



Multidetector computed tomography (MDCT) estimation of prevalence and anatomic characteristics of the sternal body foramen in the population of central Serbia

Procena učestalosti i anatomskih karakteristika otvora tela sternuma u populaciji centralne Srbije pomoću multidetektorske kompjuterizovane tomografije (MDCT)

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Abstract

Background/Aim. The most frequent form of sternal defects is a single foramen, usually located at the distal half of the sternal body, with prevalence that varies among different ethnic populations. Clinical importance of these defects arises from various diagnostic and therapeutic sternal treatments and close location of heart, lungs and other vital organs of the chest cavity. The aim of this study was to determine the prevalence and morphometric characteristics of the sternal midline foramen in the population of central Serbia. **Methods.** The multidetector computed tomography (MDCT) chest images of 422 patients of both genders were analyzed. The radiological imaging was performed on 64-slice MDCT scanner (Aquilion 64, Toshiba, Japan). All scans were performed in the axial plane, with subsequent multiplanar reconstruction (MPR). Due to the angulation of the sternal body coronal curved-planar, the images were obtained in order to show the whole length of the sternum and the vertical diameter of the sternal foramen. The measurements were done using the commercially available soft-

ware (Imaging Software ver. 4.1.14.0, Vital-Images). **Results.** The solitary foramen, located in the distal segment of the sternal body, was detected in 24 patients, representing 5.9% of the observed population with slightly higher prevalence in males. The average size of foramen was 3.9×4.2 mm. The mean distance from the skin was 12.7 ± 3.3 mm, the distance from skin to pericardium was on average 37.3 ± 8.2 mm, while the average distance from skin to pleura was 25 ± 5.9 mm. The average depth of foramen 8.7 ± 2 mm, while the mean distance from the posterior surface of foramen to pericardium was 12.7 ± 9.1 mm. **Conclusion.** The results presented in this paper confirmed the prevalence of 5.9% regarding the midline sternal foramen in the observed population. Serious complications of the sternal puncture could be prevented by prior MDCT imaging.

Key words: sternum; musculoskeletal abnormalities; multidetector computed tomography; prevalence; sternotomy; risk assessment; serbia.

Apstrakt

Uvod/Cilj. Jedna od najučestalijih anatomskih anomalija sternuma je otvor, najčešće jedan, obično lociran u donjem delu tela grudne kosti. Učestalost ove malformacije sternuma varira u zavisnosti od ispitivane etničke populacije. Klinički značaj ot-

vora tela sternuma proizilazi iz činjenice da se obično nalazi u neposrednoj blizini srca, pluća i drugih vitalnih organa grudne duplje, kao i mogućnosti nastanka po život opasnih komplikacija, usled povrede ovih organa, prilikom dijagnostičkih i terapijskih procedura na sternumu. Cilj ovog istraživanja bio je da se utvrdi učestalost i morfometrijske karak-

teristike otvora tela grudne kosti u populaciji centralne Srbije. **Metode.** U studiji su analizirani snimci multi-detektorske kompjuterizovane tomografije (MDCT) grudnog koša kod 422 pacijenata oba pola. Pregledi su obavljani na 64-slaisnom MDCT aparatu (Aquilion 64, Toshiba, Japan). Sva skeniranja su izvršena u aksijalnoj ravni, uz naknadne multiplanarne rekonstrukcije (MPR). S obzirom na angulaciju sternuma u predelu tela korišćene su kose koronalne ravni da bi se prikazala cela dužina sternuma, kao i visina sternalnog foramena. Merenje je izvršeno upotrebom komercijalno dostupnog softvera (Imaging Software ver. 4.1.14.0, Vital-Images). **Rezultati.** Otvor tela grudnog koša, lociran u distalnom segmentu tela sternuma uočen je kod 24 pacijenta, odnosno sa učestalošću od 5,9% u ispitivanoj populaciji, a sa nešto većom učestalošću kod muškaraca. Prosečne dimenzije otvora bile su $3,9 \times 4,2$ mm.

Srednja vrednost udaljenosti kože do otvora iznosila je $12,7 \pm 3,3$ mm, udaljenosti kože do perikarda $37,3 \pm 8,2$ mm, dok je prosečno rastojanje od kože do pleure iznosilo $25 \pm 5,9$ mm. Prosečna dubina otvora iznosila je $8,7 \pm 2$ mm, dok je srednja vrednost rastojanja od zadnje ivice otvora do perikarda iznosila $12,7 \pm 9,1$ mm. **Zaključak.** Studijom je utvrđena učestalost otvora tela grudne kosti od 5,9% u ispitivanoj populaciji. MDCT pregledi grudnog koša, koji prethode intervencijama na grudnoj kosti, mogu biti od značaja za prevenciju komplikacija punkcije sternuma.

