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Original Research Article

MORPHOMETRIC STUDY OF THE STERNUM IN EGYPTIAN PERSONS BY CT SCAN (FROM 10 TO MORE THAN 60 YEARS OLD)

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ABSTRACT

Background: The sternum is one of the bones of the skeleton with frequently detected variation, present study focused on morphometric study of the egyptian sternum by CT scan.

Methods: 240 CT scan film from individual aged between 10 to more than 60 years divided into 6 groups according to age each group included 40 cases (20 males and 20 females) for estimation of the sternal parameters which include the lengths of manubrium, sternal body , xiphoid process , the whole sternal length , detection of the variable maturation of the sternum and the presence of sternal foramina, sex variations of results are detected

Results: The mean length of different parts of sternum was recorded as following: manubrium was 3.8 cm in males, 3.6 cm in females. The body length was 8.6 cm in males, 7.9 cm in females, The xiphoid length was 2.5 cm in males, 1.9 cm in females. The total sterna length was 14.9 cm in males, 13.6 cm in females. The complete or partial fusion of the manbriosternal junction is noticed in all the cases above fifty years. The complete or partial fusion of the xiphisternal junction is noticed in most of subjects by the age of forty five years. The pattern of fusion of the sternal elements has no relation to sex .The sternal foramen detected only in 8.3 % of cases.

Conclusions: Identification of sternal measurement and their anomalies such as sternal foramen has medicolegal and forensic importance.

Keywords: Sternum, morphometric ,Sternal foramina.

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INTRODUCTION

The sternum is a flat bone lying in the median part of anterior thoracic wall Bermio and Jos., (2014) [1].It consists of three parts, named manubrium sterni, body of sternum or mesosternum and the xiphoid process or xiphisternum (Mittal et al., 2014) [2].

The anatomy and the developmental properties of the sternum should be well understood in cases of potential chest and sternum injuries and in several surgical procedures. Therefore, knowledge of the development and the maturation of the sternum, and sternal variations and anomalies are important (Bayaroðullarý et al., 2014) [3].

The manubrium, the superior part of the sternum, its level at the third and fourth thoracic vertebrae. The body of the sternum at the level of fifth and ninth thoracic vertebrae. It is longer, thinner and narrower than the manubrium. The xiphoid process is a thin sword-shaped process and is the smallest and most

variable part of the sternum. The manubrium and body lie in slightly different planes; hence, their junction forms a projecting sternal angle or angle of Louis (Kirum et al., 2015)[4].

Identification of sex from human skeletal remains an indispensable element of medico-legal investigation and forensic science (Mittal et al., 2014) [2].

Multidetector CT (MDCT) has become the primary imaging method for assessing the sternum due to its higher image quality and its ability to perform a three-dimensional evaluation. (Bayaroðullarý et al., 2014)[3].

The sternum is derived from a pair of vertical mesenchymal bands on ventral body wall called as sternal bars. Chondrification occurs cranio-caudally in the sternal bars to form a cartilaginous model of manubrium, sternebrae of body, and xiphoid process. Failure of fusion of these sternebrae results in a sternal foramen which is more common at the level of third and fourth sternebrae (Tandon and Gara, 2016)[5].

Usually the sternal foramen is asymptomatic and only be detected by CT scan. But at times, it may be misinterpreted as gun shot or stab wound. In clinical practice, sudden unexpected death may take place during sternal puncture and biopsy as a result of cardiac puncture and tamponed Chaudhari et al.,(2016)[6]. So awareness of a sternal foramen is important in acupuncture practice and sternal marrow aspiration (Babinski et al., 2015) [7].

The aim of this work: To evaluate the incidence of anatomical variations and maturation of human sternum bones.

SUBJECTS AND METHODS

This study was carried out on 240 normal chest CT films for Egyptian individuals of both sexes. Subjects were randomly chosen from those attend Benha University Hospital and other private radiological centers of known birth date and sex. Patients with sternal deformities, a history of severe chest trauma, a history of thoracic or sternal surgery, a sternal mass or infection, chronic disease, or malnourishment were excluded from the study.

The individuals were divided into 6 groups according to age each group included 40 cases (20 males and 20 females) as following:

1- Group A: Their ages ranged from 10 years up to less than 20 years.

2-Group B: Their ages ranged from 20 years up to less than 30 years.

3-Group C: Their ages ranged from30 years up to less than 40 years.

