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Prevalence of Abnormal Sternal Angles in a Kenyan Population

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Abstract

Abnormal sternal angles are unique anatomical variations of major clinical significance. For instance, misplaced sternal angles may cause inaccurate numbering of ribs and thus complicate intercostal nerve blocks and needle thoracostomies. They are also associated with increased risk of sternal fracture in blunt chest trauma. Additional sternal symphyses can be misinterpreted as fracture or lytic lesion in cross-sectional imaging of the sternum. These variations are rarely reported in Africans and lacking in the Kenyan population. We therefore aimed to determine the prevalence of abnormal sternal angles in a Kenyan population. 80 cadaveric adult sterna were studied at the Department of Anatomy, University of Nairobi, after ethical approval. The size of the angle was measured using a sliding protractor (CCKL, U.K). Results were analyzed by SPSS 18.0. The sternal angle was located at the level of the third costal notch in 7 cases (8.8%). It was un-ridged in 8 cases (10%). The angle measured 161.7° ± 4.7 in males and 159.9° ± 4.9 in females (p=0.165). In 9 cases (11.25%), the angle measured less than 150°. An additional sternal symphysis was present in 6 specimens (7.5%). Over 35% of sternal angles in Kenyans showed an abnormality in location, palpability or size. These variations may influence intercostal nerve blocks, interpretation of sternal images and evaluation of chest trauma. Further research is needed to correlate these findings.

Keywords: Sternal angle; Variations; Physical examination; Sternal fractures

Introduction

The sternum, a flat bone located in the middle of the chest, forms part of the anterior thoracic wall overlying the heart and great vessels in the middle mediastinum. Its caudal end, the xiphoid process, is related to the central tendon of the diaphragm and inferior border of the heart [1].

Knowledge of the anatomy and variations of the sternum is important during evaluation and treatment of various hematological and developmental diseases, planning thoracic surgery, identifying possible post-surgery complications and preventing mediastinal organ injury such as cardiac tamponade [2]. The sternum is also an important landmark in forensic medicine and anthropology.

Variations of the sternal angle are also important during physical examination of the chest, intercostal nerve blocks, insertion of underwater-seal chest drains and bedside measurement of jugular venous pressure [1]. However, these procedures can be markedly influenced by misplaced and impalpable sternal angles [3]. Furthermore, additional symphyses at the manubriosternal junction have been incorrectly labeled as fractures, traumatic fissures and lytic lesions in cross-sectional imaging of the sternum [4]. Radiologists should be aware of these variations as potential differential diagnosis.

The sternal angle measures approximately 155° to 175° which confer rigidity to manubriosternal union [5]. However, exaggerated sternal angles have been associated with sternal fractures during minor trauma to the anterior chest wall [6]. These fractures have also been documented during active compression-decompression cardio-pulmonary resuscitation [7-9]. Such fractures not only increase the likelihood of damage to underlying organs but may also impair ventilation and complicate recovery. These variations of the sternum are rarely reported in the African population and data from Kenya is altogether absent. The current study therefore aimed to determine the prevalence of abnormal sternal angles in a Kenyan population.

Materials and Methods

A total of 80 cadaveric adult sterna (42 males, 38 females) of age range 18-45 years were studied. These were obtained during routine dissection at the Department of Human Anatomy, University of Nairobi, Kenya. Ethical approval was obtained from the Kenyatta National Hospital/University of Nairobi Ethics and Review Committee before commencement of the study. Bilateral incisions were made longitudinally through the costal cartilages and the sternum was removed as a whole. The specimens were macerated in 10% formalin for a period of two months and the remaining soft tissues were carefully removed from the surface of the sternum. All specimens had fused manubriosternal symphysis. Broken and incomplete sterna and those with foramina and obvious gross abnormalities were excluded.

The sternal angle was measured on a flat surface using three landmarks: a point immediately below the inferior end of clavicular notch, immediately below manubriosternal junction, and a point inferior to the 4th costal notch [5]. Two lines were drawn to join these points (Figure 1a) and the angle subtended was measured using a sliding protractor (CCKL Creator, U.K, accurate to 0.5°), Figure 1b. Measurements were taken by a single observer at two separate sittings. The location of the angle and number of sternal symphysis were recorded. The sternal angle was considered misplaced if it did not correspond with the second costal notch. Photographs of representative sterna were taken using Fujifilm A235 digital camera with a resolution of 12.2 megapixels. Data was analyzed using SPSS version 18.0 (windows™ Inc., Chicago) and general descriptive statistics were applied to derive means and standard deviations of the measured parameters. Sex differences were determined using independent students' t-test and p value of ≤ 0.05 was taken as significant.

