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Sternal Foramina: A Study in Marathwada Population

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Abstract

Background: The knowledge of sternal variations is important as this bone is usually chosen for bone marrow aspiration. One such developmental anomaly is the presence of foramina of varying dimensions, in manubrium, body of sternum (mesosternum) or xiphisternum. Usually, the defect occurs in the lower third of sternum, in the body, as a single midline foramen (oval or round) and is usually asymptomatic and can be demonstrated only by CT scanning. The observation and knowledge of these foramina are of utmost importance in clinical, forensic and acupuncture techniques. Hence, this observation could be a useful one. *Methods:* 71 dried adult human sternae from the Department of Anatomy, Govt. Medical College, Aurangabad were studied. Measurements of sternal foramina if present were made with sliding vernier caliper and photographic documentation was obtained. *Results:* Out of 71 human sternae studied, Sternal foramina were found in 3 male sternums, resulting in an incidence of 4.22 % while none were found in female sternum. The largest sternal foramina found measured 11 x 12 mm and smallest measured 7 x 5 mm. *Conclusion:* Sternal foramina are variant quite common in the population, which is not only a focus of attention to the anatomists but also of interest to Forensic experts, orthopedicians, paediatricians, cardiothoracic surgeons, physicians because it is in very close contact with heart and lungs.

Keywords: Sternal Foramen; Fusion Defect; Incidence; Sternal Puncture; Cardiac Tamponade.

Introduction

Sternal foramina constitute congenital midline defects in sternum, caused by incomplete fusion of the multiple sternal ossification centers. Presence of Sternal foramina was firstly documented in the 17th century. Eustachius (1707) noted the existence of this anomaly [1]. Sternal foramina have been observed in the manubrium, body and xiphoid process, however, they appear mainly in the inferior part of the sternum. Incidence of Sternal foramina ranges from 3.1 to 27.4 %, while the presence of xiphoidal sternal foramina has been reported up to 57.7 % as available in the literature [1,7-12, 14-22]. Their incidence varies among different populations. The aim of this study is to evaluate the incidence of Sternal foramina in marathwada population, compare results with other populations and discuss the importance of awareness concerning their existence and topography.

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Normal Anatomy of Sternum

The STERNUM (from Greek *sternon*, "chest"; plural "sternums" or "sterna") or breastbone is a long flat bony plate shaped like a capital "T" located anteriorly to the heart in the center of the anterior wall of the thorax (chest). Thus the sternum plays an important role to protect the lungs, heart and major blood vessels from physical trauma. Its average length in the adult is about 17 cms, and is rather longer in the male than in the female. From the front, the sternum is shaped somewhat like a sword / dagger. From the side, the sternum appears as a long, flat bone with a outward curvature.

The sternum consists of 3 parts: listed superior to inferior: the manubrium, the body of sternum

(mesosternum) or gladiolus, and the xiphoid process.

The Manubrium is the broad superior portion of the sternum which connects to the 1st pair of ribs. The superior end supports the clavicles (collarbones), and its margins articulate with the cartilages of the first seven pairs of ribs forming the front of the rib cage.

The Body or Corpus Sterni or Gladiolus is the longest part of the sternum connects with the next 6 pairs of ribs. Together, these 7 pairs of ribs are known as the true ribs. The sternal angle is located at the point where the body joins the manubrium. The sternal angle is a useful landmark when counting ribs because the second rib attaches here. In early life its body is divided in four segments, called sternebrae (singular: sternebra).

Photograph showing sternal foramina in present study

The Xiphoid Process or Processus Xiphoidus or Ensiform Appendix or Xiphoid Appendix —Located at the inferior end of the sternum is the pointed and the smallest of the three pieces. It articulates above with the body and on the front of each superior angle presents a facet for part of the cartilage of the 7th, 8th, 9th and 10th ribs. It gives attachment to the linea alba and, on the posterior surface, to the diaphragm[2].

Material and Methods

The study was conducted on 71 adult human dried sternae (45 male and 25 female) from the bone bank of Department of Anatomy of Govt. Medical College, Aurangabad. The bones were examined for the presence of Sternal foramina and photographic documentation was obtained. Measurements of the Sternal foramina were also obtained using a sliding vernier caliper.

