Surg Radiol Anat (2016) 38:991–993
DOI 10.1007/s00276-016-1663-4

ANATOMIC VARIATIONS

Double sternal foramina in a dried sternum: a rare normal variant and its radiologic assessment

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Received: 19 October 2015 / Accepted: 3 March 2016 / Published online: 17 March 2016

Abstract Sternal foramina (SF) constitute developmental defects of the sternum and are usually radiologic or post-mortem accidental findings. A rare case is presented, concerning the dried sternum of Greek origin and unknown age. The manubrium, sternal body and xiphoid process were fused and ossified, while two SF of undocumented size were present. The proximal SF was located at the sternal body extending between the fourth and fifth intercostal spaces, whereas the distal SF was located at the xiphoid process being surrounded by a thin "ring-like" osseous rim. Computed tomography was utilized for further investigation. Awareness of this variation is essential for the radiologist to avoid misdiagnosis and interpret with accuracy the current combination of normal anatomic variants. Moreover, SF existence is associated with clinical and forensic implications that are shortly discussed.

Keywords Sternal · Foramen · Foramina · Dried sternum

Introduction

Sternal foramina (SF) are congenital defects of the sternum, located mainly in the inferior portion of the sternal body and the xiphoid process [1–6]. Their formation results from incomplete fusion of the sternal ossification centers. They are usually asymptomatic and constitute accidental findings during radiologic evaluation or skeletal anthropologic studies. However, their presence could cause complications during sternal puncture and be misleading for the radiologist and forensic in case of unawareness. Computed tomography (CT) has been proven irreplaceable to recognize and locate the variation.

In this article, an extremely interesting and rare case of SF variant is discussed, concerning an osseous finding of skeletal remnants. The aforementioned sternum displayed two SF of undocumented size combined together; CT scanning was also used as a method for further investigation. The radiologic assessment of such a normal anatomic variant as well as the relevant literature is briefly reviewed.

Case report

While examining the macerated skeleton of a male cadaver of Greek origin and unknown age, an interesting variation of the sternum was observed. The manubrium, sternal body and xiphoid process were ossified and fused, while two distinct large SF were present. A metric electronic digital caliper (Mitutoyo Co., Japan) was used for measurements. The proximal SF was encountered at the fourth and fifth intercostal segments, whereas the distal one was located at the xiphoid process and was surrounded by an osseous circumference between 3.5 and 11.6 mm in width. The transverse and vertical diameter were 6.3 × 12.7 mm for the SF located at the sternal body and 18.6 × 11.9 mm for the xiphoidal SF (Fig. 1). No other pathologies or variants of the osseous elements of the thoracic skeleton were detected.

Radiologic evaluation of the sternum was also obtained using CT scanning (multislice spiral CT scanner, with 3 mm axial slice thickness) to demonstrate the skeletal variant in detail. The axial section at the SF levels showed

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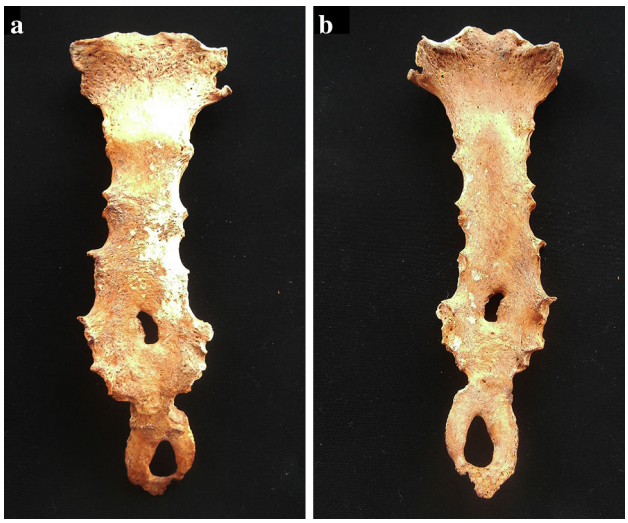

Fig. 1 The *anterior* (**a**) and *posterior* (**b**) aspects of the osseous specimen are presented. The manubrium, sternal body and xiphoid process are ossified and fused. Two sternal foramina are found in the body (fourth and fifth intercostal spaces) and the "*ring-like*" xiphoid process

a "bow-tie" formation at the level of the SF located at the sternal body (Fig. 2a), and an irregular osseous deficit at the xiphoidal one (Fig. 2b). During sagittal reconstruction, the SF were presented as defects in the continuity of the sternum (Fig. 2c), while during coronal reconstruction, the SF located at the body of the sternum was distinctively visualized surrounded by mild sclerotic area (Fig. 2d).

Discussion

SF constitute developmental defects of the sternum, with oval, circular or irregular shape. Even though they are considered solitary variations, co-existence with other developmental anomalies such as supernumerary left lung lobules and fissures has also been documented in the literature [7]. SF are found more usually than it is believed, as SF are documented in the literature with an incidence varying from 3.1 to 57.7 % including studies concerning only the anatomy of the xiphoid process [1–12]. In Greek population, SF were observed in 18.3 %, while no specimen of this origin has been documented presenting double SF of this size in the body and the xiphoid process, as the case reported [5].

