Full Length Research Article

Morphometric Evaluation of Foramen Magnum and Its Variation with Sex and Age among Computed Tomography Scanned Individuals at Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia

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ABSTRACT

Foramen magnum is one of the several apertures in the base of the skull, through which medulla oblongata and other vital structures are transmitted. Knowledge on the normal anatomy of the base of the skull, especially the foramen magnum and its associated structures, is important to correlate its morphometric features with relevant clinical practices and may be in sex determination. Some anatomical features and gender differences in the human cranium are unique to each population and may be influenced by genetic, environmental and socio-demographic factors. In the present study morphometry of foramen magnum and its variation with sex and age was evaluated. The anteroposterior diameter (APD), transverse diameter (TD), and the area of foramen magnum (AFM) of each CT scan images of individuals who had head computed tomography scan at Tikur Anbessa Specialized Hospital, Addis Ababa, were measured by using institutional picture archiving and communication system workstation through institutional MedWeb. The overall APD of FM was 34.55 ± 3.21mm, TD was 28.48 ± 3.03mm and AFM was 814.77 ± 126.52mm^2 in the present study. The mean of measurements of all the three evaluated parameters of foramen magnum was larger in males and the differences were statistically significant at $P < 0.05$ between sexes. However, no statistically significant ($P > 0.05$) difference was detected in all the measured parameters among different age groups. In conclusion, the result of our study has reinforced the idea of likelihood of determining sex by evaluating the morphology of foramen magnum when essential.

Keywords: Cranium, Computed tomography scan, Foramen magnum, Morphometry

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1. INTRODUCTION

Foramen magnum (FM) is a Latin word meaning "great hole". It is one of several apertures in the base of the skull, through which medulla oblongata and other vital structures are transmitted. The anterior border of the FM is formed by basilar process of the occipital bone, the lateral border by the left and right occipital condyles and posterior border is formed by the supraoccipital part of the occipital bone (Cunningham, 2016). Occipital condyles encroached on each side of antero-lateral margin of the FM, therefore the FM is narrow anteriorly (Naderi *et al*., 2005). The posterior part (so-called proper FM) is less involved in head motions since it is crossed by various neurovascular structures. The anterior margin of FM includes skeleto-motor structures that are important for movement and stabilization of the skull mainly on the level of atlanto-occipital and atlanto-axial joints. It also contains various ligaments and the dens of the axis (Richards and Jabbour, 2011).

The shape and size of FM are influenced by several potential factors during development. Suture closure and simultaneous development of neural structures in the FM region are some of these potential factors (Menezes, 2008).

Next to the pelvis, the skull is the most sexually dimorphic portion of the skeleton, but the determination of the sex from the skull is not reliable until well after puberty (Patil and Mody, 2005). There is little difference between the skulls of male and female until puberty. The gender differences in the human cranium are unique to each population and may be influenced by genetic, environmental and socio-economic factors (Gapert *et al*., 2009). Radiological morphometric evaluation of the basilar region of skull provides an easy method of sex determination; the computed tomography (CT) scans being a preferred diagnostic modality for this purpose (Rai *et al*., 2017).

Beside sex determination, knowledge about the normal anatomy and morphometric variations of the base of the skull, especially the foramen magnum with its associated structures, among different population, is very important for clinicians for better diagnosis, management as well as in surgical intervention (Gautam *et al*., 2012).

So far, there is little report from Africa in the literature and there have been no studies conducted in Ethiopia to determine the FM dimensions. Despite its wide range clinical importance, it helps to

determine the sexes when there is loss of other parts of the skeleton or intact body part due to several destructions or various catastrophes (Saini *et al*., 2011).

Generally, information on structural changes at FM is not an interest to only anatomists, but also to clinicians or other disciplines like: forensic medicines and anthropology (Samara *et al.*, 2017). Hence, evaluating or knowing the dimensions of FM have a range of significance (El-Barrany *et al*., 2016)

Therefore, the aim of this study was to determine and document the average dimensions of FM in relation with sex and age among adults who underwent skull CT scan at Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia, hoping that this will be used as baseline information for further studies, for clinicians and in forensics.

2. MATERIALS AND METHODS

A retrospective radiological study was conducted on 82 male and 73 female participants between 15th December 2018 to 15th January, 2019 in Addis Ababa, Tikur Anbesa specialized hospital. This hospital is the largest referral and the main teaching hospital for both clinical and preclinical training of many health relaed disciplines in the country.Various departments, faculties and residents under specialty training in the School of Medicine provide patient care in the hospital. Radiology department is one of the departments that give service for the community with different imaging techniques.

