

High Prevalence of Sternal Foramen: Quantitative, Anatomical Analysis and its Clinical Implications in Acupuncture Practice

Alta Prevalencia del Foramen Esternal: Análisis Cuantitativo y Anatómico y sus Implicancias Clínicas en la Práctica de la Acupuntura

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SUMMARY: The aim of our study was to verify the prevalence of the sternal foramen in adult cadavers and dry bones, as well as to determine its exact localization and relation to acupuncture points. One hundred eighty sternums fixed and contained in 10% formaldehyde solution were examined, of which 100 were dry bones and 80 belonged to adult cadavers. The morphometric measures were expressed in millimeters when measuring the length: 1) from jugular incision to the foramen (JI-F); 2) from sternal angle to the foramen (EA-F); 3) from xiphoid process to the foramen (XP-F). Statistical analysis was performed to compare expected vs obtained foramina frequency, using Fisher's test ($p \leq 0.05$ was considered significant). The results showed 16.6% sternal foramina, significant higher than expected ($p \leq 0.0248$). Of the 30 foramina, 53.3% were found in cadavers, of which one was a woman, and 46.7% sternums were found in dry bones. Of the cadavers with sternal foramen, 10 foramina were at the 5th sternochondral articulation level and 6 foramina at the 4th sternochondral level. Of the 14 analyzed dry bones, 9 foramina were at the space between the 4th and the 5th costal pit level and 5 foramina were at the 5th costal pit level. The mean \pm SD (mm) total length of the sternums was 151.8 \pm 34 and the measures JI-F, EA-F, and XP-F were, respectively, 103.8 \pm 22.1mm, 65.6 \pm 15mm and 46.9 \pm 15mm. Knowledge of this occurrence is important to avoid serious heart injury by needle insertion, especially as this area holds a commonly used acupuncture point and sternal puncture.

KEY WORDS: Gross Anatomy; Cadavers; Anomalies; Sternal Foramen; Acupuncture.

INTRODUCTION

Human skeletons have many variations that may occasionally necessitate distinction from pathologic changes. The sternum is one of the skeleton parts with frequent variation in appearances on images or autopsy series. In living subjects, sternal variations are frequently detected incidentally on cross-sectional images. Knowledge of radiologic appearances of sternal variations and anomalies is useful so as to not confuse those with pathologic conditions (Yekeler *et al.*, 2006).

The sternal foramen is an anatomical variation that has been well described in the aspects: morphological (McCormick, 1981; McCormick & Nichols, 1981; Bergman *et al.*, 1988; Cooper *et al.*, 1988; Williams *et al.*, 1996), in clinical acupuncture (Fokin, 2000; Hecker *et al.*, 2005), the risk of inadvertent use of acupuncture point on the foramen

(Bichel, 1989; Chen, 1995; Ernst, 1995; Peuker *et al.*, 1999) and complications of puncture through the foramen (Hasegawa *et al.*, 1991; Halvorsen *et al.*, 1995; Wolochow, 1995; Kataoka, 1997; Kirchgatterer *et al.*, 2000).

Awareness of a sternal foramen is important in acupuncture practice and sternal marrow aspiration because of the danger of heart damage (Fokin). By all means, the particular major risks that acupuncture carries are the risk of traumatic injury to an internal organ, especially the pleura, by needle penetration (Bodner *et al.*, 1983; Gray *et al.*, 1991; Rampes & James, 1995; Cantan *et al.*, 2003), and the risk of causing bacterial infections in deep structures, though the latter seems to be negligible, probably because the needle tip is too small to carry sufficient inoculum of infected material from the skin (Hoffman, 2001; White, 2006). In this

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way, several authors have collated list of complications caused by or associated with acupuncture (Norheim & Fonnebo, 1995; Ernst; Ernst & White, 1997; Rampes & James; Peuker *et al.*; White, 2004).

Sternal puncture also has been associated with potentially lethal complications (Ye, 1956; Schiff, 1965; Puschel *et al.*, 1985; Pascali *et al.*, 1987; Bichel; Halvorsen *et al.*; Peuker *et al.*; Kirchgatterer *et al.*; Van-Marum & Te-Velde, 2001).

A few works have verified the relation between the development of cardiac injuries following sternal puncture, or even acupuncture, and the existence of an anatomical anomaly, i.e., the sternal foramen (Hasegawa *et al.*; Wolochow; Halvorsen *et al.*; Peuker *et al.*; Kirchgatterer *et al.*; Van-Marum & Te-Velde). Quantitative studies on sternal foramina frequency were performed (Yamamura *et al.*, 1996) in adult patients through roentgenograms (Moore *et al.*, 1988). Therefore, the purpose of our study is to determine the prevalence and exact localization of the sternal foramen in adult cadavers and dry bones.

