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Morphometric and Morphological Study of Foramen Magnum in Dry Adult Skulls in a Southern Nigerian Population

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ABSTRACT

The foramen magnum contains the lower end of the medulla oblongata, the vertebral arteries and the spinal accessory nerve. The purpose of this study was to measure the size, determine the index and area as well as analyse the shapes of the foramen magnum in dry adult human skulls of Nigerians. The study sample comprised 74adult dry skulls of no define dage and gender. Anteroposterior and transverse dimensions were measured; and foramen magnum index and area were calculated. The shape of the foramen was also assessed. The commonest shape was oval (48.6%) followed by round (45.9%). The anteroposterior dimension was significantly longer than the transverse dimension. This will be of forensic, anthropological and clinical importance.

Key words: Foramen magnum, Morphology, Morphometry, Index, Area.

INTRODUCTION

The **foramenmagnum (FM)**is situated in an anteromedian position in the occipital bone of the cranium, and is oval, wider behind, with its greatest diameter being anteroposterior[1]. It contains the lower end of the medulla oblongata, the vertebral arteries and the spinal accessory nerve. Anteriorly, the margin of the **foramenmagnum** is slightly overlapped by the occipital condyles which project down to articulate with the superior articular facets on the lateral masses of the atlas [1]. One-third of the FM is situated in front and two-thirds behind a line joining the tips of the mastoid process [2].

It has been reported that in humans, the foramen magnum is further underneath the head than in great apes. Consequently, the neck muscles and the occipitofrontalis muscle in humans do not need to be heavily robust in order to hold the head upright. Comparisons of the position of the foramen magnum in early hominid species are useful to determine how comfortable a particular species was in bipeds rather than quadrupedal state[3].

The anthropometry of the cranium may be used for forensic and anthropological examinations of unknown individuals as it regards the human population morphological studies of age estimation, stature, ethnicity[4, 5] and sex[6-11], which is usually the first in the human identification process.

The knowledge of the dimensions of FM is of clinical importance as in brain herniation[12, 13] and conditions like achondroplasia and other bone disorders that distort the size of the FM may cause compression of vital structures that traverse it[14]. The shape of the foramen magnum is of forensic, clinical and radiological value[4]. Shapes of foramen magnum have been categorizedinto oval, round, tetragonal, pentagonal, hexagonal and irregular[15].

Despite its forensic, anthropological and clinical importance, there are only a very few anatomical studies available in the literature, with particular interest in the Nigerian population. The purpose of this study therefore, was to measure the size, determine the index and area as well as analyse the shapes of FM of Nigerian dry adult human skulls.

MATERIALS AND METHODS

The present study was conducted in the Department of Anatomy, Delta State University, Abraka, Nigeria, between January and October, 2013.An approval was obtained from the Research Ethics Committee of College of Health Sciences, of the University beforeconducting this study. The study sample comprised 74 dryskulls, obtained from the archives of the Museum of Department of Anatomyin NnamdiAzikiwe University,Awka;Anambra State,Uli; Delta State University,Abraka;University of Benin, Benin City; Ambrose Ali University, Ekpoma and Niger Delta University, Wilberforce Island. The exact adult age and gender of the skulls were not defined.

The following dimensions of foramen magnum (FM) weremeasured using digital Vernier caliper (Mitutoyo, Japan)

- Foramen magnum length: The distance between Basion and Opisthion. This is the sagittal or anteroposterior diameter (APD) (figure 1).
- Foramen magnum width: The distance between the lateral margins of the foramen magnum at the point of greatest lateral curvature. This is the transverse diameter (TD) (figure 1).
- The FM index was calculated as: Foramen magnum length/ Foramen magnum breadth.
- Area of the foramen was calculated from length and width of foramen magnum utilizing different formulae given by Teixeria[9] and Routal et al[16] and used by Singh and Talwar[17]:

  Formula given by Teixeria[9]: Area = $\pi ([LFM+WFM]/4)^2$.
  Formula given by Routal et al [16]: Area = $LFM \times WFM \times \pi / 4$.
  Where LFM is foramen magnum length and WFM is foramen magnum width.

Error of Measurements
Assessment of error of measurements was carried out by calculating the technical error of measurement (TEM) and the coefficient of reliability (R)based on global anthropometric norm[18, 19]. The APD and TD of the FM of ten dry skulls numbered '1 to 10' were measured by one observer twice, at interval of five days.

The TEM was calculated using the formula: **$TEM = \sqrt{(\Sigma D^2)/2N}$**.Where D =difference between first and second readings; N = number of dry skulls in each case.

The coefficient of reliability (R)= $1 - (\text{Total TEM})^2/SD^2$
It was observed that TEM for APD and TD was 0.059 and 0.61 respectively. These values are minimal and will not bias the result of the study. It was also observed that the coefficient of reliability (R) for APD and TD was 0.60 in each case.

