro population as observed by El-Busaid<sup>6</sup> (Kenyan study-13.8%), and by Yamamura<sup>7</sup> (Brazilian study-17.5%) and Babinski<sup>8</sup> (Brazilian study-16.6%)

Sternal anomalies can be detected by CT (multiplanar or 3D-reconstructed images) or MRI. CT is the modality of choice to evaluate anatomic detail as well as pathological conditions of the sternum, sternoclavicular joints and adjacent soft tissues. It is possible to differentiate congenital sternal anomalies from pathological conditions of sternum on CT. Factors that should be taken into consideration are corticomedullary differentiation,

cortical irregularity, identification of normal spiculations and pits, presence of any adjacent soft tissue mass, etc.<sup>9</sup>

Knowledge of sternal foramina holds clinical importance for medical practitioners while doing sternal bone marrow biopsy. Accidental penetration of puncture needle through the sternal foramen can lead to fatal cardiac tamponade, pericardial or great vessel injury.<sup>10</sup> Awareness of sternal foramen is also important for radiologists to differentiate them from pathological conditions like osteolytic lesions.<sup>11</sup> Forensic experts can confuse sternal foramina with gunshot wounds while examination of skeleton.<sup>12</sup> Sternal region at 4<sup>th</sup> and 5<sup>th</sup> sternoarticulation levels correspond to acupuncture points cv-17 and cv-16, and thus can pose great hazards while inserting acupuncture needle in persons with sternal foramen.<sup>13</sup>

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