4-Group D: Their ages ranged from 40 years up to less than 50 years.

5-Group E: Their ages ranged from 50 years up to less than 60 years.

6-Group F: Their ages were more than 60 years.

Fig.(1: A,B,C,D): A photograph of sagittal CT scan of the chest of male aged 13 years showing the following parameters; the length of manubrium(A), the length of body(B) ,the length of xiphoid(C) , the length of whole sternum (D).

Each group has been subjected for the following:

1-Personal history: name, age, locality, any chronic diseases, any trauma to the sternum, or surgical interference through the sternum.

2-The cases have been examined by chest CT scan using standardized protocol as follows:

CT scanner was used for all the thoracic CT procedures. Axial plane images were obtained and were transferred to a workstation for post-processing. At the workstation, maximum intensity projection (MIP), curved planar reconstruction (CPR), and multiplanar reformatting (MPR) of the sagittal images were performed, and three-dimensional images of the sternum were obtained (Bayaroðullarý et al., 2014) [3].

Through these chest CT films, the following parameters have been measured:

From sagittal CT films: Fig.(1).

Manubrium length: the distance from the center of suprasternal notch to the center of manubriosternal junction.

Sternal body length: the distance from the manubrio-sternal junction to the xiphi-sternal junction of the sternum in the mid-sagittal plane.

Xiphoid length: the distance from xiphi-sternal junction to the tip of the xiphoid process.

The total length of the sternum from the jugular notch to the tip of xiphoid process.

From 3DCT films: for detection of manbriosternal and xiphisternal junction and the presence of sternal foramen: fig. (3,4)

The morphometric parameters were measured using RadiAnt DICOM viewer 4.2.1(64-bit)(Digital Imaging and Communications in Medicine) program then measurements were analyzed in relation to age and sex.

These measurements have been analyzed using ANOVA

Analysis: The measured data were recorded on a report form. These data were analyzed using the computer program SPSS (statistical package for social science) version 20 to obtain:

Descriptive data: Descriptive statistics were calculated for the data in the form of:

1. Mean and standard deviation $(\pm SD)$ for quantitative data.

2. Frequency and distribution for qualitative data.

Analytical statistics: In the comparison between the different groups, the significance of difference was tested using one of the following tests:

1- Student's t-test: Used to compare mean of two groups of quantitative data.

2- Paired t test: Used to compare mean of variables in different time periods of quantitative data.

3- ANOVA test (F value): Used to compare mean of more than two groups of quantitative data.

4- Correlation coefficient: to find relationships between variables.

5- Chi-Square test (X^2): For comparison between two groups as regards qualitative data.

P value <0.05 was considered significant (*) while >0.05 insignificant, P value <0.01 was considered highly significant (**) in all analyses.

RESULTS

morphometric parameters of the sternum and were measured as the following in fig. (1):

Manubrium length in different age groups: Manubrium length was measured in group A 2.37 cm ±0.82, in group B was 3.45 cm ±0.65, in group C measured 3.66 cm ±0.55, while in group D recorded 3.86 cm ±0.33 , in group E was measured 4.57 cm ±0.44, and was measured 4.59±0.57cm in group F. These results were highly significant in all age groups as the Manubrial length increase with the increase of age

Body length in different age group: Sternal body was measured 6.18 ±1.36 cm in group A, 7.89 ±0.59 cm in group B, 8.57 cm ±0.66 in group C, 8.75 ±1.23 cm in group D, 8.72±0.70 cm in group E, and measured 9.5 ±1.76cm in group F . The body length increase with the increase of age so These result were highly significant in all age groups.

Xiphoid length in different age group: Xiphoid length was measured in group A 0.9 9 cm ± 0.17, in group B 1.27 ± 0.52 cm, 2.45 ± 0.43 cm in group C , 2.57 ± 0.57 cm in group D, 3.02 cm ±1.39 in group E and recorded 3.14±0.99 cm in group F . The xiphoid length increase with the increase of age .These result were highly significant in all age groups.

Total length of sternum in different age group (the sum of manubrium length plus body length plus xiphoid length):

Total length of sternum was measured 9.8 ±2.61 cm in group A , 13.5 ±1.18 cm in group B, 14.78 ±1.23 cm in group C, 15.03 ±1.19 cm in group D, 16.03 ±3.07 cm in group E, and was measured 16.33±2.01 in group F. These result were highly significant in all age groups.

