

Anatomic evaluation of the xiphoid process with 64-row multidetector computed tomography

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Abstract

Objective The aim of this study was to evaluate the interindividual variations of the xiphoid process in a wide adult group using 64-row multidetector computed tomography (MDCT).

Materials and methods Included in the study were 500 consecutive patients who underwent coronary computed tomography angiography. Multiplanar reconstruction (MPR), maximum intensity projection (MIP) images on coronal and sagittal planes, and three-dimensional volume rendering (VR) reconstruction images were obtained and used for the evaluation of the anatomic features of the xiphoid process.

Results The xiphoid process was present in all patients. The xiphoid process was deviated ventrally in 327 patients (65.4%). In 11 of these 327 patients (2.2%), ventral curving at the end of the xiphoid process resembled a hook. The xiphoid process was aligned in the same axis as the sternal corpus in 166 patients (33.2%). The tip of the xiphoid process was curved dorsally like a hook in three patients (0.6%). In four patients (0.8%), the xiphoid process exhibited a reverse S shape. Xiphoidal endings were single in 313 (62.6%) patients, double in 164 (32.8%), or triple in 23 (4.6%). Ossification of the cartilaginous xiphoid process

was fully completed in 254 patients (50.8 %). In total, 171 patients (34.2%) had only one xiphoidal foramen and 45 patients (9%) had two or more foramina. Sternoxiphoidal fusion was present in 214 of the patients (42.8%).

Conclusions Significant interindividual variations were detected in the xiphoid process. Excellent anatomic evaluation capacity of MDCT facilitates the detection of variations of the xiphoid process as well as the whole ribcage.

Keywords Xiphoid bone · Tomography · Spiral computed · Individual differences

Introduction

Morphology of the xiphoid process, the smallest part of the sternum, might demonstrate significant interindividual variations although it is presented in anatomy textbooks to be a flat and totally ossified single ending bone with one foramen and no deviation. The xiphoid process is included in the sectional imaging of thoracic and abdominal regions during daily radiology routine and its variations might be detected incidentally.

The xiphoid process articulates superiorly with the inferior border of the sternal corpus and affords attachment to the medial fibers of the rectus abdominis muscle and aponeuroses of the external and internal oblique muscles anteriorly, with linea alba inferiorly, and with diaphragmatic slips posteriorly. Ossification of the cartilaginous xiphoid process generally starts from proximal portion at about the age of three [1].

Studies in the literature are mainly based on autopsy series. There are studies in radiology the literature evaluating the variations of the sternum and its parts with direct

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radiography, CT, and magnetic resonance imaging [2–8]. Moreover, ultrasonography features of prominently long and ventrally deviated xiphoid processes, which might be the reason of a pseudomass in the epigastric region, are also presented [9–11]. However, according to our knowledge, there is no dedicated study investigating the frequency of the positional variations of the xiphoid process specifically in a wide patient population in the literature. Therefore, the aim of this study was to examine morphologically the dimension, shape, position, and ossification features of the xiphoid process, existence of xiphoidal foramen, sternoxiphoidal fusion, and sternoxiphoidal pseudoforamen in an adult population using 64-row MDCT.

Materials and methods

The study protocol was approved by the institutional review board and informed consent was obtained from the patients who enrolled in the study.

Between July 2008 and March 2010, a total of 577 consecutive patients who underwent coronary CT angiography participated in the study. A total of 77 patients were excluded from the study group, 45 of whom had a history of coronary bypass surgery and 32 had poor image quality. MDCT images of 500 adult patients (373 men and 127 women; age range 18–90 years; mean age, 52 years) were evaluated retrospectively to detect anatomical variations of the xiphoid process. There was no specific disease in these patients involving the xiphoid process.

MDCT imaging was performed with a 64-row MDCT scanner (Philips Brilliance 64; Philips Medical System, Best, Netherlands). A breath-hold helical CT scan was obtained with intravenous injection of contrast medium using the following parameters: 120 kV, 600–1,050 mAs, 400-ms tube rotation time, 64×0.625 mm collimation, and 0.67-mm minimum slice thickness.

