Int. J. Morphol.,
43(4):1128-1132, 2025.

Topographic Morphometry and Incidence of Foramina on Sternal Body and Fully Ossified Xiphoid Process in Northeastern Thai Dry Sternums

Morfometría Topográfica e Incidencia de los Forámenes en el Cuerpo Esternal y el Proceso Xifoides Completamente Osificada en Esternones Secos del Noreste de Tailandia

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TANGSRISAKDA, N.; ARUN, S.; POODENDAEN, C.; DUANGCHIT, S.; MAIHONG, A.; KLAIKRAN, S. & IAMSAARD, S. Topographic morphometry and incidence of foramina on sternal body and fully ossified xiphoid process in northeastern Thai dry sternums. *Int. J. Morphol., 43(4)*:1128-1132, 2025.

SUMMARY: Presence of the foramen in the sternal body or xiphoid process has clinical, radiological, and forensic significances. It can be misdiagnosed during radiographic imaging. Prevalence and morphometrics of sternal foramen have been in many populations but not in Northeastern Thais. This study; therefore, aimed to investigate the topographic morphometry and incidence of sternal foramen (SF) and xiphoid foramen (XF) in Thai dry sternums. Identified 390 dry sternums (200 males and 190 females) with ossified xiphoid process were observed for incidence of foramen appearance. On sample with any foramen on sternal body, the morphometrics including distance from sternal angle to uppermost of sternal foramen margin (USF), lowermost of sternal foramen margin to lower end of the sternal body (LSF), and its diameters (VSF, vertical and TSF, transverse diameters) were measured. For xiphoid foramen, distance from lower end to uppermost of xiphoid foramen margin (UXF) and lowermost to lower end of xiphoid (LXF), and xiphoid foramen diameters (vertical [VXF] and transvers [TXF] planes) were also analyzed. The results showed the incidences of SF and XF were 5.38 % and 3.08 %, respectively. Compared between sexes, it was greater in male SF (3.59 %) and XF (2.05 %). In addition, USFs were 35.94 - 89.22 mm (male) and 51.18 - 98.09 mm (female) and LSF was 8.42 -27.77 mm (male) and 4.37 - 25.64 mm (female). The highest SF diameters (VSF x TSF) in male and female were 20.47 x 9.66 mm and 11.90 x 9.11 mm. UXFs were 8.50 - 71.51 mm and 1.86 - 29.83 mm observed in males and females while LXF was 3.85 - 17.79 mm (male) and 4.38 - 27.59 mm (female). The highest XF diameters (VXF x TXF) observed in male and female were 18.83 x 8.35 mm and 4.06 x 4.55mm, respectively. In conclusion, this study provided the baseline epidemiological data about sternal and xiphoid foramens in Northeastern Thais. These foramen topographies were varied between sexes and sides and prevalence of SF and XF should be noted to avoiding misdiagnosis and misinterpretation as pathologic or traumatic conditions during radiographic imaging.

KEY WORDS: Sternal foremen; Xiphoid foramen; Morphometrics; Prevalence; Northeastern Thais.

INTRODUCTION

Sternal body and xiphoid foramen, known as a developmental defect of the sternum, are the complete perforation in their structures. The sternal foramen (SF) or xiphoid foramen (XF) is classified as a congenital anatomical defect. In clinics, such foramen has no symptom and can usually be found incidentally in radiological images including computed tomography (CT), radiographic studies (X-ray), multidetector computed tomography (MDCT), high-resolution computed tomography (HRCT), and magnetic resonance imaging (MRI). In anatomical teaching, this variation also can be observed in the dry sternum. For forensic sciences, it is possible to be found in sternal remains or during sternal autopsy. In clinical practice of both modern and traditional medicines, sternal foramina can cause complications during medical procedures like acupuncture and bone marrow biopsy (Boruah *et al*., 2016; Choi *et al*., 2017). Therefore, knowledge of SF and XF is crucial for training of chest surgeons, clinicians, radiologists, and forensic scientists.

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FUNDING.This study was granted by Faculty of Medicine, Khon Kaen University, Thailand (Grant Number AS67003).