Ključne reči:

sternum; mišićno-skeletne anomalije; tomografija, kompjuterizovana, multidetektorska; prevalenca; rizik, procena; srbija.

Introduction

The human sternum is the flat bone of the anterior thoracic wall, adjacent to pleura, pericardium and the great vessels of thoracic cavity. Embriologically, sternum is composed of two mesenchymal bars that are merged in the median line to form a pre-cartilage sternal lamina, divided into three parts: manubrium, corpus sterni and xiphoid processus. Any deviation from this process may form various sternal defects, including clefts, fissures and sternal foramina^{1,2}.

Prevalence of these sternal defects may differ in various countries and is generally believed to vary between 2% and 8% in the general population³, although it is reported to be as high as 13.8%⁴. The most frequent form is a single sternal foramen, usually located at the distal half of the sternal body, at the level of the fourth or fifth intercostal space^{2,5}.

The clinical importance of these defects arises from the sternal punctures, acupuncture treatment and close location of heart, lungs and other vital organs of the chest cavity⁶. The most serious complications are heart tamponade⁷ and puncture of the ascending aorta⁸.

The current study is undertaken in order to ascertain the frequency, morphometric characteristics of the sternal body foramen and its distance from the adjacent organs of thoracic cavity, analyzing the multi-detector computed tomography (MDCT) images in the population of central Serbia.

Methods

The study was designed as a retrospective descriptive non-randomized observational study, that used data from MDCT patients' chest images archived in the hospital information system for data archiving (PACS). The patients were examined at the Department of Diagnostic Radiology, Clinical Center of Kragujevac, Serbia in the period from January 2016 to September 2016. The radiological imaging was performed on the 64-slice MDCT scanner (Aquilion 64, Toshiba, Japan). All scans were performed in the axial plane, with subsequent multiplanar reconstruction (MPR). Due to the angulation of the sternal body coronal curved-planar, the images were obtained in order to show the whole length of

the sternum and the vertical diameter of the sternal foramen. The scope of the thoracic scan examination was from thoracic inlet to the level of the adrenal glands, including the sternum in the field of scanning. The study included 422 patients (222 male and 200 female) aged from 21 to 80 years, without sternal deformities and pathological changes, which are referred to this examination for various reasons. The patients with sternal deformities, trauma or prior the sternal surgery, tumor changes of the sternum and younger than 20 years of age were excluded from the study. The patients who underwent chest imaging in the indicated period more than one time, were included in the study only once.

The MDCT examination was conducted in the native and post-contrast series, after intravenous injection of a contrast medium. The scanning parameters were: 120 kVp, mAs 90–120, gantry rotation of 0.75 sec, pitch 0.5 mm, slice thickness of 0.5 mm and 0.6–0.8 mm thickness reconstruction. The analysis of all images and MDCT data are performed on the Vitrea 2 workstation ver. 4.1.14.0 (Vital Images). All measurements were done by two independent radiologists, the experts in this field, using the commercially available software (Imaging Software ver. 4.1.14.0, Vital-Images). The measured values are given in millimeters. For the evaluation of inter-observer reliability, the intra-class correlation coefficient (ICC) was used and $ICC > 0.8$ was considered as an excellent agreement.

The obtained results were statistically analyzed according to gender. The analysis was done by using the statistical program (IBM SPSS Statistics 20) and included descriptive and analytical methods. Normality of data distribution was tested by the Kolmogorov-Smirnov test. The Student's *t*-test was used for a comparison of normally distributed data and the Mann-Whitney test was applied to the analysis of the variables which were not normally distributed. The level of a statistical significance was set at 0.05.

Results

The solitary foramen, located in the distal segment of the sternal body, was detected in 24 patients, representing 5.9% of the observed population (Figure 1). The presence of

the sternal foramen showed tendency of increasing with age. The average age in the group with detected foramen was 63.5 ± 7.5 years (63 ± 8.8 in the males and 64.3 ± 5.5 in the females). This developmental variant of sternum was usually oval-shaped and its transverse diameter varied in range from 1.7 to 10.6 mm. The mean width was 3.9 ± 1.9 mm, while the mean vertical diameter of the observed sternal foramen was 4.2 ± 1.7 mm and ranged from 2.5 to 8.4 mm. The sternal foramen was found in 14 males, representing 6.3% of male or 3.3% of all study participants. In females, this sternal variant was found in 10 of them, which was 5% of our female participants or 2.4% of whole study group. The males represented 58.3% and females 41.7% of the participants with the midline sternal foramen. The diameters of the detected sternal foramen in the males and females are given in Table 1.