In all subjects, axial thin slice source images were recalled from Picture Archiving Communications System (PACS) and loaded to a commercial workstation (Philips Extended Brilliance Workspace; Philips Medical Systems).

All data were analyzed with post-processing tools; and MPR and MIP images on coronal and sagittal planes, coronal curved MIP images were obtained and three-dimensional VR were acquired. Reconstructed images were evaluated in consensus by two radiologists (KA, DK) with 10 and 7 years of experience in CT interpretation, respectively. The following morphological features of the xiphoid process were evaluated including length, width, thickness, existence and location of ossification, ending pattern, existence of xiphoidal foramen, sternoxiphoidal fusion, and sternoxiphoidal pseudoforamen. The alignment between the axis of the xiphoid process and the sternum

were respectively evaluated in the sagittal view without regarding the relation of the sternum to the ribcage. A line uniting the middle and distal portions of the sternal corpus to the end of the xiphoid process was drawn for evaluation. The xiphoid process ending anterior to this line was noted to be ventrally deviated, and posterior to this line was noted to be dorsally deviated. The xiphoid process ending in the same or nearly the same axis with this line was noted to be not deviated.

Results

The xiphoid process was present in all patients.

Xiphoidal dimensions Mean length of the xiphoid process was 50 mm (range 20.6–81.5 mm), mean width was 22 mm (range 6.5–46.7 mm), and mean thickness was 7.3 mm (range 3.6–18.1 mm).

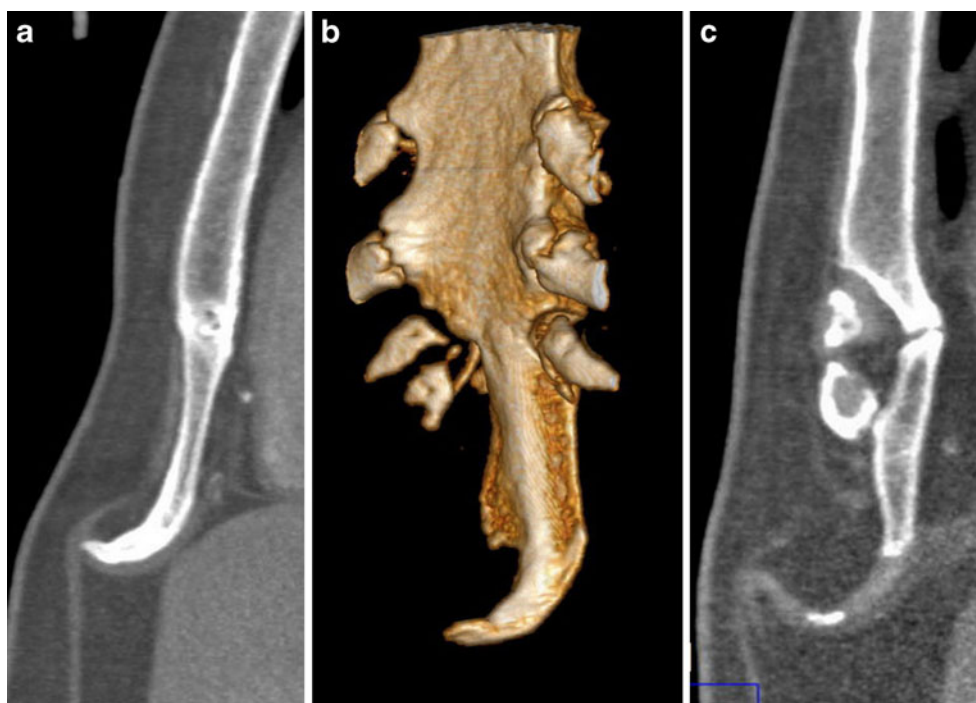
Positional variations The xiphoid process was ventrally deviated in 327 patients (65.4%) (Fig. 1). Ventral curving at the end of the xiphoid process resembling a hook accompanied ventral deviation in 11 of these 327 patients (2.2%) (Fig. 2a, b, c). In 166 patients (33.2%), the xiphoid process was aligned in the same or nearly the same axis as the sternal corpus (Fig. 3). The tip of the xiphoid process was curved like a hook towards dorsal aspect in three patients (0.6%) (Fig. 4a, b). In four patients (0.8%), the xiphoid process was deviated dorsally in its proximal portion and ventrally in its distal portion exhibiting a reverse S shape (Fig. 5) (Table 1).