Received: 2025-01-28 Accepted: 2025-05-14

The reports of this foramen incidence are recently increasing in various populations. A short review by Gkantsinikoudis *et al*. (2017) has reported that the prevalence of SF ranged from 0.06 to 18.3 % as documented in previous works (Moore *et al*., 1988, Cooper *et al*., 1988; El-Busaid *et al*., 2012; Bayarogˇulları *et al*., 2014; Macaluso & Lucena, 2014; Paraskevas *et al*., 2015; Babinski *et al*., 2015; Boruah *et al*., 2016). Currently, using a meta-analysis (Pasieka *et al*., 2023), the incidence of SF and XF has been reported to be ranging from 0.2 % up to 57.8 % (Xie *et al*., 2014; Verna *et al*., 2015).

In Thailand, only CT study has shown 9.5 % of SF/XF prevalence in a central Thai population (Yurasakpong *et al*., 2022). However, the fundamental data of this variation on dry/cadaveric sternum in Thais has never been reported. The incidences of SF observed in anatomic sample (also called dry specimens) have been documented in many populations including East Africans (13.3 %), Europeans (4 %), Greek (18.3 %), Uganda (12.9 %), and Ethiopian (19.1 %), respectively (Ashley, 1956; Paraskevas *et al*., 2015; Kirum *et al*., 2017; Lema, 2023). The aim of this study was therefore, to investigate not only the topographic morphometrics but also the incidence of sternal and xiphoid foramen in the Northeastern-Thai dry sternal specimens.

MATERIAL AND METHOD

This study used 390 dry sternums with fully-ossified xiphoid foramens of Northeastern Thai skeletons (200 males and 190 females) that were kindly obtained from the Unit of Human Bone Warehouse for Research (UHBWR, 7th floor, premedical building), Department of Anatomy, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand. The exclusion criteria of bone collection in this study were broken specimens, those with any damage, or incomplete part of the sternum.

For the morphometric parameters (Fig. 1), the distance from sternal angle to uppermost of sternal foramen margin (USF) and lowermost of sternal foramen margin to lower end of sternum sternal body (LSF) were measured using a digital Vernier caliper. Figure 1 demonstrated the two measured planes (VSF, vertical diameter of sternal foramen and TSF, transverse diameter of sternal foramen) for the sternal foramen diameter.

Figure 2 demonstrated the measurements of morphometric parameters on fully ossified xiphoid process and its foramen diameter. The UXF (distance from lower end of sternum to uppermost of xiphoid foramen margin) and LXF (lowermost of xiphoid foramen margin to lower end of xiphoid) were measured a digital Vernier caliper (Fig. 2). In addition, the VXF (vertical diameter of xiphoid foramen) and TXF (transverse diameter of xiphoid foramen) were also conducted to reveal general topography of xiphoid foramen diameters as demonstrated in Figure 2. This study has been approved for the human ethics from the Center for Ethics in Human Research, Khon Kaen University (approval code: HE661235).

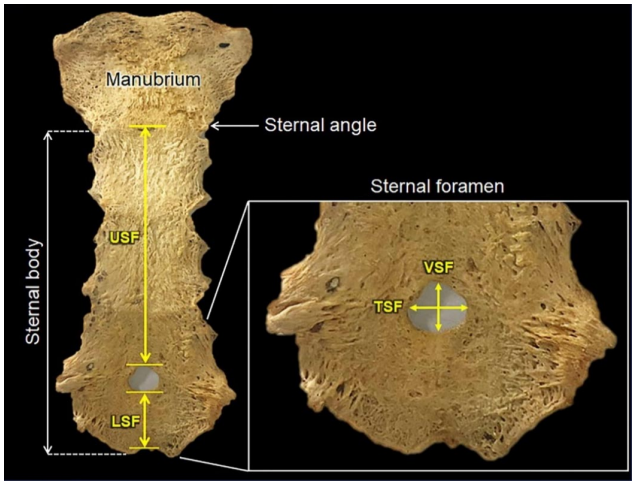

Fig. 1. Morphometric parameter measurements on the sternal body and its foramen. USF, distance from sternal angle to uppermost of sternal foramen margin; LSF, lowermost of sternal foramen margin to lower end of sternum; VSF, vertical diameter of sternal foramen; TSF transverse diameter of sternal foramen.