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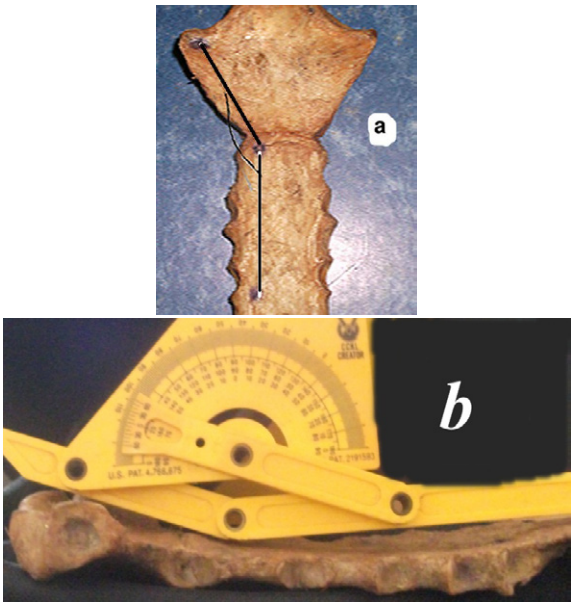

Figure 1: a: Macrograph showing the landmarks used in measuring the sternal angle
b: Macrograph illustrating the materials and methods used in the study.

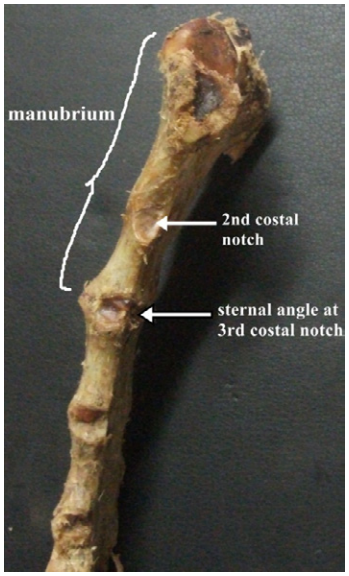

Figure 2: Macrograph showing sternal angle at the third costal notch (misplaced sternal angle).

Results

The sternal angle was misplaced (i.e. located at the third costal notch instead of second) in 7 cases 8.8% (Figure 2). It was un-ridged in 8 cases (10%), Figure 3. The angle ranged from 145.0° to 172.0° with an average of 161.7° ± 6.0 in males and 159.9°± 5.9 in females. This difference was however not statistically significant (p=0.165).

In 9 cases (11.25%), the angle measured less than 150° (Figure 4). An additional sternal symphysis was present in 6 specimens (7.5%), and was located at the level of third costal notch (Figure 5).

Discussion

The size of the sternal angle

In the present study, the average size of sternal angle in males and females was 161.7° ± 6.0 and 159.9° ± 5.9 respectively. This difference was not statistically significant. A review of literature found a single study that documented the size of the sternal angle in Croatians (Table 1).

This table depicts smaller sternal angles in the study population. This difference may be attributed to geographical variations in the size of the angle and probably body mass index, as sample size and methodology used in these studies were similar. Further, the present study found 9 cases (11.25%) of sternal angles measuring less than 150°. This variant has been associated with sternal fractures in mild trauma to the anterior chest wall [7,6]. A sternal fracture is a very common injury that occurs after motor vehicle collisions, particularly

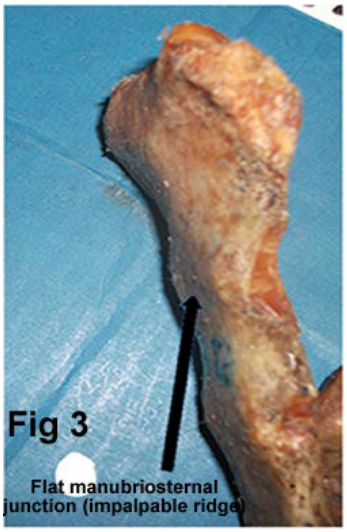

Figure 3: Macrograph showing un-ridged/flat manubriosternal junction.

Figure 4: Macrograph showing sternal angle measuring 145°.