MATERIAL AND METHOD

The work complies with the Helsinki Declaration from 1995 (as revised in Edinburgh, 2000). The protocol for the present work has been approved by the Department of Morphology from Biomedical Center at Fluminense Federal University.

One hundred eighty sternums were examined, of which, 100 were dry bones and 80 were from adult cadavers (most of them more than 40 years old), fixed and kept in a 10% formaldehyde solution, 72 of them belonging to men and 8 belonging to women.

After dissection of the anterior part of the chest wall (Fig. 1), the sternum was exposed in details with the removal of the periosteum on the anterior medium line (Fig. 2A), in 3cm width along the whole extension of the sternal body (external and internal surface). The sternocostal articulations and the intercostal spaces were viewed with the aim of relating them to the sternal foramina.

Morphometrical parameters: The morphometric parameters were expressed in millimeters (mm), and through them we obtained the following linear measures(length): 1) from jugular incision to the foramen (JI-F); 2) from the sternal angle (Louis' angle) to the foramen (EA-F); 3) from the xiphoid process to the foramen (XP-F); 4) diameter of

the foramen, and 5) thickness of the foramen. All macroscopic measurements were made to the nearest 0.01mm using digital calipers, and no distinction was made as to ethnical and sexual dimorphism of the dry bones. In cadavers that showed the existence of sternal foramen (Figs. 1,2A-B), a puncture needle was made to verify the correspondence of the sternal foramen with the heart (Fig. 3A-C).

Statistical analysis: For statistical analysis of the frequency of sternal foramen, the software GraphPad Prism 4 statistical software (GraphPad Inc., CA, USA) was used. Fisher's exact test was performed to analyze a contingency Table (Table I), with results showed in Figure 4. The values with $P \leq 0.05$ was considered significant.

RESULTS

Of the 180 analyzed sternums from cadavers and skeletons, 30 (16.6%) sternal foramina were found, this result was significant ($p \leq 0.0248$), higher than we expected (Fig. 4). Of the 30 foramina found, 16 (53,3%) were observed in cadavers (Fig. 1, 2A), among which 1 was woman (Fig. 2B) and 46.7% (14/30) of sternal foramina were found in dry bones.

The morphometric data (mean \pm SD) related to the length of the sternums (cadavers and dry bones) and anatomical location (JI-F, EA-F and XP-F) (Fig.1), were respectively: 151.8 \pm 34mm, 103.8 \pm 22.1mm, 65.6 \pm 15mm, and 46.9 \pm 15mm.



Fig. 1. Photomacrography showing the sternum with a oval sternal foramen well defined (asterisk).



Fig. 2A) A man cadaver with the sternum exposed in details showing an oval sternal foramen (asterisk).

Fig. 2B) A woman cadaver with sternal foramen (arrow).