Table (2): Length of manubrium increased by about 1.08 cm from group A to group B then increased by about 0.28 cm every 10 years with average increase from A to E group 0.4 cm . Length of body increased by about 0.4 cm every 10 years with average increase from A to E group 0.6 cm. Length of xiphoid process increased by about 0.3 cm every 10 years with average increase from A to E group 0.3 cm.. Total

Table 1: Shows length, body len

length of the sternum increased by about 0.7 cm every 10 years with average increase from A to E group 1.3 cm This rate of increase of length was highly significant in relation to age in all groups .

Table 1: Shows sternal diameters (manubrium length, body length, xiphoid length, total length of the sternum) in different age groups.

	Group A	Group B	Group C	Group D	Group E	Group F	P value
Manubrium length	2.37±0.82	3.45±0.65	3.66±0.55	3.86±0.33	4.57±0.44	4.59±0.57	0.001**
Body length	6.18±1.36	7.89±0.59	8.57±0.66	8.72±0.70	8.75±1.23	9.5±1.76	0.001**
Xiphoid length	0.99±0.17	1.27±0.52	2.45±0.43	2.57±0.57	3.02±1.39	3.14±0.99	0.001**
Total length of sternum	9.8±2.61	13.5±1.18	14.78±1.23	15.03±1.19	16.03±3.07	16.33±2.01	0.001**

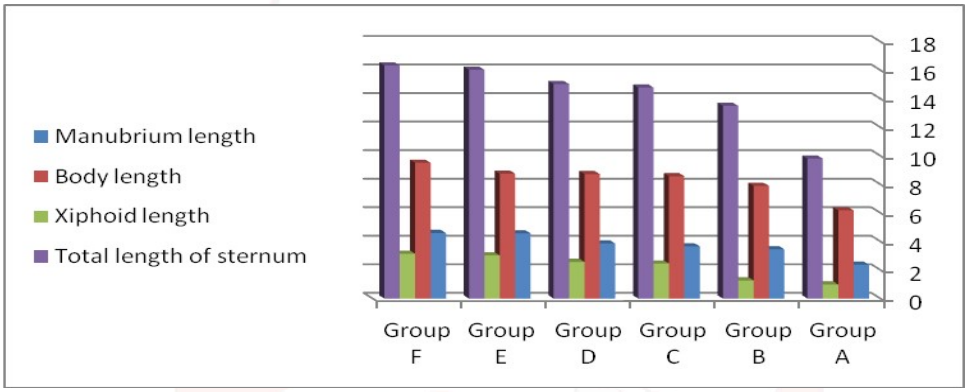
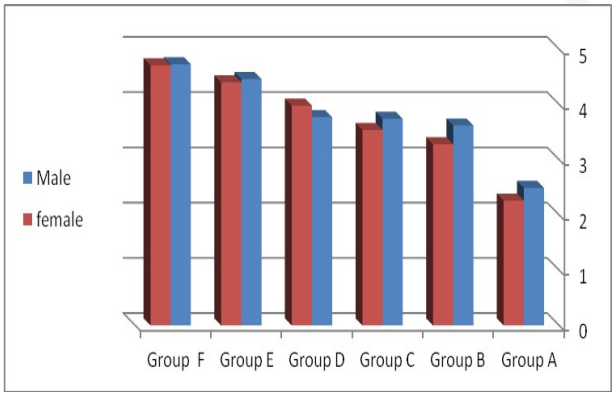


Table 2: The rate of increase of parameters in each age group.

Rate of increase	Group A&B	Group B&C	Group C&D	Group D&E	Group E&F	Rate of increase every 10 years	Average increase from A to E groups	P value
Manubrium length	1.08±2.26	0.21±1.19	0.2±1.4	0.71±1.5	0.02±.41	0.28	0.4	0.001**
Body length	1.71±3.61	0.68±1.22	0.15±0.98	0.03±0.46	0.75±17.58	0.4	0.6	0.001**
Xiphoid length	0.28±1.11	1.18±1.42	0.12±2.13	0.45±2.06	0.12±0.89	0.3	0.3	0.001**
Total length of sternum	3.7±4.05	1.28±1.84	0.25±0.65	1.01±1.23	0.3±0.43	0.7	1.3	0.001**

Table 3: Showing Sex distribution of length of manubrium.