SF may be found in the manubrium [9, 10] the sternal body or the xiphoid process. Multiple SF have also been reported in the literature, located at the sternal body [10] and mainly at the xiphoid process [5, 6, 8]. Most investigators suggest that SF are more often found at the lower sternal body and xiphoid process [1–6], whereas co-existent of SF with sternal cleft and "keyhole formation" of the xiphoid process has been documented [5, 6, 9]. In the current case, the oval shaped xiphoidal SF led to a "ring-

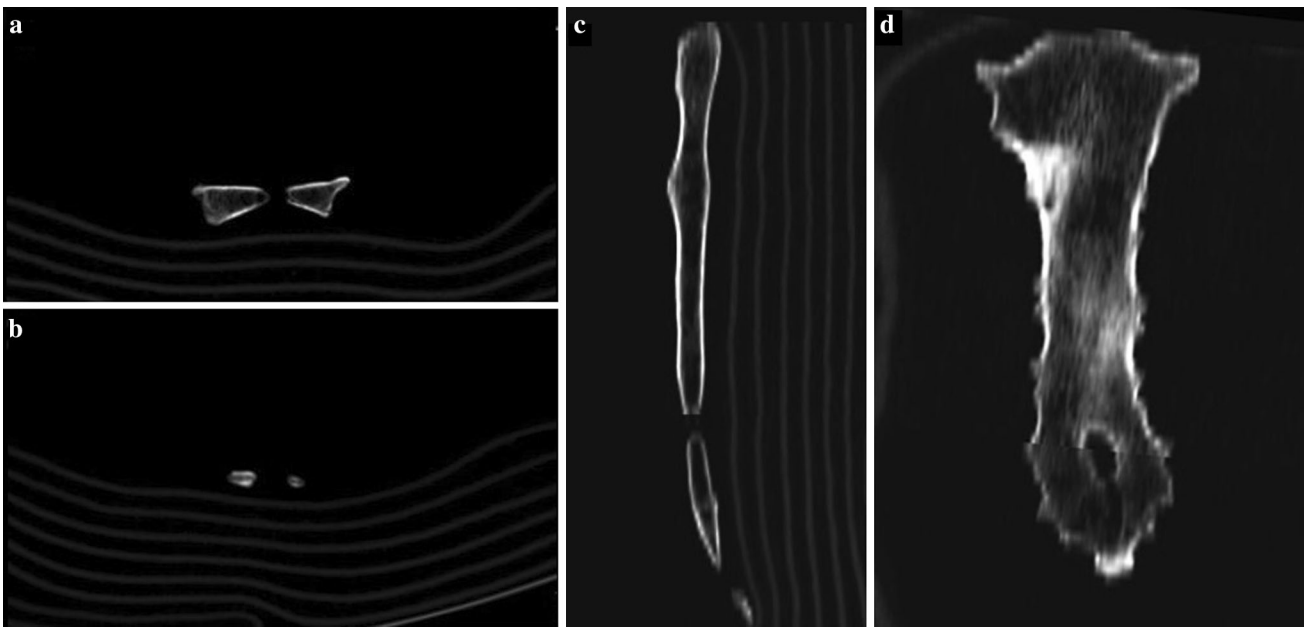

Fig. 2 Radiologic evaluation of the sternum using computed tomography. The axial sections present a "bow-tie" defect at the level of the sternal foramen located at the body (**a**) and an irregular one at the xiphoidal foramen (**b**). During sagittal (**c**) reconstruction the sternal foramina are visualized as discontinuation of the sternum, while during coronal (**d**) reconstruction, the oval defect surrounded by mild sclerosis represents the sternal foramen of the body

like" formation of the xiphoid process (Fig. 1) and the specimen may be classified as type II with an L pattern, according to Xie et al., found in 14.9 % of the xiphoidal SF studied [12].

As mentioned before, SF are asymptomatic and mainly constitute accidental findings during radiologic or post-mortem evaluation. Nevertheless, unawareness of this variation could lead to misdiagnosis and complications especially during sternal puncture. Knowledge of this unrare variation is of great importance for the radiologist, as presence of SF could lead to misdiagnosis and the assumption of present sternal pathology. SF are usually visualized by CT as "bow-tie" formations in axial sections, however in the discussed case the xiphoidal SF was shown as an irregular defect (Fig. 2b). The osseous defect is better demonstrated during saggital and coronal reconstruction (Fig. 2c, d). It should be noted that in cases of SF smaller than the slice thickness, the variant may not be visualized [5].

Moreover, during scintigraphy and single photon emission tomography, SF are represented as areas of hypocaptation. In the study of Ishii et al. [2], cases of photopenic sternal areas were evaluated using multidetector CT scanning. Interestingly, the authors concluded that 43.1 % of the cases presenting hypocaptation were correlated to SF, while approximately a quarter of the total SF were not visualized with bone scintigraphy. Sternal biopsy in cases of located hypocaptation may be hazardous if the possibility of SF existence is not excluded [2].

Due to the proximity of SF located at the body of the sternum to vital structures of the thoracic cavity, sternal puncture could result in severe complications in cases of SF presence. After studying fifteen cases of SF situated at the body of the sternum using CT scanning, Gossner found that the SF were adjacent to the lung and the pericardium in 53.3 % and 20 %, respectively [11]. Fatal cases of cardiac tamponade have been documented in the literature, following sternal bone marrow aspiration and acupuncture [13, 14]. Thus, to avoid unnecessary risk, radiologic assistance, including ultrasonography could be utilized during sternal puncture [5, 11].

In case where the existence of SF has been established, this information should be recorded in the patient's records. Awareness is important to avoid potential complications during sternal puncture, as well as forensic implications. Besides the fact that the sternal defect could complicate the investigation of cause of death, as it may resemble a bullet-entry point or an osteolytic lesion [3, 10] knowledge of this personal trait may also assist in the forensic investigation for identification of skeleton remains, especially in unique cases as the one under discussion [4].

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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