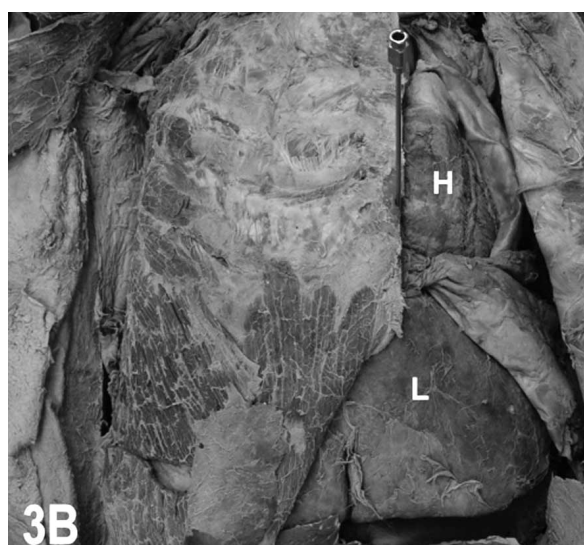
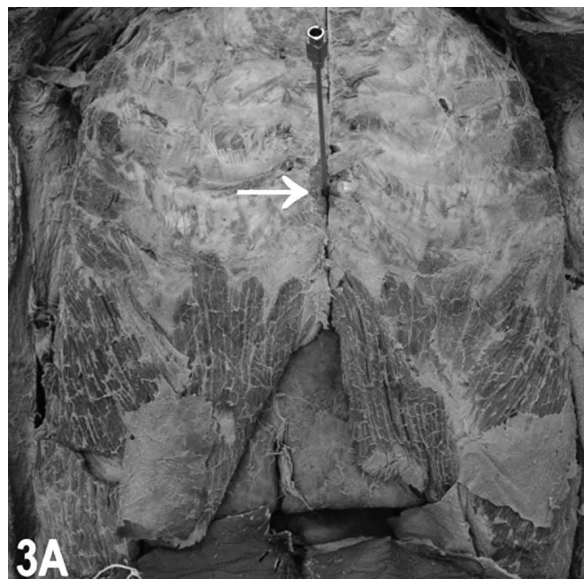
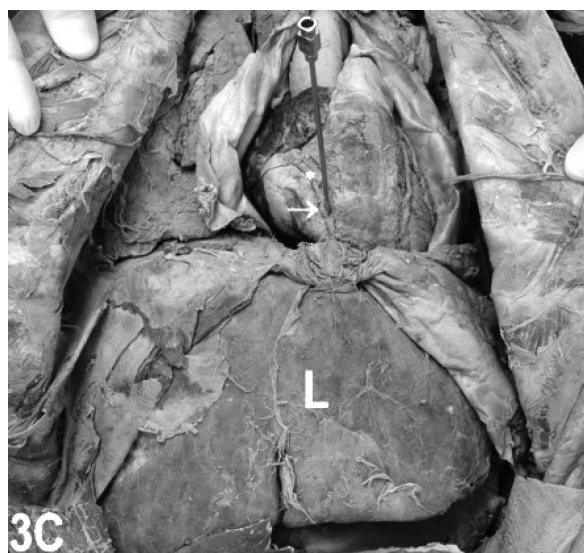


Fig. 3A) A man cadaver with trans-thoracic penetration (arrow) with puncture needle.

Fig. 3B. Check the correspondence of the oval sternal foramen with the heart (H); L= Liver

Fig. 3C. The damage has occurred (arrow) through trans-thoracic penetration with needle; L= liver; asterisk= right coronary artery.



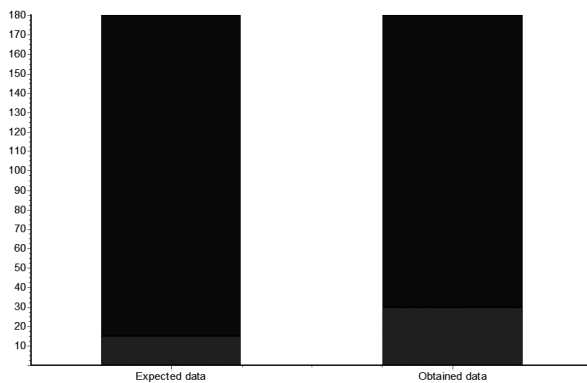


Fig. 4. Analysis between percent data expected (Table I en Results) vs. obtained of the 180 sternums studied.

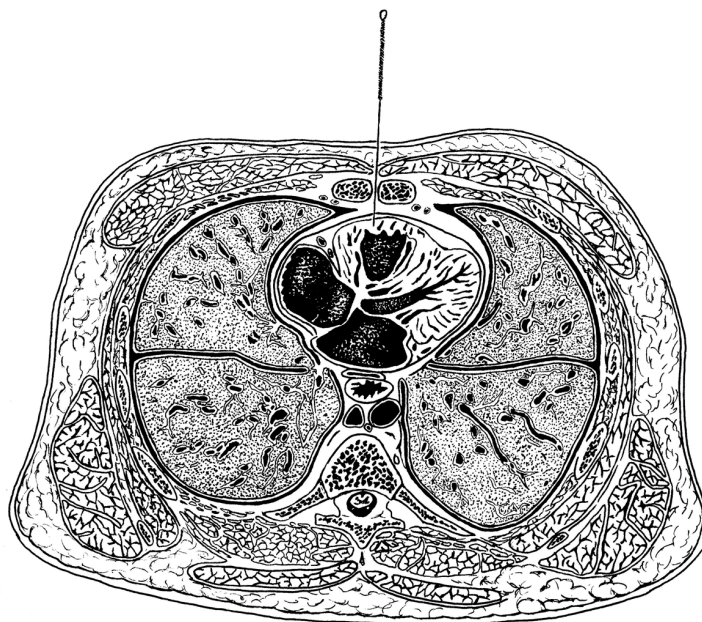


Fig. 5. A schematic drawing of a transversal section of the thorax at the T7 vertebra level representing a perforation of the heart through the presence of the sternal foramen according to figure 3 B-C

Table I. Analysis between percent data expected (*) vs. obtained of the 180 sternums studied. The $p \leq 0,05$ was considered significant. *Expected data according to literature (McCormick, 1981; Cooper *et al.*, 1988; Peuker *et al.*, 1999; Van-Marum and Te-Velde, 2001; Hecker *et al.*, 2005).