Results

Out of 71 sternums (45 male and 25 female) studied, Sternal foramina were found in 3 male sternums, resulting in an incidence of 4.22 % while none were found in female sternum. The topography and measurements of the 3 sternal foraminas are summarized in Table 1. All 3 Sternal foraminas were found only in male sternums and they were seen on the body of sternum (mesosternum) in the midline. The largest sternal foramina found measured 11 x 12 mm and smallest measured 7 x 5 mm.

Discussion

Sternal foramen is an oval or round defect usually present in the lower third of body of sternum. Foramina have also been reported in manubrium sterni and xiphisternum.It may be of various sizes and shapes. Other sternal defects have been reported as complete midline sternal cleft, hybrid abnormalities like key-hole shaped deformity [3] and multiple sterna foramina [4]. All these are fusion defects of sternum [5].

Embryological Basis

In the fetus, the sternum consists of two cartilaginous bars (bars of mesenchymatous tissue)

Table 1: Topography and measurements of the sternal foramina documented in the present study

S. No	Sex	No. of sterna foramina seen	Location of sterna foramina	Measurements (transverse x vertical in mm)
1	Male	one	On the body of sternum (mesosternum) in the midline Corresponding to articulating facet of 5th rib & extending upto articulating facet of 6th rib	11 x 12
2	Male	one	On the body of sternum (mesosternum) in the midline corresponding in between 5th & 6th articulating facets for ribs	7 x 5
3	Male	one	On the body of sternum (mesosternum) in the midline corresponding exactly opposite to the articulating facet of 5th rib	9 x 12

called sternal bars which become attached to the upper nine costal cartilages on each side of the midline. During the eighth week of gestation, these bars migrate, converge towards the midline and fuse with each other in a cranio-caudal pattern. This fusion is completed by the tenth week, forming the manubrium and body. The xiphisternum is formed as a caudal extension of the sternal bars.

The ossification of sternum is by six centres: one for manubrium, four for body and one for xiphoid process. They appear between the articular facets for costal cartilages and divide the sternum into six transverse pieces. The fourth and fifth pieces are often formed from paired ossification centres.The third and fourth appear during the fourth and fifth months of fetal life respectively. The fifth usually appears an year after birth. Incomplete fusion of sternal bars in this region accompanied by eccentric centres of ossification account for the occurrence of sternal foramen or sternal fissure. Ossification of sixth part (xiphoid process) does not begin until the fifth to eighteenth year of life and partial cartilaginization may persist into adult life. Thus, xiphoid abnormalities are rare as compared to manubrial and gladiolal defects [5,6].

The complete fusion defect leads to cleft sternum whereas partial fusion defects lead to sternal foramina. Failure of fusion may be due to an early disturbance affecting midline mesodermal structures during sixth to ninth weeks of gestation.

Incidence

Incidence of Sternal foramina present show great variability in different studies and populations, while literature data of Sternal foramina incidence are documented in Table 2. In the literature, Sternal foramina incidence ranges between 3.2 and 18.3 % in studies using dried sterna [1,7-10], whereas in the present study, incidence of the Sternal foramina is found to be 4.22 % in the population of Marathwada. The existence of multiple xiphoidal Sternal foramina has been noted in 1.2–9 % of the total population [1,8,10,11]. Multiple Sternal foramina located at the sternal body have been documented in the literature [4,12,13], while presence of Sternal foramina in the manubrium has also been noted [12,14]. However, manubrial foramen or xiphoidal foramen were not found in the present study.

Location of the Sternal foramina may vary (Table 2). In 77.8 % of the Sternal foramina is present at the sternal body, the defects were encountered at the level of 5th intercostal segment[8], while in the present study, the Sternal foramina of the sternal body were located in the midline at the level close to the articulating facet for the 5th rib (Table 1). Some studies indicate a higher prevalence of Sternal foramina in the xiphoid process [10,15,16]; a finding that is not in accordance to the present study. None Sternal foramina were noted in the xiphoid process in the present study. However, some authors reported a greater incidence of Sternal foramina in the sternal body [8,9.14]; a finding which is in accordance to the present study. The size of Sternal foramina is also variable, ranging from 2 to 18 mm in the literature and 5 to 12 mm in the present research. The largest Sternal foramina detected in our study was of 11 x 12 mm size.