The mean distance from the skin was 12.7 ± 3.3 mm (12.9 ± 3.4 in the males and 12.5 ± 3.4 in the females). The distance from skin to pericardium was on average 37.3 ± 8.2 mm in the whole observed population, with mean of 38.9 ± 8.9 mm in the males (ranged from 25.1 to 58.3 mm) and 35.1 ± 7 mm (ranged from 22.6 - 44.8 mm) in the females. In 6 males and 5 females, it was found that pleura was adjacent to the sternal foramen and the mean value of the distance from skin to pleura in the males was 25.7 ± 6 mm and 24.2 ± 6.4

mm in the females. The average value for both genders was 25 ± 5.9 mm.

The average depth of the foramen was 8.7 ± 2 mm, with the mean value of 8.5 ± 2.1 mm in the males and 8.9 ± 1.9 mm in the females. The mean distance from the posterior surface of foramen to pericardium was 12.7 ± 9.1 mm with a statistically significant gender difference as well as the distance from the skin to pericardium (Table 1).

Discussion

Importance of better knowledge of the anatomical variations has been pointed out among the anatomist and clinicians during the last decades. These structural fluctuations are often combined and ethnically different^{6, 9, 10}. A good knowledge of human morphology is necessary for the proper interpretations of radiological images and diagnosis as well as planning of medical interventions. It is also important for the proper conclusions in pathology and forensic medicine¹¹.

The fluctuations of morphology of the anterior thoracic wall are not rare and are always interesting as potential clinical problems. They include the variations of sternum and the ribs as well as the joints of the thoracic wall caused by the aberrant development^{9, 11}.

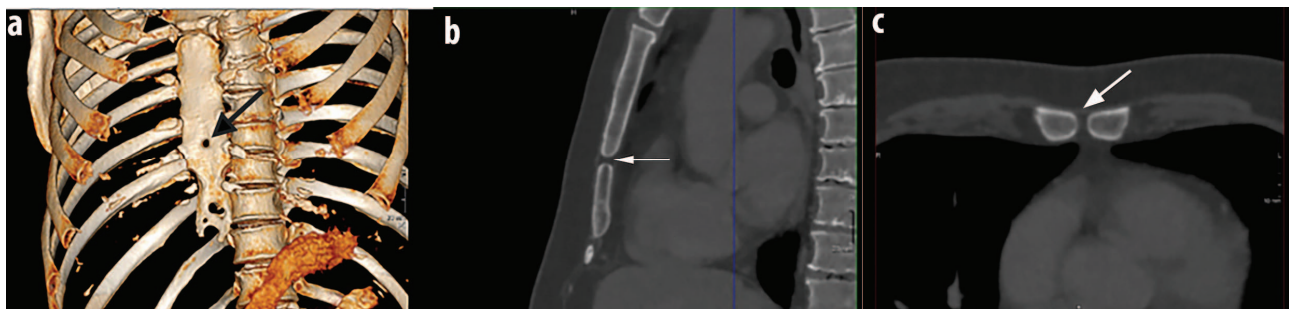


Fig. 1 – The foramen of the sternal body (marked by arrow): a) 3D reconstruction; b) multiplanar (MPR) sagittal reconstruction; c) MPR axial reconstruction.

Table 1

The morphometric characteristics of a single sternal body foramen (the measures are given in mm)

Foramen of the sternal body	Male	Female	Both gender
Transverse diameter, mean \pm SD	4.0 ± 2.3	3.7 ± 1.2	3.9 ± 1.9 $p > 0.05$
Vertical diameter, mean \pm SD	4.1 ± 1.9	4.3 ± 1.4	4.2 ± 1.7 $p > 0.05$
Foramen depth, mean \pm SD	8.5 ± 2.1	8.9 ± 1.9	8.7 ± 2.0 $p > 0.05$
Skin – foramen distance, mean \pm SD	12.9 ± 3.4	12.5 ± 3.4	12.7 ± 3.3 $p > 0.05$
Skin – pleura distance, mean \pm SD	25.7 ± 6.0	24.2 ± 6.4	25.0 ± 5.9 $p > 0.05$
Skin – pericardium distance, mean \pm SD	38.9 ± 8.9	35.1 ± 7.0	37.3 ± 8.2 $p < 0.05^*$
Foramen (posterior surface) – Pericardium distance, mean \pm SD	13.1 ± 8.9	10.3 ± 7.3	12.7 ± 9.1 $p < 0.05^*$

*statistically significant gender difference; SD – standard deviation.