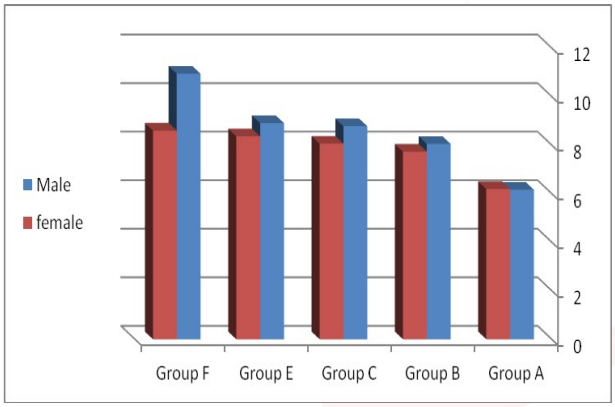
Manubrium length	Male	female	P value
Group A	2.49±0.97	2.26±0.63	0.39
Group B	3.62±0.79	3.28±0.42	0.098
Group C	3.74±0.38	3.54±0.54	0.015*
Group D	3.77±0.55	3.98±0.21	0.021*
Group E	4.46±0.54	4.4±0.43	0.015*
Group F	4.73±0.38	4.71±0.60	0.17



The mean length of manubrium in males and females: The mean length of manubrium in group A was 2.49±0.97 cm in males, while in females was 2.26±0.63 cm. The mean length of manubrium in group B was 3.62±0.79 cm in males, while in females was 3.28±0.42 cm. The mean length of manubrium in group C was 3.74±0.38 cm in males, while in females was 3.54±0.54 cm .This difference was statistically significant. The mean length of manubrium in group D was 3.77±0.55cm in males, while in females was 3.98±0.21 cm. This difference was highly statistically significant (p value > 0.001). The mean length of manubrium in group E was 4.46±0.54cm in males, while in females was 4.4±0.43 cm. This difference was highly statistically significant. The mean length of manubrium in group F in males was 4.73±0.38, while in females was 4.71±0.60cm This difference was highly statistically significant.

Table 4: Sex distribution of length of the sternal body.

Body length	Male	female	P value
Group A	6.16±1.47	6.19±1.27	0.95
Group B	8.05±0.49	7.73±0.64	0.086
Group C	8.78±0.72	8.06±0.47	0.041*
Group D	8.91±1.37	8.36±0.52	0.001**
Group E	8.91±1.37	8.36±0.52	0.001**
Group F	10.94±1.33	8.6±1.09	0.001**



The mean length of body in males and females: The mean length of body in group A in males was 6.16±1.47 cm, while in females was 6.19±1.27cm. The mean length of body in group E in males was 9.09±0.48 cm, while in females was 8.36±0.70 cm. The mean length of body in males in group F was 10.94±1.33cm, while in females was 8.6±1.09cm. This difference was highly statistically significant in these age groups.

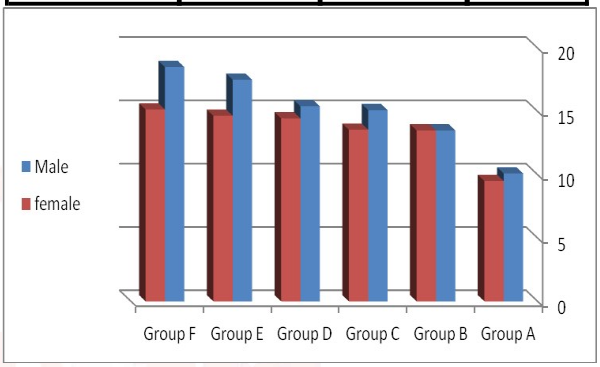
Table 5: Sex distribution of length of xiphoid.

Xiphoid length	Male	Female	P value
Group A	1.07±0.14	0.90±0.16	0.001**
Group B	1.34±0.60	1.19±0.43	0.37
Group C	2.5±0.74	2.19±0.80	0.23
Group D	2.54±0.36	2.36±0.83	0.46
Group E	3.84±1.37	2.37±0.49	0.001**
Group F	3.91±0.21	2.64±0.34	0.001**

The mean length of xiphoid in males and females: The mean length of xiphoid in group A in males was 1.07±0.14 cm, while in females was 0.90±0.16 cm. This difference was highly statistically significant. In group B was 1.34±0.60 cm in males, while in females was 1.19±0.43 cm. In group C was 2.5±0.74 cm in males, while in females was 2.19±0.80 cm. In group D was 2.54±0.36 cm in males, while in females was 2.36±0.83cm. In group E was 3.84±1.37 cm in males, while in females was 2.37±0.49cm. This difference was statistically highly significant. In group F males was 3.91±0.21 cm, while in females was 2.64±0.34 cm. This difference was highly significant.