Although Sternal foramina are usually solitary malformations, association with accessory fissures and supernumerary left lung lobules has been noted during high resolution CT evaluation [7]. Coexistence with sternal cleft is also reported in the literature [3,11,14]. Moreover, coexistence of Sternal foramina and vertical sclerotic bands localized superiorly or inferiorly to the foramen was noted in 73 % of the multidetector computed tomography scans which revealed the presence of Sternal foramina [11].

The morphology of the xiphoid process constitutes a subject of interest in anatomical research. In the literature, the presence of xiphoidal Sternal foramina varies between 2.5 and 57.7 % (Table2). Xie et al. [15] have suggested a classification of different types of xiphoidal morphology in relation to the Sternal foramina existence. The authors, recommended four patterns: pattern L and pattern S include the presence of a single Sternal foramina with diameter more than 5 mm and less than 5 mm, respectively, while pattern LS includes specimens which present a large and a small Sternal foramina and pattern SS two or more small Sternal foramina. They report an incidence of 55.5, 28.5, 9.2 and 6.8 % for L, S, LS and SS pattern, respectively. Thus, the aforementioned researchers detected single xiphoidal Sternal foramina in 84 % of the subjects studied.

CT- computed tomography, MDCT- multi-detector computed tomography, HRCT- high resolution computed tomography. SF- Sternal foramina *****In this studies, only the xiphoid process was studied.

Clinical Implications

The clinical importance of this defect lies in the fact that a fatal cardiac tamponade can occur following insertion of needle (sternal puncture) in this region. If the needle is inserted without the knowledge of the presence of a foramen, it may easily penetrate the pericardium through the foramen. Sternum is one of the two bones chosen for bone

marrow aspiration in hematological diseases (the other site being the posterior part of iliac crest of hip

Table 2: Incidence of sternal foramina found in different studies are as follows

Author	Year	Population	Specimen	No. of sterna studied	Presence of sternal foramina		
					No. of sterna having SF	Location	Incidence (%)
Ashley[1]	1956	East africans Europeans	Dried sterna Dried sterna	98 573	13 23	--- ---	13.3 % 4 %
Mc Cormick[17]	1981	USA	X-rays (cadavers)	324	25	Sternal body (lower third)	7.7 %
Stark[18]	1985	USA	CT	140	06	Sternal body (lower third)	4.3 %
Moore et al.[19] Cooper et al[12]	1988	White, black, Hispanic,oriental , amerind	X-rays (cadavers)	Total 2016	135	---	16.1 %
Schratter et al.[20]	1997	Germans	CT	100	06	Sternal body	6 %
Aktan and Savas[7]	1998	Turkish	HRCT Dried sterna	350 62	19 02	--- Sternal body	5.4 % 3.2 %
Yekeler et al.[11]	2006	Turkish	MDCT	1000	45 274	Sternal body Xiphoidal	31.9 %
*Akin et al.[16]	2011	Turkish	MDCT	500	216	Xiphoidal	43.2 %
El-Busaid et al.[8]	2012	Kenyans	Dried sterna	80	09 02	Sternal body Xiphoidal	13.8 %
Ishii et al.[21]	2012	Japanese	MDCT	1053	33	Lower sternum	3.1 %
Bayarogullari et al.[14]	2013	Turkish	MDCT	250	14 01	Sternal body manubrium	6 %
Shivakumar et al.[9]	2013	Indian	Dried sterna	86	06 03	Sternal body Xiphoidal	10.5 %
Macaluso et al.[22]	2014	Spanish	X-rays (cadavers)	122	04	Sternal body (lower third)	3.3 %
*Xie et al.[15]	2014	Korean	Cadaveric MDCT	943	544	Xiphoidal	57.7 %
George et al.[10]	2015	Greek	Dried sterna	60	03 08	Sternal body Xiphoidal	18.3 %
Present study	2016	Marathwada	Dried sterna	71	03	Sternal body	4.22 %

bone). Improper sternal prick / puncture may lead to cardiac tamponade or great vessel injury.