Anatomic characteristic	Expected data N (%)	Obtained data N (%)
Normal anatomy of sternum	165 (92)	150 (85.4)
Abnormal anatomy: Sternal foramen	15 (8*)	30 (16)
Total	180 (100)	180 (100)

In all specimens (30) presenting sternal foramen, these were always unique, usually oval or circular in sternal midline location (Figs. 1, 2A). This anomaly was a complete defect with denser connective tissue on the sternal foramen. In cadavers (16), the distance from the skin to the posterior surface of the sternum

(thickness) was estimated at 15mm, with a variation of 12-20mm.

From the total amount of cadavers with sternal foramen, 62.5% (10/16) were leveled at the 4th sternochondral articulation and 38.5% (4/16) foramina were leveled at the 5th articulation (Fig. 2A). Of 14 analyzed dry bones, 64.2% (9/14) were located at the same level of the space between the 4th and the 5th costal pits, and 35.8% (5/14) were leveled at the 5th costal pit. The mean length of the longitudinal diameter of the foramen was 5.5mm, varying between 4.0-7.0mm. The mean cross diameter was 4.5mm, varying from 3.0-6.5mm.

In all cadavers that presented the sternal foramen (16), damage to the heart right ventricle by foreign bodies has occurred through trans-thoracic penetration with a needle, the correspondence between the sternal foramen and the heart being thus verified (Figs. 3A-C, 5).

DISCUSSION

The development and ossification of the sternum is well documented (Ashley, 1956; Pfeiffer, 1956; Riach, 1967; Cooper). During the fetal period, cells migrate from two lateral plates of mesoderm on either side of the anterior chest wall to fuse in the midline, forming the sternum by the 10th fetal week. McCormick & Nichols reported that ossification begins in manubrium and progresses to mesosternal (body) segments, presenting cranial to caudal development. The manubrium is reported to ossify first, in the 6th fetal month (Kozielec, 1973; Kim *et al.*, 1981; Orita *et al.*, 1985; O'Neal *et al.*, 1998). The mesosternum is reported to ossify in a craniocaudal direction, with ossification occurring first in segment 2 and last in segment 4. Ossification is reported to be present at birth (Kozielec; Kim *et al.*; Orita *et al.*; O'Neal *et al.*).

These congenital anomalies or anatomic variations in the anterior chest wall may involve malignancies, injuries and/or severe traumas (Donnelly *et al.*, 1999; Peuker *et al.*; Donnelly, 2001; Hecker *et al.*). Thus, some studies shows that asynchronous ossification of one of the superior four ossification sites may be suggestive of a number of disease processes (Kozielec; Kim *et al.*; Orita *et al.*; O'Neal *et al.*).

Several studies have stated that sternal segments 1-4 demonstrate ossification centers at birth. The timing of the xiphoid process or sternal segment 5 ossification varies much more, and the xiphoid process may remain non-ossified for years (Ashley; Pfeiffer; Riach; McCormick & Nichols; Rush *et al.*, 2002). McCormick & Nichols described the sternal foramen, and Cooper reported the development and morphology of the sternal foramen in this ossification site. Other chest wall anomalies have also been considered (Bergman *et al.*, 1988; McCormick, 1998; Ellis, 1989; Faro *et al.*, 1993; Lancaster *et al.*, 1995; Ontell *et al.*, 1997; Donnelly *et al.*, 1997).

The sternal foramen is a common congenital abnormality (incomplete fusion of the sternal plates). According to Peuker *et al.*, 7 cases of injuries to the heart and the pericardium have been described in scientific literature (Ye; Schiff; Nieda *et al.*, 1973; Cheng, 1991; Hasegawa *et al.*; Halvorsen *et al.*; Kataoka), among which 3 were fatal (Ye; Schiff; Halvorsen *et al.*), two of the fatal cases were caused by lack of awareness of the sternal foramen.