Data Analysis
The data wereanalysed using Statistical Package for Social Sciences (SPSS) version 16.0.Descriptive statistics was used, and paired t-test was also used to ascertain statistical significant difference between FM length and width. P-value < 0.05 is considered statistically significant.

Figure 1: Foramen Magnum and masurements taken.
AP= Anteroposterior diameter, TD=Transverse diameter.

RESULTS
The results of the present study are presented in table 1 to 3 and figure 2

Table 1: Descriptive statistics of parameters measured

Parameter	Minimum	Maximum	Mean	SD
Anteroposterior diameter (mm)	30.67	43.06	38.18	2.02
transverse diameter (mm)	25.99	38.45	31.97	2.41
foramen magnum index	0.99	1.36	1.20	0.08
Teixeria area (mm^2)	630.13	1174.61	968.84	101.88
Routal et al. area (mm^2)	625.83	1174.57	960.24	102.94

Table 2: Paired t-test of dimensions and areas studied.

Parameters		Mean	SD	t	Df	Sig. (2-tailed)
Pair 1	anteroposterior diameter (mm) transverse diameter (mm)	6.20	2.33	22.95	73	0.001
Pair 2	Teixeria area – Routal et al. area	8.60	5.34	13.86	73	0.001

Table 3: Paired Samples Correlations of parameters.

time		N	Correlation	Sig.
Pair 1	anteroposterior diameter& transverse diameter	74	0.459	0.001
Pair 2	Teixeria area &Routal et al. area	74	0.999	0.001

Table 1 shows the descriptive statistics of the dimensions, index and area of the foramen magnum in the present study. The mean anteroposterior dimension is greater than the mean transverse diameter. The mean area of the foramen magnum based on Teixeria[9] formula is greater than the value based on Routal et al [16].

Table 2 shows tests of significant difference between dimensions and between area categories. The mean anteroposterior diameter is significantly greater than the transverse diameter. The mean area of the foramen magnum using Teixeria[9] formula is significantly greater than the value based on Routal et al [16].

Table 3 shows correlations between the dimensions and between the area categories.
There was significant correlation between the anteroposteriorand the transverse diameters. There was significant correlation between the area of the foramen magnum based on Teixeria[9] and Routal et al. [16] formulae.

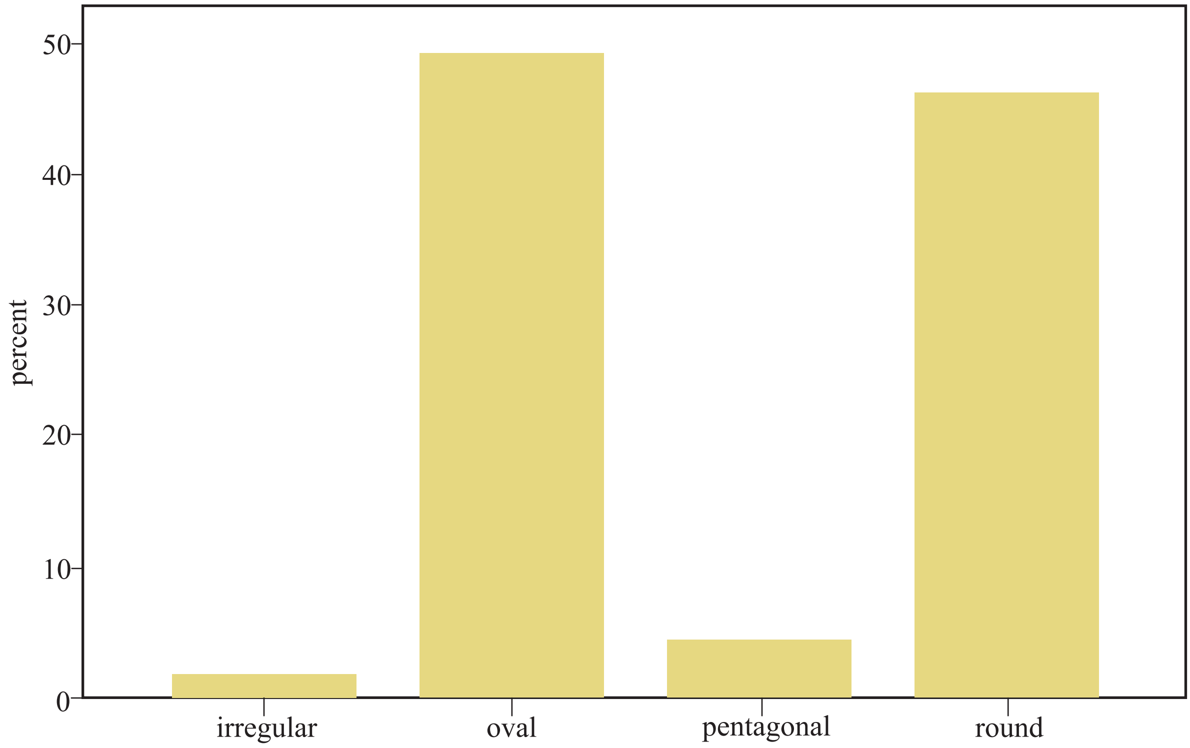

Figure 2: Distribution of shapes of foramen magnum in the population.

