Morphometric Analysis of the Sudanese Foramen Magnum: A Computerized Tomography Study

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Abstract

The foramen magnum (FM) is an important anatomical region of the skull base and is of significance for anatomy, anthropology and other medical fields.

This study aimed to verify the morphological characteristics of the (FM) for gender determination in Sudanese individuals by measuring the antero-posterior, transverse diameter, area , circumference and characterizing its shape. Cases were selected among 123 Sudanese skulls (75 were males and 48 were females) who had 3D head computerized tomography scans.

The (FM) shapes were determined as a round shape in 30(24.4%) of the cases, oval in 59 (48.0%), irregular in 14(11.4%) and arrow head in 20(16.3%). The mean antero-posterior and transverse diameters of the (FM) were determined as 34.1±3.1 (mm) and 29.4±2.6 (mm) respectively. Area of the (FM) was 774.3±120.7 (mm^2) and Circumference of the (FM) was 104±12.1 (mm). A significant difference between genders was detected at p-value<0.05.

The data obtained from this study may help the neurosurgeons in characterizing the anatomy of the (FM) for Sudanese as well as enlightening the anthropologists and clinical anatomists.

Keywords: Foramen magnum, CT scan, Gender**.**

1. Introduction

The foramen magnum (FM), is a region between vertebral column and cranium, its importance comes from its relationship to the brain, the spinal cord, vessels and nerves.[Philipp Gruber et al ,2009]Knowledge of normal and variations of skull base foramina is important for neurosurgeons, and anatomists.[Berlis A et al ,1992]

In neurosurgery, the assessment of the (FM) dimensions is used for the access of the brainstem lesions [Furtado SV et al ,2010].Studies accounted that studying the anatomy of the skull base is important for this approach [Muthukumar N,2005].Neurosurgeons performing surgery at that area should be aware of the normal morphology or any variations. [Oksipital Kondil et al, 2011]

Anthropological and medical studies focused on the (FM) morphometry [Sendemie E et al 1994] and changes related to gender [Uysal RMS,et al, 2005], and the use of the (FM)as an important landmark in the forensic science [Holland TD.,1989].Regardless its clinical and anatomical significance, there is lack of reports available in the open literature. Studies about the (FM) are pointed at its importance because it is positioned between brain and spine, and are deliberated about changes of its morphology over time [Henneberg M et al ,1995]

We reported measurements of (FM) collected from Sudanese population and we hope that this information may be valuable for future studies. To the best of our knowledge no studies were done in the open literature regarding the Sudanese, so the objectives of this study were to measure and characterize the (FM) and to verify its dimensions as well as to grant basic data for Sudanese in relation to gender, age and ethnicity.

2. Materials and Methods

2.1 Patients and CT Scanners

A prospective study of 123 consecutive Sudanese patients (75 were males and 48 were females) were enrolled. They were referred to the Radiology Department in the IBN ALHYTAM MEDICAL CENTER , Khartoum, Sudan, in which the patients subjected to CT for Brian for different clinical indications. The study design was approved by the Research Council Ethical Committee –College of Medical Radiological Science .Patients with previous trauma, surgery or pathology in the region of the (FM) were excluded.

All patients examined on a multislice CT scanner (Asteion, TX-021B Toshiba scanner). The scan is performed with the patient in the supine position. It was ensured that there was no rotation or tilt of head in order to demonstrate any bilateral asymmetry, the protocol used for routine head scanning from base of skull through apex, with kVp of 120 and 200 mAs, slice thickness is depending on the structure being scanned, thin data and bone require slice thickness of 5mm and 2mm for reformatted images. Because of the dense bone of the base of skull beam-hardening artifacts are often seen in images of the posterior fossa , thin slices was used to reduce these artifacts .Helical mode is primarily used for the required 3D reformations.

2.2. Method of (FM) measurements

All (FM) measurements were taken from reformatted images (axial, maximum intensity projection and 3D volume rendering), by the measurement function available in the CT system (Asteion , TX-021B Toshiba scanner). For radiological measurements, the Foramen Magnum(FM) measurements were taken as follows :Length of the foramen magnum (LFM) is the distance taken in a straight line from the end of the anterior border (basion) through the center of the foramen magnum until the end of the posterior border toward the median sagittal plane(Antero posterior diameter) .Width of foramen magnum (WFM) was taken as a distance in a straight line from the end of the border right side, with the concavity stronger through the center of the foramen magnum to the opposite end of the lateral border of concavity more pronounced, with transverse direction (transverse diameter).The measurements of foramen magnum area and circumference by tracing the bony border in the 3D volume rendering reformatted images.

2.3 Statistical analyses methods

The data obtained were analyzed statistically by computing descriptive statistics like Mean, ± SD values and percentages. Chi-square test and independent t- test were obtained using IBM SPSS Statistics software package (Inc., Chicago, Illinois version 16). A value of $P<0.05$ was considered significant.