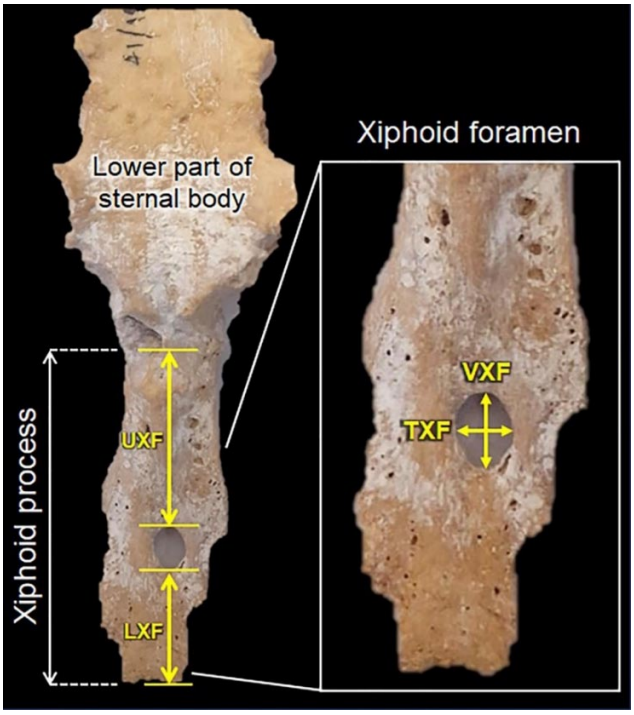

Fig. 2. Morphometric parameters on fully ossified xiphoid process and its foramen. UXF, distance from lower end of sternum to uppermost of xiphoid foramen margin; LXF, lowermost of xiphoid foramen margin to lower end of xiphoid; VXF, vertical diameter of xiphoid foramen; TXF, transverse diameter of xiphoid foramen.

RESULTS

From 390 sterna with xiphoid process, it was found that the incidences of sternal foramen and xiphoid foramen observed in Northeastern Thais were approximately 5.38 % and 3.08 %, respectively (Table I). These variations were greater in male (3.59 %; sternal foramen and 2.05 %; xiphoid foramen).

In Table II, results showed all topography and parameter measurements of the sternal foramina. The distances from sternal angle to uppermost of sternal foramen margin (USF) of Northeastern Thai males and females were 35.94 - 89.22 mm and 51.18 - 98.09 mm while their lowermost of sternal foramen margin to lower end of sternum (LSF) was 8.42 -27.77 mm in male and was 4.37 - 25.64 mm respectively. The highest diameters of sternum foramen (VSF x TSF) observed in male and female were 20.47 x 9.66 mm and 11.90 x 9.11 mm (Table II).

Table III showed the topography and parameter measurements of the xiphoid foramen. It was revealed that the ranges of distance from lower end of sternum to uppermost of xiphoid foramen margin (UXF) in Northeastern Thai males and females were 8.50 - 71.51 mm and 1.86 - 29.83 mm while, lowermost of xiphoid foramen margin to lower end of xiphoid (LXF) was 3.85 - 17.79 mm in male and was 4.38 - 27.59 mm respectively. The highest diameters of sternum foramen (VXF x TXF) observed in male and female were 18.83 x 8.35 mm and 4.06 x 4.55 mm, respectively as shown in Table III.

DISCUSSION

In normal development of human sternum, the condensed mesenchymal cells usually form paired sternal bars located on right and left sides of the midline, before processing of the chondrification and ossification centers. The SF of XF is a result of fusion failure of the ossification

Table I. Incidences of sternal and xiphoid foramina observed in Northeastern Thai sternums (n, 390; 200 males and 190 females.

	Incidences of foramina observed in 390 sterna.		
Foramina	Total	Male	Female
Sternal foramen	21 (5.38 %)	14 (3.59 %)	7 (1.79 %)
Xiphoid foramen	12 (3.08 %)	8 (2.05 %)	4 (1.03 %)

Table II. Topography and measurements of the sternal foramina observed in Northeastern Thai dry sterna.