We observed, in our study, that 16.6% (30/180) of total specimens (cadavers and dry bones) presented sternal foramen. This percentual rate anomaly/total specimens is significantly higher than what we expected ($p \leq 0.0248$) (Fig. 4) and was previously reported (McCormick; Cooper *et al.*; Halvorsen *et al.*). Peuker *et al.* reported its existence in approximately 5-8% of the population. Cooper *et al.*, detected a sternal foramen in 6.7% of all autopsies they performed, and McCormick reported 7.7%. Although this author (McCormick) had demonstrated 25 sternal foramina in 324 cadaver's studies, Halvorsen *et al.* and Wolochow mentioned that the sternal foramina are noted in 9-6% men and 4-3% women.

Yamamura *et al.* analyzed 35 Brazilian adult cadavers, of which 27 were men, 8 women, and 5 dry bones. They noticed a higher percentage, 17.5% (7/40), compared to our results. However, we found sternal foramina in 16.6% (30/180), where these total of anomalies 53.3% (16/30) were found in cadavers (15 men and 1 women) and 46.7% (14/30) were found in dry bones. When compared to the results of Yamamura *et al.*, our results are approximately similar, and this reinforces the hypothesis that the percentual rate of sternal foramina could be higher in the Brazilian population.

Van-Marum & Te-Velde, pointed out that the prevalence of sternal foramen is estimated at 7% for the whole population. They could not find any data on the association of prevalence of sternal foramina with complications.

We observed that the sternal foramen presented as a complete defect with denser connective tissue on the foramen, and the distance from the skin to the posterior surface of the sternum presented a variation from 12-20mm, which is in accordance with Halvorsen *et al.*, and Wolochow, who had reported 13-19mm. This foramen can vary from a minor periosteal indentation to a complete defect, probably resulting from a congenital fusion abnormality (Ashley; McCormick & Nichols; Van-Marum & Te-Velde).

Regarding the sternal foramina diameter, our results are consistent to the results reported by McCormick; the sternal foramina were always single, usually from oval to circular shape, at the sternum midline level. The sternal diameters in our study are smaller than those reported by McCormick: longitudinal 4.0-7.0mm (mean 5.5mm) and transversal from 3.0-6.5mm (mean 4.5mm).

Schratter *et al.*, (1997) evaluated 100 chest CT scans and distinguished 4 types of these abnormalities, varying from incomplete retraction of the sternal cortex to complete foraminal defects. With reference to the incidence of sternal foramen and its features, they found 8% of incidence, and 6% presented a size sufficiently large to represent risks of complications during medical interventions.

The size of the foramen, compared to the caliber of acupuncture needles (0.20=0.40mm), is enormous, and the depth of the sternum is relatively small. Thus, the improper and inadvertent use of acupuncture needles (Reichmanis *et al.*, 1976; Nguyen & Recours-Nguyen, 1984; Chen; Hecker *et al.*) in the sternal region, at the 4th sternocostal articulation level or at the 4th parasternal intercostal space, can transfix the sternum (Fig. 3A) and cause an injury in the right ventricle of the heart (Figs. 3C, 5).

Of the total amount of cadavers with sternal foramen, we observed that 62.5% (10/16) were at the 4th sternochondral articulation level, and 38.5% (4/16) at the 5th articulation level. This means that, according to Hirata *et al.*, (1996), 62.5% corresponded to the Shangzong acupuncture point (CV 17) and, in 38.5% corresponded to the Zhongting acupuncture point (CV 16). Of the 14 dry bones analyzed 64.2% (9/14) were at the space between the 4th and the 5th costal pit level and 35.8% (5/14) foramen were at the 5th costal pit level. According to Peuker *et al.*, the sternal foramen is usually located at the level of the fourth intercostal space, i.e., precisely at the acupuncture conception vessel point 17 (CV 17).

For Wolfson *et al.*, (1986) these foramina are typically detected through roentgenograms, whereas to Halvorsen *et al.* and Peuker *et al.* it cannot be identified by standard chest

X-ray films. Using computed tomography (CT) scan, Stark (1985) found this variation in 4.8% of his sample.

Several risk factors have been considered (Hasegawa *et al.*; Rampes & James; Ernst; Peuker *et al.*; White; Hecker *et al.*), e.g., damage to the heart and great vessels through the foramina has occurred in transthoracic and abdominal penetration, as well as through the peripheral blood. In our study, damage to the anterior wall of the right heart ventricle through sternal foramen of cadavers was tested by transthoracic penetration with a needle and heart perforation of occurred in all cases (Figs. 3A-C).