Sample size was determined by using single population mean formula taking standard deviation of anteroposterior diameter of FM (SD ± 3.1) (Alamin *et al., 2015*) 95 % ($Z\alpha/2 = 1.96$) confidence interval, and margin of error 0.5. On average 40 skull CT scan images were examined per month and around 480 skull CT scan images with the individuals' identification were stored in the Institutional Medweb system in one year. A sample frame was developed and simple random sampling technique was applied by using SPSS to get the study participant. After adding 5% non-response rate the final sample size was 155. Adult (>18 years of old) cranial CT scan images with complete foramen magnum distinctly showing clear margins of FM were included in this study

while cranial CT scan images with damaged or deformed foramen magnum and when associated with pathological conditions were excluded.

Data was collected through observation checklist that was developed using different related literature. The checklist consisted of socio demographic data (sex and age) and measurement parameters for FM dimensions. Foramen magnum dimension was measured by using institutional picture archiving and communication (PACS) workstation through institutional MedWeb.

To ensure the data quality, the data collecting radiologist was briefed on the objective of the study and on each component of the checklist. Measurement of the selected parameters was done on the stored skull CT scanned images by a single Radiologist twice at different time and the values were then averaged.

The maximum antero-posterior diameter was measured from the basion to the opisthion, whereas the maximum transverse diameter was measured between the lateral margins of the FM at the point of greatest lateral curvature (Figure 1). The Area of FM was obtained after tracing the bony margin of the FM on the CT scanned images (Figure 2).

Data was coded, entered and cleaned using EpiData version 3.1 software and exported into SPSS version 20 software for analysis. The statistical analysis for sex comparison was made using *t*-test while One-way ANOVA was applied to compare the mean of FM among age group. The results were considered significant when $P \leq 0.05$. To determine the relationships between the studied parameters, Pearson correlation coefficients were calculated.

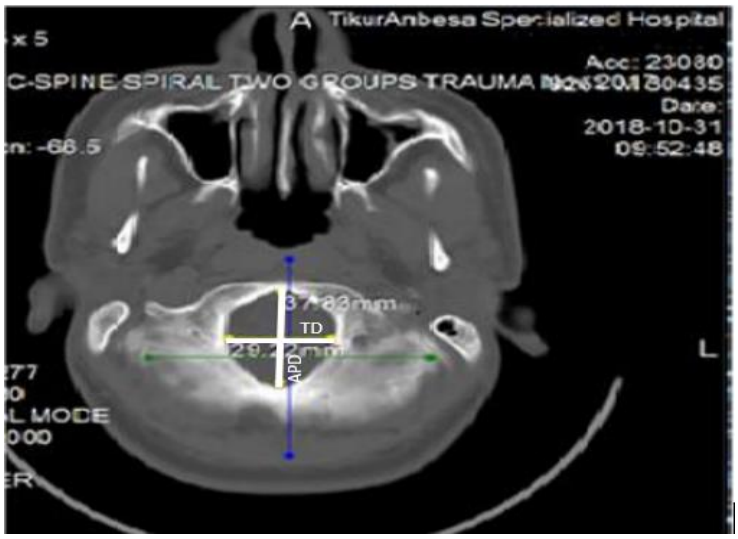

Figure 1. White solid lines indicating measurement of anteroposterior (APD) and transverse diameters (TD) of FM on skull CT scanned images at Tikur Anbessa Specialized Hospital, Addis Ababa

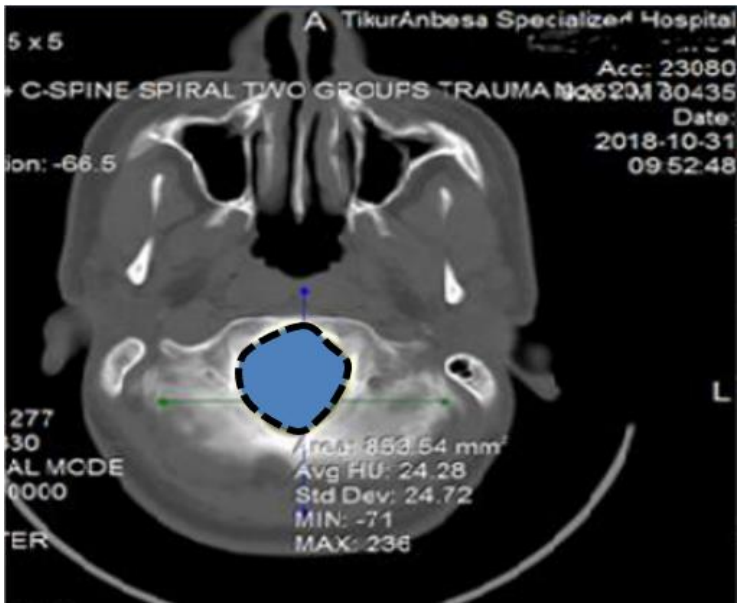

Figure 2. Square dot line indicating outline of the Area of FM on skull CT scanned images at Tikur Anbessa Specialized Hospital, Addis Ababa.