Table 6: Showing Sex distribution of total length of sternum.

Total length of sternum	Male	Female	P value
Group A	10.1±2.99	9.5±2.21	0.48
Group B	13.5±1.05	13.5±1.31	1
Group C	15.1±1.29	13.55±1.36	0.095
Group D	15.4±0.75	14.45±1.1	0.044*
Group E	17.5±1.73	14.65±1.42	0.001**
Group F	18.5±2.14	15.15±1.53	0.001**



Total length of the sternum in males and females: The mean total length of the sternum in group A in males was 10.1±2.99 cm, while in females was 9.5±2.21 cm. In group B was 13.5±1.05 cm in males, while in females was 13.5±1.31 cm. In group C was 15.1±1.29 cm in males, while in females was 13.55±1.36 cm. In group D was 15.4±0.75 cm in males, while in females was 14.45±1.1cm. This difference was significant . In group E was 17.5±1.73cm in males, while in females was 14.65±1.42cm. This difference was highly significant. In group F was 18.5±2.14 cm in males , while in females was 15.15±1.53cm. This difference was highly significant.

Ossification of the sternum in different age groups:

Table 7: shows the degree of fusion of manubriosternal (M-S) and xiphisternal (X-S) junctions.

	Group A	Group B	Group C	Group D	Group E	Group F	P value
M-S junction							
No fusion	40(100%)	40(100%)	25(62.5%)	28(70.0%)	0	0	0.001**
Partial fusion	0	0	15(37.5%)	12(30.0%)	28(70.0%)	0(0.0%)	
Complete fusion	0	0	0	0	12(30.0%)	40(100%)	
X-S junction							
Not fusion	40(100%)	40(100%)	22(55.0%)	3(7.5%)	0(0.0%)	0(0.0%)	0.001**
Partial fusion	0(0.0%)	|0(0.0%)	18(45.0%)	22(55.0%)	0(0.0%)	0(0.0%	
Complete fusion	0	0	0	15(37.5%)	40(100%)	40(100%)	

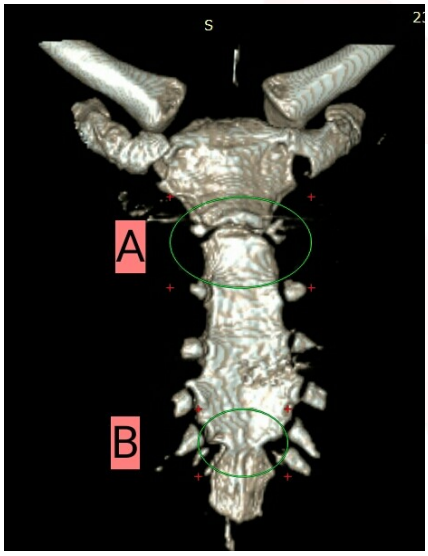
Table 8: shows the degree of fusion of manubriosternal (M-S) and xiphisternal (X-S) junctions in different age groups in males.

	Group A	Group B	Group C	Group D	Group E	Group F	P value
M-S junction							
No fusion	20(100%)	20(100%)	**11(55.0%)**	14(70.0%)	0(0.0%)	0(0.0%)	0.001**
Partial fusion	0(0.0%)	0(0.0%)	**9(45.0%)**	6(30.0%)	14(70.0%)	0(0.0%)	
Complete fusion	0	0	**0**	0	6(30.0%)	20(100%)	
X-S junction							0.001**
No fusion	20(100%)	20(100%)	11(55.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
Partial fusion	0	0	9(45.0%)	11(55.0%)	0(0.0%)	0(0.0%)	
Complete fusion	0	0	0	9(45.0%)	20(100%)		

Table 9: shows the degree of fusion of manubriosternal (M-S) and xiphisternal (X-S) junctions in different age groups in females.