Figure 1 shows the position of the foramen magnum and the dimensions measured. AP is the foramen magnum length (anteroposterior or sagittal diameter). TD is the transverse diameter (foramen magnum width). OC is occipital condyle which slightly overlaps the foramen magnum.

Figure 2 shows distribution of shapes of foramen magnum. The dominant shape type of the 74 adult dry human skulls studied was oval (48.6%), closely followed by round (45.9%). The irregular (1.4%) shape trailed behind pentagonal shape (4.1%).

DISCUSSION

Conceptually and empirically, varied reports have been presented across the globe on the shape of the foramen magnum (FM). In the present study, oval and round shapes are outstanding, with the former being commonest in the population. This confirms the concept that FM is oval in shape [1]. It is also similar to an Indian study [20] that reported oval shape as the most common type, followed by round, tetragonal and pentagonal.In a related study in Turkey[15], round shape was the commonest (21.8%), followed by hexagonal shape (17.2%), pentagonal (13.6%), tetragonal (12.7%), irregular (type A = 10.9%, type B = 9.09%), oval type (8.1%) and egg shape (6.3%). The authors classified the irregular shape into type A and type B. Also, Chethan et al. [21] reported round shape as the commonest (22.6%), followed by egg and tetragonal (18.9% respectively), oval and irregular (15.1% respectively), hexagonal (5.6%) and pentagonal (3.8%). In a Kenyan study, the shape of the FM was polygonal (63%), circular (24%) and oval (13%) [22]**.** It has been opined that the shape of the FM is determined by the spinal cord and the hind brain [23]. The varied shapes from the different reports suggest ethnic or racial variability in the FM morphology, which may be characteristics of each population that are influenced by genetic, environmental, and socioeconomic factors [24].

The present study also determined the anteroposterior diameter (APD) or sagittal diameter and transverse diameter (TD); FM index and the area of the FM. The mean APD and TD were 38.18±2.02 mm and 31.97±2.41mm respectively. These are higher than the average values obtained in some related Indian studies [20,21, 25]. The mean APD in the present study is higher than the average value of APD, but approximates the value of the TD in a Turkish study [15], an Iraqi study [26], and a Brazilian study[7]. In a Kenya study [22] the mean APD is similar to but the TD higher than values in the present study. In Nigeria, previous studies [6, 27] also reported APD and TD lower than the present study. The differences observed in the various studies points to genetic, environmental, geographic and ethnic or racial variations. Another factor that may affect results is the sample size, as the larger the sample the closer it approximates population mean. It is worthy of note that error of measurements also affect the outcome of results. In the presents study, the error of measurements was assessed and found to be small and of no effect on the results. The results have been noted to be reproducible and reliable based on the coefficient of reliability of the measurements. It is therefore imperative to know the error and reliability of anthropometric technique of a study.

The mean FM index was calculated to be 1.20±0.08. This is similar to the finding of a previous study in India [21]. Though the present study did not take into cognizance the morphology of the occipital condyles, it has been opined that wide sagittally inclined and medially protuberant occipital condyles in addition to FM index greater than 1.2 will require much more extensive body resection in surgeries of this area [28].

It was observed in the present study that the mean FM area was 968.84±101.88 based on Teixeria formula, and 960.24±102.94 based on Routal et al formula. These values are higher when compared with a Turkish study [15] and an Iraqi study [26] that employed computerized tomographic images. The mean area in both formulae in the present study is also much higher than an Indian study [25] and a Nigerian study [6]. This is a reflection of the anteroposterior and transverse dimensions of the foramen magnum.

The correlation between anterior-posterior and transverse dimensions was significant (r=0.46; p=0.001). This is similar to the report in which correlation between anterior-posterior and transverse dimensions was significant [26]. Also, correlation between the area of the FM derived from the two formulae was significant (r=0.999; p=0.001). This is expectedly so as both dimensions of the foramen grow together.

In present study, a test of significant difference between the length and breadth of the FM was analysed and found out that the length is significantly greater than the width. This agrees with the report that anteroposterior diameter is the greatest [1]. Similarly, the area of the FM based on Teixeria formula is significantly greater than the area based on Routal formula (p=0.001). This implies that these formulae are distinct, and the result of one cannot be used for the other.

In conclusion, the study has shown that the oval and round types are the main foramen magnum shapes in this population. The anteroposterior dimension is significantly longer than the transverse dimension. There is significant correlation between the anteroposterior and the transverse dimensions.

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