3. RESULTS AND DISCUSSION

The socio-demographic characteristics showed that among 155 skull CT scanned images 82 (53.9%) were male with response rate of (98%). The age range of the subjects was 19 to 79 with mean age 44.78 ± 13.12 years (Table 1).

Table 1. Age category distribution among skull CT scanned individuals at Tikur Anbessa Specialized Hospital, Ethiopia, 2018/19

Age category (*years*)	**Frequency**	**Percent**
19-29	23	15.1
30-39	30	19.7
40-49	36	23.7
50-59	36	23.7
60-69	24	15.8
≥70	**3**	**2.0**
Total	152	100.0

The overall APD of FM among the study participants' skull CT scanned image was (34.55 ± 3.2mm) with 95% CI (34.03-35.06mm) and is in line with a study conducted in Iran and Sudan with a measurement value of (35.04±2.1mm) and (34.1±3.1mm), respectively (Aghakhani *et al*., 2016; Alamin *et al*., 2015).

The general TD of the current study was (28.48 ± 3.03mm) with 95% CI (28-29mm) which is also similar with the findings from Sudan that was figured as (28.57±2.48mm) (Ibrahim, 2016).

A finding from USA on AFM was found consistent with the present study with a mean value of (820± 100mm^2) for the males and (814.77 ± 126.52mm^2) with 95% CI for the females (Wanebo and Chicoine, 2001).

However, the overall mean measurements of APD, TD and AFM in this study were lower than the studies documented in Jordan; (35.1±3.2mm), India; (29.41±2.96mm), and Iran; (860.31±109mm^2), but higher than findings in India; (33.1±3.5mm), (27.6±3.1mm) and (729.15 ±124.87) respectively for respective parameters . Such inconsistencies could have been seen as a result of the smallest

sample size they have used and the distinctiveness of the geographical location of the study population (Samara *et al.*, 2017; Vinutha, 2018; Aghakhani *et al.*, 2016; Kanodia *et al.*, 2012).

The dimensions of foramen magnum was compared between sexes and the mean APD of FM among male and female were (35.08±3.16mm) with 95%CI (34.38-35.77) and (33.92±3.18) with 95%CI (33.17-34.68) respectively. The mean TD of FM was (28.98±2.89 mm) with 95%CI (28.34-29.61) for male and (27.89±3.1mm) with 95% CI (27.15-28.63) for female. The mean AFM was (850.73±133.19mm^2) with 95%CI (821.7-880.00) with 95%CI and (772.64±104.26) with 95%CI (747.78-797.50) for male and female, respectively (Table 2).

Table 2. Comparison of the mean FM dimensions in relation to sex among skull CT scanned individuals at Tikur Anbessa Specialized Hospital, Ethiopia, 2018/19

	Groups	**Mean ± SD**	**T-test**	**P-value**
Anteroposterior diameter of foramen magnum	Male	35.08±3.16	2.239	0.027
	Female	33.92±3.18		
Transverse diameter of foramen magnum	Male	28.98±2.89	2.223	0.028
	Female	27.89±3.11		
Area of foramen magnum	Male	850.73±133.19	3.974	<0.001
	Female	772.64±104.26		

The results in the present study on APD, TD and AFM among male were consistent with study conducted in Iraq; (34.9 ± 2mm), (29.5 ± 2.5mm) for APD and TD respectively, and in Sudan for AFM (835.20 ± 98.23mm^2). Similarly on APD, TD and AFM among females were consonant with findings from India; (33.83±3.51mm), (27.98 ± 2.53mm), (758±109) respectively for respective parameters (Uthman *et al*., 2012; Alamin *et al*., 2015; Vinutha, 2018; Shepur *et al*., 2014). However, the mean figures of APD, TD and AFM in this study among male were lower than study conducted in Switzerland and India with (38. 17 ± 2.70), (30.05 ± 2.61) and (916 ± 145 mm^2) respectively for the respective variables. Similarly, on APD, TD and AFM among females, the present study have

lower value than study revealed from Switzerland; (36.66 ± 2.26), (31. 34 ± 2.19) and (887.69 ± 124.10) (Edwards *et al*., 2013; Jaitley *et al*., 2016)