Among female group	Group A	Group B	Group C	Group D	Group E	Group F	P value
M-S junction							0.001**
No fusion	20(100%)	20(100%)	**14(70.0%)**	14(70.0%)	0(0.0%)	0(0.0%)	
Partial fusion	0(0.0%)	0(0.0%)	**6(30.0%)**	6(30.0%)	14(70.0%)	0(0.0%)	
Complete fusion	0(0.0%)	0(0.0%)	**0(0.0%)**	0(0.0%)	6(30.0%)	20(100%)	
X-S junction							0.001**
No fusion	20(100%)	20(100%)	11(55.0%)	3(15.0%)	0(0.0%)	0(0.0%)	
Partial fusion	0(0.0%)	0(0.0%)	9(45.0%)	11(55.0%)	0(0.0%)	0(0.0%)	
Complete fusion	0(0.0%)	0(0.0%)	0(0.0%)	6(30.0%)	20(100%)	20(100%)	

Fig. 2: 3D CT scan of sternum of female aged 42 years showingpartial fusion of manubriosternal joint (A), and complete fusion of xiphisternaljoint(B).



Manubriosternal junction: In the first and second age groups, there was no evidence of fusion of manubrium with the body. In the third age group, 15 cases(37.5%) showed partial fusion of manubrium with the body (9 males (45%) and 6 females(30%)), while 25 cases (62.5%) showed no evidence of fusion (11 males(55%) and 14 females(70%)), In the fourth age group, 12 cases (30%)showed partial fusion of manubrium with the body (6 males(30%) and 6 females(30%)), while 28 cases (70%) showed no evidence of fusion (14 males(70%) and 14 females(70%)), In the fifth age group, 28 cases(70%) showed partial fusion of manubrium with the body (14 males(70%) and 14 females(70%)), while 12 cases(30%) showed complete fusion (6 males(30%) and 6 females(30%)), In the sixth age group, all cases (100%)showed complete fusion (20 males (100%) and 20 females(100%)). Tables (7,8,9),

Xiphi-sternal junction: In the first and second age groups, there was no evidence of fusion of manubrium with the body. In the third age group, 18 cases (45%) showed partial fusion of manubrium with the body (9 males(45%) and 9 females(45%)), while 22cases (55%) showed no evidence of fusion (11 males(55%) and 11 females(55%)), In the fourth age group, 22 cases (55%) showed partial fusion of manubrium with the body (11 males(55%) and 11 females(55%)), while 3 cases(7.5)% showed no evidence of fusion (3females(15%)), while 15 cases (37.5%) showed complete fusion (9 males(45%) and 6 females(30%)) In the fifth and sixth age groups, all cases(100%) showed complete fusion (20 males(100%) and 20 females(100%) These obtained results showed highly significant

changes as complete fusion of xiphi-sternal junction starts from age of 50 years onwards tables .(7,8, 9).

Foramina in the sternum: These were present in the body and xiphoid process in varying frequencies. Overall, they occurred in 20 cases (8.3%). The highest frequency of foramina was in the sternal body, 15cases (6.25%). Xiphoid foramina were present in 5 specimens (2.1%). Its presence not correlated with the age. Tables (10), Fig.(4).

Fig. 4: 3D CT scan of sternum of male aged 48 years showing sternal foramen in the xiphoid process (A).

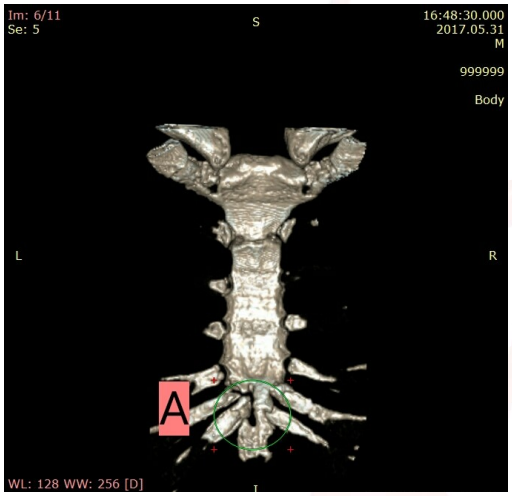


Table 10: The incidence of foramen in different age groups in both sexes.