Figure 5: Macrograph showing an additional sternal symphysis at the third costal notch.

Author	Population	Sample size	Mean sternal angle (⁰)
Selthofer et al. [5]	Croatians	90	M= 166.4 ± 7.4 F= 165.3 ± 7.2
Present study, 2013	Kenyans	80	M= 161.7 ± 6.0 F= 159.9 ± 5.9

M=Male; **F**=Female

Table 1: Population differences in the size of sternal angle.

in restrained front seat occupants [10]. Some authors have shown up to 8% to 10% of patients who are hospitalized with blunt chest trauma have sternal fractures [11,12]. Recently, the number of chest injuries has increased because of the steady increase of injuries from motor vehicle collisions in Kenya [13]. This warrants extra caution when evaluating anterior chest wall trauma.

Misplaced and impalpable sternal angles

The sternal angle is known to correspond with the second costal cartilage, and this has been used as a major landmark during physical examination. However, the current results document seven cases (8.8%) of misplaced sternal angles. In these specimens the sternal angle was actually located at the level of third costal notch. Although this variation has been rarely reported [14], it may lead to inaccurate numbering of ribs and thus pose a challenge during chest procedures such as intercostal nerve blocks or needle decompression of pneumothorax or hemothorax [15]. Further, the present study also found eight cases (10%) of unpalpable sternal angles as manubriosternal junctions in these specimens were un-ridged. This variation may also create inaccuracy in the above procedures.

Additional sternal symphyses

The sternum has a single symphysis at the junction of the manubrium and the sternal body [3]. However, the current study found 6 cases (7.5%) of additional sternal symphyses at the third costal notch. This variation may be misinterpreted as fracture, traumatic fissure or lytic lesion in cross-sectional imaging of the sternum. Radiologists should be aware of this variation as a potential differential diagnosis.

The variations of the sternal angle observed in our study may have an embryological basis. The sternum arises from paired longitudinal concentrations of mesenchymal tissue located on each side of the anterior chest wall called "sternal bars" during the 6th week of development [16]. Afterwards, these sternal bars migrate towards the midline and fuse to form the sternal plate. This fusion begins at the cephalic end of the sternal bars and progresses in a cranio-caudal direction and is completed by the 10th week [17]. After maturation into cartilage, the sternum undergoes several transverse divisions into a series of six cartilaginous segments called "sternebrae" or "segments". There is one segment for the manubrium, four for the body and one for the xiphoid process. The segments then ossify gradually in a craniocaudal succession from the cartilaginous precursors by endochondral ossification producing the definitive bones of the sternum [18]. Any failure in this developmental process results in various sternal anomalies such as fissure or foramen [19,20]. Fusion of the inferior end of the sternum is sometimes incomplete, resulting in a bifid or perforated xiphoid process [21]. An abnormally long manubrium may arise as a result of fusion of accessory ossification centers in the manubrium [22,23]. This may shift the sternal angle from its normal position to the level of the third costal cartilage as observed in the present study.

Several studies have also reported variations in the anatomy, development and maturation of the sternum. In a study by Donnelly et al. [24] of 200 subjects aged 3 months to 19 years, anterior chest wall variations were found in up to one third of patients. These included a tilted sternum (14.5%), pectus excavatum (2%) and pectus carinatum (2%) among others. The authors concluded these were asymptomatic variations and should not be considered alarming when palpated at physical examination.

A study by Hanifi et al. [2] depicted variations in the developmental pattern of the sternum. This study found a spherical-shaped (rather than trapezoid) ossification center for the manubrium sterni in up to 18% of a pediatric population aged 0-25 years using a multidetector CT. In this study the sternal angle was partially fused in 3% while suprasternal bones and tubercles were present in 7.5%. Finally, in the largest study evaluating sternal variations by multidetector CT scanning, Yekeler et al. [4] reported complete manubriosternal and sternoxiphoid fusions in those younger than 45 years in 19.6% of cases. Sternal foramina were present in 4.5% while sternal sclerotic bands were present in 37.1% among other variations. The authors concluded that early manubriosternal and sternoxiphoid fusions can be seen in early adulthood without osteodegeneration.

Conclusion

Over 35% of sternal angles in Kenyans showed an abnormality in location, palpability or size. Although the sample size is limited to generalize our data, these variations may influence intercostal nerve blocks, interpretation of sternal images and evaluation of chest trauma. Further clinical research is needed to correlate these findings.

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