Table 2
The comparison of the prevalence of midline sternal foramen to the findings of the previous studies and in the different populations

Study	Population	Sample size	Data / methodology	Prevalence of the midline sternal foramen		
				Male (% of male sample)	Female (% of female sample)	Total study sample (%)
Schratter et al. ¹⁶	Austrian	100	CT	No data	No data	6
Cooper et al. ¹⁷	USA	2016	Postmortem radiographs	68.9 (6.9)	31.1 (6.2)	6.7
Gossner ⁶	German	352	CT	62.5	37.5	4.5
Paraskevas ¹⁸	Greek	60	Dried sterna	100	/	5
Aktan and Savas ²⁰	Turkish	350	CT	63.2 (6.9)	36.8 (4)	5.4
		62	Dried sterna	No data	No data	3.2
Yekeler et al. ³	Turkish	1000	MDCT	No data	No data	4.5
Babinski et al. ²²	Brazilian	180	Cadavers; Sceletons	93.75 No data	6.25 No data	16.6
Babinski et al. ²³	Brazilian	114	MDCT	58.3 (13.5)	41.7 (8.1)	10.5
Singh and Pathak ²⁴	Indian	343	Cadaveric	80.5 (13.1)	19.5 (8.8)	11.9
El-Busaid ⁴	Kenyan	80	Dried sterna	No data	No data	11.2
Macaluso and Lucena ¹¹	Spanish	122	Postmortem radiographs	100 (6.1)	/	3.3
Ishii et al. ²⁵	Japanese	1053	MDCT	No data	No data	3.1
Present	Serbian	422	MDCT	58.3 (6.3)	41.7 (5)	5.9

CT – computed tomography; MDCT – multidetector computed tomography.

During the embryological development, the body of sternum consists of 4 segments (sternabrae) in the form of two cartilaginous sternal bars which migrate to the midline to be fused in cranio-caudal direction ^{2,12}. The failure in fusing of the sternal bars or later ossification process results in defects such as foramina of the sternal body, manubrium or xiphoid process, sternal clefts, or the combinations of these ^{3,6,13}. The sternal variations and aberrant morphology may have clinical implications regarding normal functions of internal organs. They also may be associated with heart and lung abnormalities ¹⁴. The solitary perforations of the sternal body are common along the midline and are known as the sternal midline foramina ¹⁵.

Several earlier studies of different ethnic populations were focused on the prevalence and morphometry of the sternal midline foramina (Table 2). Similar to our results are those from the CT study conducted in Austria, with a diameter of the sternal body foramen ranging from 3 to 12 mm ¹⁶.

The prevalence of commonly single, round to oval sternal body foramen, with a diameter range from 3–10 mm, was slightly higher in a large cadaveric study conducted in the USA. In this study, this anatomic malformation was less frequent in the participants of white race (5.76%) and the hispanic population (5.84%) and with higher prevalence among the Afro-American population (9.01%). As expected, the most of these sternal variants are found in the elderly population group. The multiple sternal foramina were also described as well as the elongated ones ¹⁷.

The sternal body foramen was found on the CT scans in the German population ⁶ with lower prevalence in compari-

son to our study, while its mean width was similar (3.3 mm in the German population versus 3.9 mm in the Serbian population). It was emphasized that the practitioners may be aware of serious complications that may occur due to the presence of the sternal foramina and that the knowledge of the distance from the skin to pericardium may be helpful for a safe needle insertion, with conclusion that the sternal puncture with a needle inserted up to 2.5 cm is not life-threatening ⁶. The average skin-pericardium distance that we found was greater than this, but the minimal one was 22.5 mm. The pericardium was adjacent to the foramen in 2 cases of our study (8.3%), while the lungs were adjacent in 45.8% cases (versus 53.3% in German study ⁶) with skin-pleura distance ranging from 19.6 mm to 35.7 mm. The mediastinal fat adjacent to the sternal foramen was observed in 15 patients whose CT images we analyzed (62.5%), which is higher than in German population (33.33%) ⁶.

The slightly lower prevalence of midline sternal foramen was found in the Greek cadaveric study, while the diameters were similar to those that we observed. In their study sample, the number of sternal foramina was from one to five. The foramen of the sternal body was always single, while the multiple foramina were detected on the xiphoid process ¹⁸. However, the same authors in their earlier case report, described the sternal body foramen in a combination with the foramen of the xiphoid process ¹⁹. We did not find similar case in our study.