Another importance of sternum is that the acupuncture point CV-17 (Danchu or Shanzong or sea of energy) is located at the level of nipples in the midline. Vertical insertion of acupuncture needle can lead to pericardial effusion followed by cardiac tamponade. An oblique insertion of needle is recommended in these cases. However, in lean individuals who can have skin-heart distance of only 1-2 cm, even correct needling could lead to pericardial perforation [23].

Another problem is in the diagnosis of this foramen. It is usually asymptomatic, usually not palpable because of the overlying muscles and not normally visible in a radiograph because of the underlying pericardium. But, it can be well demonstrated in a CT. Multiplanar and 3D reconstructed Multi-Detector CT (MDCT) images are the modality of choice for detecting sternal anomalies. Thus, a sternal puncture performed without the knowledge of these anomalies could be fatal.

Forensic Misinterpretations

The sternal foramen could be misinterpreted as bullet injuries. On the forensic side, they could also be confused with ante-mortem traumatic injuries. A close examination of the specimen should confirm the presence of sternal foramen: The defect will be located in the midline, usually the lower half of body of sternum;the measurement of this defect will be the same on both outer and inner surfaces of the bone; a careful examination of the edges would reveal it to be smooth and covered with cortical bone.In specimens exposed to insects,fauna,etc. , characteristic erosion,

teeth or claw marks maybe present around the foramen, but it should not be mistaken for ante-mortem traumatic injury.

The misinterpretation of such defects in medicolegal cases can be a serious pitfall in determining the nature and cause of death in some suspected cases of homicide and suicide [6].

Medico Legal Importance

1. In badly decomposed bodies or skeletonized human remains a sternal defect may present a problem that can lead to misinterpretation and wrong conclusions which have serious consequences.
2. Postmortem artifacts of advanced putrification can obscure and mask the gross and microscopic changes of associated trauma.
3. In skeletons the character of the edges of the defect may be altered by scavenger animals or, when evaluating human skeletons which have been exposed or buried for longer periods of time, demineralization and erosion of the margins of the defect may have occurred.
4. The possibility of an old or recent gunshot wound or a traumatic penetrating lesion caused by an object other than a missile. X-rays of the body or remaining tissue parts and organs are necessary to rule out the presence of a missile. A separate X-ray of the sternum will disclose small metallic fragments about the defect that would be undetectable by gross examination.
5. Imaging of sternal foramen simulating osteolytic lesion [6,24].

The defect in the body of sternum leaves only the skin separating the pleura and heart from the surface at the affected site, thus any penetrating injury would easily access the heart and cause more severe damage than would normally be. The longer manubrium is unusual and can be both a clinical, radiological and medico-legal challenge when encountered [25].

Applied Aspects

1. Clinicians should be aware of this anatomic variation, because needle insertions in this area may lead to fatal complications. Knowledge of the existence of such anatomic variants is important to avoid misdiagnosis as an osteolytic process [24].
2. The possibility of a sternal foramen should be mentioned to the clinician because infiltration, biopsy or acupuncture of this area may lead to fatal cardiac complications [8].
3. Sternal foramina may pose a great hazard during sternal puncture, due to inadvertent cardiac or great vessel injury. They can also be misinterpreted as osteolytic lesions in cross-sectional imaging of the sternum [24].
4. Variant xiphoid morphology such as bifid, duplicated, or trifurcated may be mistaken for fractures during imaging [24]. These variations may complicate sternal puncture, and due caution is recommended. The variant xiphisternal morphology may raise alarm for xiphoid fractures and may therefore be considered a differential [8].

Also, important in radiological diagnosis, therapeutic procedures, forensic and medico legal or pathological identifications. It is also essential to know for students of medicine, radiology, anatomy and forensic pathology just as each variation could have unique features different from others.

Conclusion

The knowledge of anatomical variants such as congenital foramina of sternum (sternal foramina) is essential, especially for medical professionals, radiologists and acupuncturists, because of the danger of penetration of needle into pericardium during bone marrow aspiration or acupuncture. As it is asymptomatic, proper MDCT imaging could help in avoiding the risk of fatal cardiac tamponade.

List of Abbreviations used

CT – Computed Tomography

MDCT - Multi-Detector computed tomography

HRCT- High resolution computed tomography

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