The findings in this study on APD, TD and AFM among male have higher value than study conducted in India and Iraq with (33.8 ± 3.4), (28.2 ± 2.6) and (765.2 ± 98) respectively for respective parameters of FM. Similarly on APD, TD and AFM among females, the present study have higher value than the study in Iraq (32.9 ± 2) for APD, India (26.6.6 ± 3.5) for TD and Iraq (670.2 ± 93.7 mm^2) for AFM (Uthman *et al*., 2012); Vinutha, 2018; Kanodia et al., 2012). The possible reason for the differences in all the above stated figures might be geographical and racial variation of the study participants.

In general, the present study and most of other related studies have revealed that males do have a greater value in all the measured FM parameters as compared to female groups and the differences were mostly statistically significant. However, a CT scan study from Nigeria (Bello *et al*., 2013) showed that there is no statistically significant difference in APD of FM among male and female, and other two studies that examined dry skull in Switzerland (Gruber *et al*., 2009) and India (Singh and Talwar, 2013),did not find statistically significant difference among male and female group.

As to our finding, there is no significant variation in all the evaluated parameters of FM between different age groups. Valuations of FM dimensions in different age categories were signposted as the highest value of mean APD of FM among CT scanned individuals was measured in the age category of 70-79 (36.66±3.08 $mm^{2)}$ and lowest value in the age group of 19-29 (33.72±3.81 mm). The mean TD of FM had the highest value in the age group of 40-49 (28.7± 3.25 mm) and the lowest value was found in the age group of 70-79 (26.45± 3.54 mm). AFM has the highest mean value in the age category of 70-79 (838.7±238.74 mm^2) and the lowest mean value in the age category of 19-29 (795.78±124.42mm^2) (Table 3).

Table 3. Comparison of the mean foramen magnum dimensions in age groups among skull CT Scanned individuals at Tikur Anbessa Specialized Hospital, Ethiopia, 2018/19

Parameters	**Age category**	**Frequency**	**Mean±SD**	**F-test**	**P-value**
Anteroposterior diameter of foramen magnum	19-29	23	33.72±3.81	0.76	0.58
	30-39	30	34.69±2.93		
	40-49	36	34.3±3.22		
	50-59	36	34.66±2.97		
	60-69	24	35.1±3.27		
	70+	3	36.66±3.80		
Transverse diameter of foramen magnum	19-29	23	28.27±3.18	0.35	0.88
	30-39	30	28.48±3.10		
	40-49	36	28.70±3.25		
	50-59	36	28.41±2.87		
	60-69	24	28.69±2.84		
	70+	3	26.45±3.54		
Area of foramen magnum	19-29	23	795.78±124.42	0.19	0.96
	30-39	30	815.09±121.25		
	40-49	36	809.89±121.10		
	50-59	36	825.09±146.80		
	60-69	24	821.42±104.90		
	70+	3	838.74±238.74		

Pearson correlation equation was applied to see the correlation between all the measured FM dimensions. Variables were positively correlated to each other and there was higher correlation between TD of FM and AFM r= 0.678 at (P > 0.001) and the weakest positive correlation was observed between APD of FM and TD of FM (r =0.28) (Table 4). The present study is the first of its kind in Ethiopia. Therefore, the findings of this study could serve as base line data for further studies.

Table 4. Correlation between the three morphometric variables among skull CT scanned individuals at Tikur Anbessa Specialized Hospital, Ethiopia, 2018/19

		Anteroposterior diameter of foramen magnum	Transverse diameter of foramen magnum	Area of foramen magnum
Anteroposterior diameter of foramen magnum	Pearson Correlation	1	0.282*	0.653*
	Sig. (2-tailed)		<0.001	<0.001
	N	152	152	152
Transverse diameter of foramen magnum	Pearson Correlation	0.282*	1	0.678*
	Sig. (2-tailed)	<.001		<.001
	N	152	152	152
Area of foramen magnum	Pearson Correlation	.653*	.678*	1
	Sig. (2-tailed)	<.001	<.001	
	N	152	152	152

4. CONCLUSION

The present finding indicated that there was a significant morphometric difference in skull CT scanned images between male and female participants. We suggest that the metric parameters of FM should be taken into consideration during surgical intervention around FM for sexes. It is also important to employ these findings for forensic and anthropological investigation of unknown individuals for determining sex.

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Conflict interest

The authors declare that they have no competing interests.

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