Other traumas may occur in the heart, as the rupture of the anterior wall of the right ventricle by sternal puncture already described (Bichel *et al.*; Van-Marum & Te-Velde). Bichel *et al.*, collected 34 cases of fatal outcome, and some smaller series were published by others (Puschel *et al.*; Pascali *et al.*). The most frequently injury mentioned is puncture below the second intercostal space. Also, in most patients, the heart is below this level during inspiration. Puncture depth should not exceed 4mm. However, in contrast with these anatomical considerations, there were 34 cases of fatal cardiac tamponade (Van-Marum & Te-Velde). Pascali *et al.* suggested that the inexperience of the performing physician was the most relevant risk factor, whereas others related the complication to an inaccurate style guard adjustment.

The usual care observed while performing acupuncture in the conception vessel (VC), specifically in the Zhongting (VC 16) and Shangsong (VC 17) points, has been mentioned in all Traditional Chinese Medicine (TCM) textbooks (Reichmanis *et al.*; Nguyen & Recours-Nguyen; Xinnong, 1987; Chen) e.g., angulation of the needle (slightly at 45°), depth of insertion (usually 0.3-0.5 Cun = a Chinese measure equivalent to 1 inch). Once these requirements are met, the

consequent cardiac puncture will be avoided (Fig. 5), which could cause a cardiac tamponade (Hasegawa *et al.*; Halvorsen *et al.*; Wolochow; Yamamura *et al.*; Van-Marum & Te-Velde).

A large portion of complications and accidents that have been reported could have easily been avoided if the therapists had a basic knowledge in anatomy, and had considered the basic principles of any invasive form of therapy. In other words, these incidents can be attributed to incorrect application of the procedure during diagnosis and therapy. Still, the issue cannot be dismissed with the simple notion that acupuncture would probably be free of side effects if performed by a physician. It doesn't matter whether side effects are due to the procedure or its application. It is the duty of educational organizations and their teachers to point out these potential risks. In connection with the quality assurance required in acupuncture, it is necessary to conduct not only scientifically correct studies on its effects and effectiveness, but also conduct reliable studies on its adverse events and complications (Hecker *et al.*, 2005).

CONCLUSION.

Our results indicate that the sternal foramina is frequent in 16.6% of Brazilians cadavers and these percentages were significantly higher than expected of literature. In addition, the knowledge of this occurrence is important to avoid serious heart injury by needle insertion, especially since this area holds a commonly used acupuncture point and sternal puncture. This anatomical curiosity should be kept in mind by clinicians and resident medical students that may manipulate this anatomical area.

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RESUMEN: El objetivo del estudio fue verificar la prevalencia del foramen esternal en cadáveres adultos y huesos secos, así como, determinar su localización y su relación con los puntos de acupuntura. Fueron examinados 180 esternones fijados en solución de formol al 10%, 100 eran huesos secos y 80 pertenecían a cadáveres de individuos adultos. Las medidas morfométricas se expresaron en milímetros, efectuándose las siguientes mediciones: 1) desde la incisura yugular al foramen; 2) desde el ángulo esternal al foramen y 3) desde el proceso xifoides hasta al foramen. El análisis estadístico permitió comparar la frecuencia de los forámenes, usando el test de Fisher ($p \leq 0,05$). Los resultados mostraron la presencia del foramen esternal en 16,6% de los casos, siendo significativamente mayor a lo esperado ($p \leq 0,0248$). De los 30 forámenes, el 53,3% se encontró en cadáveres y en el 46,7% en los huesos secos. De los cadáveres con foramen esternal, 10 forámenes se encontraban a nivel de la 5ª articulación esternocostal y 6 a nivel de la 4ª articulación esternocostal. De los 14 forámenes de los huesos secos, 9 forámenes se encontraban entre el 4 y el 5º espacio intercostal y 5 se localizaban a nivel del 5ª articulación. La longitud total del esternón fue $151,8 \text{ mm} \pm 34$ y las medidas desde la incisura yugular al foramen, desde el ángulo esternal al foramen y desde el proceso xifoides hasta al foramen fueron, $103,8 \pm 22,1 \text{ mm}$, $65,6 \pm 15 \text{ mm}$ y $46,9 \pm 15 \text{ mm}$, respectivamente. El conocimiento de este hecho es importante para evitar la lesión cardíaca grave por la inserción de agujas, ya que esta zona tiene un punto de acupuntura de uso común en la punción esternal.

PALABRAS CLAVE: Anatomía; Cadáveres; Variaciones; Foramen esternal; Acupuntura.

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