Xiphoidal ending and ossification Xiphoidal endings had three different types: single in 313 (62.6%), double in 164

Fig. 1 3-mm sagittal MIP image shows ventrally deviated xiphoid process in a 70-year-old woman. The line demonstrating the sternal axis is shown in the top left image. The tip of the xiphoid process is located ventral to the line



Fig. 2 Ventrally deviated xiphoid process with totally ossified hook-like ending in a 51-year-old man. 3.2-mm sagittal image (a), VR image (b). 1.7-mm sagittal MIP image shows partial ossified hook-like ending in another patient, a 57-year-old man (c)



(32.8%) (Fig. 6), or triple in 23 patients (4.6%) (Fig. 7). Ossification of the cartilaginous xiphoid process was fully completed in 254 patients (50.8%). Partial ossification was detected in the 1/3 superior portion of the xiphoid process in 53 patients (10.6%), in the 2/3 superior portion in 182 patients (36.4%), 1/3 middle portion in five patients (1%), 1/3 middle and inferior portion in one patient (0.2%), and 1/3 superior and inferior portion in three patients (0.6%). Apart from these patients, the xiphoid processes of the 70-

and 80-year-old patients were detected to be substantially cartilaginous. Minimal ossification in several millimetric foci was detected in one of these patients in the 1/3 proximal portion of the xiphoid process (Fig. 8) and 2/3 proximal portion in the other patient (Table 2).

Xiphoidal foramen Xiphoidal foramen was present in 216 patients (43.2%); 171 patients (34.2%) had only one foramen; 31 patients (6.2%) had two, seven patients

Fig. 3 2.9-mm sagittal MIP image shows the line demonstrating the sternal axis in the *top left* and a xiphoid process aligning in the same axis as sternal corpus in a 35-year-old woman

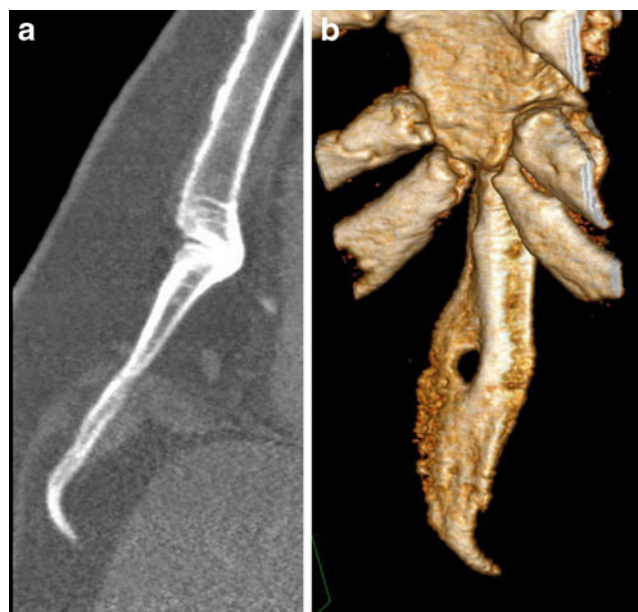


Fig. 4 1.7-mm sagittal MIP image (a) and VR image (b) of a 55-year-old man with hook-like dorsally deviated xiphoid process

Fig. 5 1.4-mm sagittal MIP image shows reverse S-shaped xiphoid process in a 48-year-old man



(1.4%) had three, and seven patients (1.4%) had four or more xiphoidal foramina (Fig. 6).