3. Discussion

It was reported that the (FM) as one of the bony features in the cranium, has undergone developmental changes [Nevell L et al 2008;Scot JH , 1958]. The development of skull base in early fetal growth, starts as a cartilaginous structure with many ossification centers including the FM [Scot JH , 1958]. The morphology of the (FM) may vary. [Murshed KA et al ,2003]

The difference in the (FM) morphology from various reports indicates racial variability. [Chet Han et al ,2012] but the irregular shape of (FM) is highlighted by the developmental cranial anomalies [Furtado SV et al 2010] .The most common (FM) shape is the oval [Avci E et al ,2011;Zaidi SH et al, 1988;SindelM et al ,1989; Espinoza E et al ,2011;Hecht JT et al, 1989]

Studies on the anatomical and morphological characteristics of the (FM), along with its variations have particularly contributed towards enabling surgeons to improve the surgical access conditions in cases of tumor resection, and cerebral herniation in the (FM), which may make such procedures more successful [Radhakrishna S et al, 2012]

In our study, oval-shaped (FM) was the morphological type of most frequently found in Sudanese ;(Zaidi SH et al ,1988; Espinoza et al. ,2011 ; Radhakrishna et al. ,2012; Avci et al. ,2011) reported similar findings. Table (1) shows that there is variation in the morphological types of (FM) in Sudanese. The variations have been attributed, among some authors due to different factors such as sexual dimorphism [Ukoha U et al ,2011], types of population [Krıshnamurthy A et al ,2012], and ethnic groups [Espinoza E et al ,2011]. The oval morphological types of (FM) substituted 59(48%)of the sample and the rounded proceeded 30(24.4%) , other types with their respective frequencies of occurrence have been found as arrow head shape in20(16.3%) where it was found with higher percentages in females (8.9%)than males (7.3%) as noticed in table (2),and the irregular shape achieved 14(11.4%),similar findings were described by many authors [Chethan P et al, 2012 , Natsis K et al ,2013]

Table (3) showed that there were differences in the measurements of LFM,WFM,AFM,CFM as well as ,TDH,SDH, between the males and females at $p<0.000$ .The females measurements were less than the males and also showed that the sagittal diameter and transverse diameter are within the same values found in other populations [Schmeltzer A et al., 1971; Catalina-Herrera CJ , 1987; Wanebo JE et al ,2001 and Tubbs RS et al, 2010] ,although the measurements were less than the Spanish(Herrera CJC , 1987).The sex determination is of great value in forensic medicine as well as in anthropology. Therefore , we corroborate that the sagital and transverse diameters of the (FM) were of great value for this determination and the correlation between the area and circumference of the (FM) is of highly significance with the transverse and sagital diameter of the head and (FM) as shown in table(4)

Our study findings may be considered as reference for Sudanese, and the measurements may describe the normal morphological variants of (FM) for Sudanese. Since the anatomy of the (FM) is of interest to many radiological fields, the radiologists must have knowledge of normal anatomy of skull base to determine the presence of abnormality and to help in surgical planning .We trust that the information gained from the present study will be useful to all the medical and radiological fields.

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Table 1 The Sudanese foramen magnum morphology, frequency and percentages.

Foramen Magnum (FM) morphology	Frequency	Percentages (%)
Round	30	24.4
Oval	59	48.0
Arrow head	20	16.3
Irregular	14	11.4
Total	123	100.0%

Table2 The Sudanese foramen magnum morphology cross tabulated with Gender

Morphology of The Foramen Magnum * Gender Cross tabulation					
			Gender		Total
			Male	Female	
Morphology of The Foramen Magnum	Round	Count	21	9	30
		% of Total	17.1%	7.3%	24.4%
	Oval	Count	37	22	59
		% of Total	30.1%	17.9%	48.0%
	Arrow head	Count	9	11	20
		% of Total	7.3%	8.9%	16.3%
	Irregular	Count	8	6	14
		% of Total	6.5%	4.9%	11.4%
	Total	Count	75	48	123
		% of Total	61.0%	39.0%	100.0%
Chi-Square Tests/ P-value 0.343					

Table 3: Variables related Gender, mean and standard deviations, maximum, minimum values.

Variables related Gender						Independent Samples Test T-test for Equality of Means
	Gender	N	Mean ± S. D	Min	Max	P-value
LFM (mm)	Male	75	35.48±2.69	31.3	42.1	.000**
	Female	48	32.00±2.61	25.8	38.3	
WFM (mm)	Male	75	30.62±2.40	26.6	39.5	.000**
	Female	48	27.62±1.98	23.0	32.4	
AFM (mm^2)	Male	75	835.20±98.23	646.1	1102	.000**
	Female	48	679.31±86.74	463.5	892	
CFM (mm)	Male	75	109.36±11.04	88.0	147.3	.000**
	Female	48	95.75±8.84	74.7	125	
TDH (mm)	Male	75	122.68±7.17	104.0	141	.000**
	Female	48	116.29±6.88	101.6	136	
SDH (mm)	Male	75	157.08±8.48	136.0	175	.000**
	Female	48	148.76±9.73	121.0	167	
LFM stands for Length of foramen magnum=Antero Posterior diameters, WFM stands for Width of foramen magnum=transverse diameter, CFM stands for Circumference of foramen magnum and AFM stands for Area of foramen magnum.TDH= transverse diameter of the head, SDH=Sagital diameter of the head. ** Correlations are significance at p value < 0.01						

Table4 The Sudanese foramen magnum morphology area(AFM) and circumference(CFM) correlated with transverse(TDH) and sagittal diameter of the head(SDH),Antro posterior(LFM) and transverse diameter(WFM) of the foramen magnum**.**

Correlations between the variables					
		TDH	SDH	LFM	WFM
AFM (mm^2)	Pearson Correlation	.360**	.285**	.874**	.878**
	P-value	.000	.001	.000	.000
	N	123	123	123	123
CFM (mm)	Pearson Correlation	.295**	.318**	.773**	.780**
	P-value	.001	.000	.000	.000
	N	123	123	123	123
LFM stands for Length of foramen magnum=Antero Posterior diameters, WFM stands for Width of foramen magnum=transverse diameter, CFM stands for Circumference of foramen magnum and AFM stands for Area of foramen magnum.TDH= transverse diameter of the head, SDH=Sagital diameter of the head. **Correlations are significant at p< 0.01 .					