Presence of Foramen	Group A	Group B	Group C	Group D	Group E	Group F	P value
Foramen in Body	3(7.5%)	6(15.0%)	0(0.0%)	0(0.0%)	0(0.0%)	6(15.0%)	0.001**
Foramen in Xiphoid	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	5(12.5%)	0(0.0%)	

DISCUSSION

In this study the mean manubrial length was measured 3.8 cm in males, 3.6 cm in females who aged between 10 to more than 60 years. This result was nearly similar to that of Dkhar, (2014), Mittal et al., (2014), and Manoharan et al., (2016) [8,2,9]]who studied among103 indian persons aged between 15 years and 75years and it was 4.9 cm in males and 4.5 cm in females. But differed from Selthofer et al., (2006) [10], who studied among Croatian with average age 65 and it was5.5 cm in males and 5.2 cm in females.

In the current study the mean body length was recorded 8.6 cm in males, 7.9 cm in females who aged between 10 to more than 60 years. This result was nearly similar to that of Dkhar, (2014), Mittal et al., (2014), and Manoharan et al., (2016) [8,2,9]who studied among103 Indian persons aged between 15years and 75years and it was 9.4 cm in males and 7.5 cm in females. But differed from Selthofer et al., (2006)[10] and Ateºogluet al., (2018) [11], who performed MDCT scan on 200 persons aged between 18-87 years and it was 10.2 cm in males and 8.6 cm in females. The measurements presented some variations in comparison with previous studies. These different values could be due to racial, ethnic, and regional variations. This data can be used for demographic studies, comparative studies among different population groups and forensic cases.

In this study the mean xiphoid length was 2.5 cm in males, 1.9 cm in females who aged between 10 to more than 60 years. This result was nearly similar to that of Dkhar, (2014) [8], who performed CT scan on 60 persons of different age groups and it was 2.5 cm in males and 2 cm in females, But differed from Selthofer et al., (2006)[10] and Ateºogluet al., (2018) [11], who performed MDCT scan on 200 persons aged between 18-87 years and it was 3.9 cm in males and 2.9 cm in females. This shows that for each of the age groups the tendency is that the male measures are larger than the female measures. and this agree with the results of (Jit et al., (1980; Pedersen et al .,2007) [12,13] who also found a difference in sternum size between the genders, support this finding.

In this study, it was recorded that the degree of fusion of manubrium with the body of the sternum begins between age of 30 and 40. No sternum was found with absent fusion after the age of 60 years. Also complete fusion of xiphi-sternal junction starts before manubrio-sternal junction. The pattern of fusion has no relation to sex. These results were nearly similar to that of Chandrakanth et al., (2012)[14] who studied among South India aged above 20 years which start at the age of 35 years in males and 31 years in females but differed from those of Tayal et al., (2013)[15] who studied among North West Population of Punjab, India where the fusion of the manubrium with the body of the sternum begins after the age of 40 years.

In this study, it was recorded that the degree of fusion of xiphoid process with the body of the sternum begins between age of 30 and 40. No

sternum was found with absent fusion after the age of 50 years. The pattern of fusion has no relation to sex. These results were nearly similar to that of Chandrakanth et al., (2012)and Tayal et al., (2013)[14,15] who studied among North West Population of Punjab, India in which earliest fusion of xiphisternal junction was observed at the age of 30 years in males and females.

In this study the incidence of sternal foramen was 6.7%. This result was nearly similar to Schratter et al., (1997)[16] and Yekeler et al., (2006)[17] who examined 1000 persons using CT and it was 4.5%. But differed from Babinski et al., (2015)[7] and Boruah et al., (2016)[18] who examined 1180 persons using CT and it was 11.6%.

In this study it was found that most of sterna foramina were located in sterna body and few of them were located in xiphoid process. This result was similar to El-Busaidy et al., (2014)[19] who studied among Kenyan population of age range 18 to 45 years , but differed from Paraskevas et al., (2015)[20] who studied among Greek population and revealed that most of sterna foramina were located in xiphoid process.

Identification of such variations is important to prevent fatal complications during sterna marrow aspiration and acupuncture. complications like cardiac tamponade can occur Duraikannu et al., (2016) [21].

CONCLUSION

The knowledge of anatomical variants and congenital foramina of sternum and xiphoid process are essential, especially for radiology (X - ray, CT, MRI) , bone marrow sampling, forensic medicine post-mortem reporting and acupuncture practice to avoid complications during various surgical procedures , and the radiological study of fusion of manubrium and xiphoid process with the body of sternum is valuable index in determination of age in the living

Conflicts of Interests: None

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