No.	Sex	Length (mm)		
		USF	LSF	Diameter (VSF x TSF)
1	Male	35.94	16.98	7.61 x 6.02
2	Male	70.53	11.86	3.71 x 3.6
3	Male	76.27	17.48	7.75 x 6.83
4	Male	75.30	21.68	7.52 x 8.19
5	Male	70.70	17.50	8.15 x 9.09
6	Male	72.08	17.92	8.05 x 7.6
7	Male	70.86	14.82	2.58 x 1.63
8	Male	69.05	18.85	6.58 x 6.65
9	Male	75.81	14.93	20.47 x 9.66
10	Male	70.93	10.36	9.06 x 7.25
11	Male	69.58	18.22	3.67 x 2.84
12	Male	80.30	27.77	7.55 x 6.41
13	Male	68.09	19.76	13.37 x 6.22
14	Male	89.22	8.42	5.54 x 3.51
Range (min - max)		(35.94 - 89.22)	(8.42 -27.77)	(2.58 - 20.47) - (1.63 - 9.66)
15	Female	64.17	20.42	2.04 x 2.45
16	Female	69.27	4.37	4.78 x 2.50
17	Female	52.29	14.75	4.21 x 3.06
18	Female	63.88	25.64	4.15 x 3.72
19	Female	57.18	20.73	11.90 x 9.11
20	Female	51.18	11.14	4.56 x 3.39
21	Female	98.09	6.38	4.36 x 3.41
Range (min - max)		(51.18 - 98.09)	(4.37 - 25.64)	(2.04 - 11.90) - (2.45 - 9.11)

USF, distance from sternal angle to uppermost of sternal foramen margin; LSF, lowermost of sternal foramen margin to lower end of sternum; VSF, vertical diameter of sternal foramen; TSF, transvers diameter of sternal foramen.

Table III. Topography and measurements of the xiphoid foramina observed in fully ossified xiphoid process of Northeastern Thai dry sterna.

No.	Sex	Length (mm)		
		UXF	LXF	Diameter (VXF x TXF)
1	Male	39.77	8.51	2.82 x 2.92
2	Male	71.51	17.79	5.49 x 5.29
3	Male	16.53	16.11	5.78 x 4.38
4	Male	8.77	14.38	2.17 x 2.00
5	Male	26.15	3.85	14.24 x 9.60
6	Male	8.50	6.99	8.01 x 2.68
7	Male	45.23	4.16	18.83 x 8.35
8	Male	21.75	11.69	8.34 x 7.42
Range (min - max)		(8.50 - 71.51)	(3.85 - 17.79)	(2.17 - 18.83) x (2.00 -9.60)
9	Female	3.58	12.75	3.80 x 2.46
10	Female	1.86	25.56	2.40 x 2.26
11	Female	29.83	4.38	4.06 x 4.55
12	Female	5.36	27.59	2.89 x 1.75
Range (min - max)		(1.86 - 29.83)	(4.38 - 27.59)	(2.40 - 4.06) x (1.75 - 4.55)

UXF, distance from lower end of sternum to uppermost of xiphoid foramen margin; LXF, lowermost of xiphoid foramen margin to lower end of xiphoid; VXF, vertical diameter of xiphoid foramen; TXF, transverse diameter of xiphoid foramen.

centers to across their midline. Indeed, such foramen variations have impacts on clinical, radiological, and forensic significances. For clinicians and acupuncturists, the SF could be penetrated, especially during bone marrow biopsy, causing pericardial or underlying structure damages (Choi *et al*., 2017). For radiological evaluation, SF can be misdiagnosed as different pathologies including lytic bone lesions, trauma, fractures, and gun shots (Duraikannu *et al*., 2016; Gkantsinikoudis *et al*., 2017). For anthropologists and forensic experts, unawareness of SF/XF could be misinterpreted and result in misclassification of manner and mode of death (Babinski *et al*., 2015; Gkantsinikoudis *et al*., 2017).

Although the prevalence of this anatomic variation has been reported in a CT study observed in central Thais (approximately 9.5 %) by Yurasakpong *et al*. (2022), the topographic morphometry and incidence (8.46 %) of SF/XF were revealed in Northeastern Thai for the first time. Such prevalence is very close but we also reported that it was higher in male (5.64 %) as compared to female (2.82 %). It was assumed that the embryological development of SF/XF is different sexes.