Sternoxiphoidal fusion and pseudoforamen Sternoxiphoidal fusion was present in 214 patients (42.8%) (Fig. 6). Mean ages of the patients with and without sternoxiphoidal fusion were 53.1 and 50.7, respectively. Pseudoforamen due to the incomplete fusion of sternoxiphoidal junction was observed in six patients (1.2%) (Fig. 9).

Discussion

Evaluation of the xiphoid process with direct radiography might be troublesome due to technical limitations. Rapid developments in MDCT technology have facilitated the evaluation of bone structures with the post-processing tools. The reason for choosing MDCT images of coronary CT angiography in this study to evaluate the anatomical variations of the xiphoid process is its excellent anatomic characterization, provided with high spatial resolution by this technique. Higher spatial resolution offers more comprehensive evaluation by performing post-processing tools such as MPR, MIP, curved MIP, and three-dimensional VR. Slight convexity of the sternal corpus and the deviation of the xiphoid process according to

Table 1 Distribution of xiphoidal deviation patterns

Xiphoidal deviation	Number of patients	Hook
Ventral (%)	327 (65.4)	11
No deviation (%)	166 (33.2)	-
Dorsal (%)	3 (0.6)	3
Reverse S (%)	4 (0.8)	-

Fig. 6 65-year-old man with double-ended xiphoid process. Coronal curved MIP image also shows multiple foramina and sternoxiphoidal fusion



sternal corpus axis that might be occasionally visualized could disable the visualization of the xiphoid process in one single image, especially in the coronal plane. This difficulty was eliminated by using specially curved coronal MIP reconstructions in this study. As a result of the same reason, we believe that the determination of a cut-off degree for angle in evaluation of xiphoidal deviation would be difficult and probably not standardisable. All images were reviewed and the decision of the xiphoidal deviation was made visually in consensus by the two observers.

Although the xiphoid process was reported to be not present in 113/354 (32%) and 11/1000 (1.1%) of patients in two reports evaluating the CT features of the sternum [3, 4], the xiphoid process was present in all patients in the present study. In our opinion, in part, these different results might

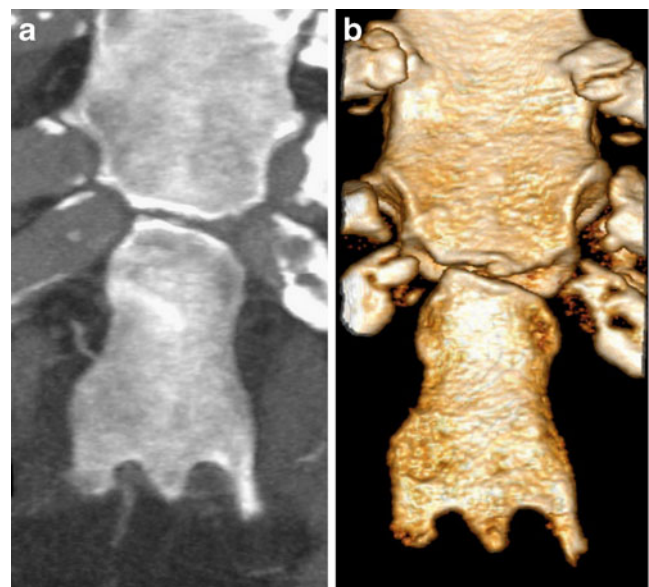


Fig. 7 3.6-mm coronal MIP (a), and VR images (b) show triple-ended xiphoid process in a 63-year-old man

Fig. 8 70-year-old woman with minimal ossified xiphoid process (*arrow*). 1.4-mm coronal curved MIP image shows marked cartilaginous portion

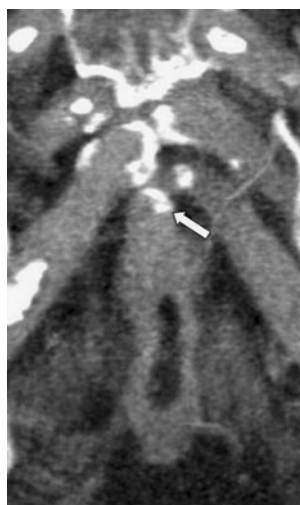


Fig. 9 48-year-old man. 3-mm coronal curved MIP image shows sternoxiphoidal pseudo-foramen (*arrow*)



originate from the difficulties in visualization of the cartilaginous portion of the xiphoid process or its differentiation from neighboring soft tissue structures.