The CT study conducted in the Turkish population found the sternal midline foramen in both genders, with prevalence similar to one found in our population. Their

study also included the prepared sternal bones sample and the midline sternal foramen was found only in 2 of 62 cases²⁰. In another Turkish study, the MDCT images were evaluated and the prevalence of the midline body foramen was lower. Among the other variants and defects of sternum, the foramen with a common localization in the distal half of the sternal body, had the mean diameter of 6.5 mm (ranging from 2 to 16 mm) which was higher than in other studies. In one case, it was associated with the sternal cleft in its continuation, while 73% of participants with the sternal body foramen had sclerotic band superior or inferior in its continuation³. A case of similar keyhole-shaped defect of sternum, as the foramen of the most distal part of the sternal body with continuation in the form of the xiphoid cleft, was described in a study of Saccheri et al.²¹.

The analysis of cadaveric and dry sternal bones in Brazilians estimated the presence of the sternal midline foramen, with the highest prevalence in comparison to other studies, with the most common localization in the level of fourth costal notch of sternum. These foramina were solitary and round to oval in shape, as ones found in our study. The mean longitudinal and transverse diameter was also higher than we described²². Another study included MDCT images of the Brazilian patients of both genders and the sternal foramen was also highly prevalent, slightly more in females. The distribution among the gender groups was similar to our study while the mean distance and the range of distance from the skin to pericardium was equal²³.

The study conducted among the Indian population included the sternal samples of both genders, collected and analyzed postmortem, and revealed the high prevalence of the midline sternal foramen. It was higher in males than in females, with a tendency of increasing with age, which was also observed in our study, probably because of the increased muscle markings in the elderly²⁴. The higher prevalence of the sternal body foramen with the common localization in the 5th intercostal segment was also found in the Kenyan population⁴.

The percentage of the sternal body foramen that we found is higher in comparison with one found in a Spanish forensic study that described those foramina as solitary, size-variable, round to oval, located in the distal part of the sternal body that is similar to our findings¹¹. Contrary to our observation, all cases with the sternal foramen were males. The lower prevalence was also found in the CT study conducted among the Japanese population, where the mean diameter was 5.3 mm²⁵.

Several case reports described the occurrence of the sternal midline foramen. Bermio and Hemalatha² described 5 × 6 mm sternal body foramen in the level of the junction of the third and fourth sternbrae. A case of a round, 18.75 ×

12.50 mm large foramen of the distal half of a sternal body, found during autopsy, was also described by Jakhar et al.¹⁴. Another single large sternal foramen, with dimensions of 11.4 × 20.8 mm was described in a case report from India²⁶.

These variations are usually asymptomatic and observed during the radiological and forensic examinations or autopsy^{19,23}. However, they may be a serious risk factor for the severe complications that may occur during the sternal biopsy or acupuncture, considering the fact that the pleura, pericardium or great vessels are adjacent to the sternum^{6,23}. The bone marrow aspiration, that is often performed on sternum, may be complicated by unwanted needle penetration through the sternal foramen leading to pneumothorax, cardiac tamponade, or hemorrhage due to laceration of aorta^{4-6,21,27-30}. According to some studies, in 80% of cases, the pneumothorax and cardiac tamponade could be a result of needle insertion through the sternal foramen^{6,18}. Although rare, infections of internal organs, were also reported as a complication of acupuncture, in the presence of the sternal foramina²³. Regarding that, the biopsy of iliac crest, in order to perform a bone marrow aspiration, when possible, is considered to be safer. The clinicians must be aware of these unwanted possibilities, their asymptomatic character and difficult visibility on radiographs as well as the fact that these foramina are not palpable. Considering all above, the preventive ultrasound or CT images are recommended before the sternal biopsy or acupuncture procedures^{6,16,31}. Also, these procedures should be performed in the proximal part of sternum, because common localization of the sternal foramina in the distal half of the sternal body³.

Awareness of the possibility of the sternal variations is also important for the proper conclusions in forensic medicine or pathology, because these perforations could incorrectly be considered as gun wounds and injuries caused before death or the osteolytic lesion^{20,31}.

Conclusion

The results presented in this paper confirmed the prevalence of 5.9% of the midline sternal foramen in the observed population, that is in accordance with the findings of the most similar studies conducted in another ethnic groups. The similarity is the most pronounced with those conducted in the Caucasian race, as expected. The existence of the anatomical sternal variations, usually asymptomatic, and its vicinity to the vital organs must not be ignored and the practitioners as well as forensics must be aware of such a possibility. Considering that, the preceding MDCT imaging could prevent serious complications of the sternal puncture.

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