The SF/XF incidence in this study was comparable to that prevalence investigated in the countries of Turkey (Bayarog˘ulları *et al*., 2014; Kuzucuoglu *et al*., 2020), USA (McCormick *et al*., 1981), India (Nayak *et al*., 2018), Australia (Schratter *et al*., 1997), and Poland (Spa?ek *et al*., 2016). For comparative foraminal localization in the sternum, the SF prevalence (5.38 %) observed in recent study was similar to that of Turkish (4.5 %) and Greek (5 %) populations (Yekeler *et al*., 2006; Paraskevas *et al*., 2015). However, our XF incidence (3.08 %) was lower than those populations, 27.4 % in Turkish and 11.3 % in Greek. Interestingly, the XF observed in Northeastern Thais was comparable to that prevalence studied in Kanyan population (El-Bushaid *et al*., 2012).

To our knowledge, the SF and XF are common anatomical variations also found in the Northeastern Thai sternums. In conclusion, it is necessary to be aware of the presence of these sternal and xiphoid variations for professions such as clinicians, radiologists, and forensic anthropologists to avoid the misinterpretation and misdiagnosis in daily practice.

ACKNOWLEDGEMENTS. This study was granted by Faculty of Medicine, Khon Kaen University, Thailand (Grant Number AS67003). We also would like to thank Unit of Human Bone Warehouse for Research (UHBWR), Department of Anatomy, Faculty of Medicine, Khon Kaen University for providing valuable-identified dry sterna donated from Northeastern Thais.

TANGSRISAKDA, N.; ARUN, S.; POODENDAEN, C.; DUANGCHIT, S.; MAIHONG, A.; KLAIKRAN, S. & IAMSAARD, S. Morfometría topográfica e incidencia de los forámenes en el cuerpo esternal y en el proceso xifoides completamente osificado en esternones secos del noreste de Tailandia. *Int. J. Morphol., 43(4)*:1128-1132, 2025.

RESUMEN: La presencia de un foramen en el cuerpo esternal o en el proceso xifoides tiene relevancia clínica, radiológica y forense. Puede diagnosticarse erróneamente durante las imágenes radiográficas. La prevalencia y la morfometría del foramen esternal se han estudiado en muchas poblaciones, pero aún no en los tailandeses del noreste. En este estudio se propuso investigar la morfometría topográfica y la incidencia del foramen esternal (FE) y

el foramen xifoides (FX) en esternones secos de individuos tailandeses. Se identificaron 390 esternones secos (200 hombres y 190 mujeres) con proceso xifoides osificados, y se observó la incidencia de la aparición del foramen. En muestras con foramen en el cuerpo esternal, se realizó la morfometría, incluyendo la distancia desde el ángulo esternal hasta el margen superior del foramen esternal (FES), el margen inferior del foramen esternal hasta el extremo inferior del cuerpo esternal (FEI), y sus diámetros (FEV, vertical y FET, transversal). Para el foramen xifoideo, también se analizó la distancia desde el extremo inferior hasta el margen superior del foramen xifoideo (FXS) y desde el extremo inferior hasta el inferior (FXI), y los diámetros del foramen xifoideo (planos vertical [FXV] y transversal [FXT]). Los resultados mostraron que las incidencias de FE y FX fueron del 5,38 % y el 3,08 %, respectivamente. En comparación con los sexos, fue mayor en los hombres FE (3,59 %) y FX (2,05 %). Además, los FES eran de 35,94 a 89,22 mm (hombres) y de 51,18 a 98,09 mm (mujeres) y el FEI era de 8,42 a 27,77 mm (hombres) y de 4,37 a 25,64 mm (mujeres). Los diámetros más altos del FE (FEV x FST) en hombres y mujeres fueron 20,47 x 9,66 mm y 11,90 x 9,11 mm, respectivamente. Los FXS fueron 8,50 - 71,51 mm y 1,86 - 29,83 mm observados en hombres y mujeres, mientras que el FXI fue 3,85 - 17,79 mm (hombres) y 4,38 - 27,59 mm (mujeres). Los diámetros más altos del FX (FXV x FXT) observados en hombres y mujeres fueron 18,83 x 8,35 mm y 4,06 x 4,55 mm, respectivamente. En conclusión, este estudio proporcionó los datos epidemiológicos de referencia sobre los forámenes esternales y xifoideos en los tailandeses del noreste. Estas topografías del foramen variaron según el sexo y el lado, y debe tenerse en consideración la prevalencia de FS y FX para evitar diagnósticos e interpretaciones erróneos como afecciones patológicas o traumáticas durante las radiografías.

PALABRAS CLAVE: Foramen esternal; Foramen xifoides; Morfometría; Prevalencia; Noreste de Tailandia.

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