Xiphoidal dimensions showed significant interindividual variations in our study. The maximum values for length, width, and thickness were measured as 3.95-, 7.18-, and 5.02-fold the minimum value, respectively.

The most common positional variation detected in our study was ventral deviation in 327 patients (65.4%). The tip of xiphoid processes in 11 patients (2.2%) of these 327 patients resembled a hook. This condition might mimic an epigastric mass especially in the case of a long xiphoid process [2]. Although a lateral chest or upper abdominal radiograph is sufficient for diagnosis, this might be occasionally an indication for further examination with ultrasonography [9–11], but as a limitation of our retrospective study, we did not have the chance to question these patients for any complaints or physical examination findings relevant to this variation. Interestingly, the tip of the xiphoid process was curved dorsally like a hook in three patients (0.6%) and exhibited a reverse S-shape in four patients (0.8%). We could not find a report investigating the frequency of the positional variations of the xiphoid process in the literature.

Table 2 Number of patients and patterns of xiphoidal ossification

Xiphoidal ossification		Number of patients
Total (%)		254 (50.8)
Partial	1/3 superior (%)	53 (10.6)
	2/3 superior (%)	182 (36.4)
	1/3 middle (%)	5 (1)
	1/3 middle and inferior (%)	1 (0.2)
	1/3 superior and inferior (%)	3 (0.6)
One or several ossification foci (%)		2 (0.4)

It is a well-known fact that the ossification of the cartilaginous xiphoid process progresses with age [12]. Ossification was detected in the xiphoid process at different portions with varying degrees in all patients. Surprisingly, however, the two patients with minimum ossification foci were 70 and 80 years old, which suggests that ossification also exhibits significant interindividual variations like other anatomic features. However, we could not find any data on these patients for the presence of osteopenia to correlate our finding with the metabolic status of the bones, which might be considered a limitation of our study.

The xiphoid process with triple ending and three foramina were first described by Yekeler et al., and frequencies were 0.7% and 0.3%, respectively [4]. The only study with the largest patient population evaluating the sternum and xiphoid process with CT in the radiology literature belongs to these authors. These frequencies were 4.6% and 1.4% in the present study, respectively. In addition, four or more foramina were also detected in seven patients (1.4%).

Yekeler et al. reported the frequency of the (complete or incomplete) sternoxiphoidal fusion 62.7% in their study [4]. This frequency was determined as 42.8% in the present study. Mean ages of the patients with and without sternoxiphoidal fusion were 53.1 and 50.7, respectively, in our study, which suggests that sternoxiphoidal fusion is not essentially related to age. Similar to the results of Yekeler et al., sternoxiphoidal fusion was detected in young patients, and the youngest patient with sternoxiphoidal fusion was 25 years old in our study. Sternoxiphoidal pseudo-foramen, first described by Yekeler et al. and reported to be as frequent as 3.6%, was detected to be 1.2% frequent in our study.

In conclusion, the xiphoid process might demonstrate significant anatomic interindividual variations. Excellent anatomic evaluation capacity of MDCT by means of high spatial resolution facilitates the detection of variations of

the xiphoid process as well as the whole ribcage in daily radiology routine. Especially prominent ventral deviation and hook-like ending of the xiphoid process should be considered in the differential diagnosis of the suspected epigastric masses.

Conflict of interest The authors declare that they have no conflicts of interest.

The authors also declare that they have no financial relationship related to this study.

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