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SEX DETERMINATION FROM FORAMEN MAGNUM USING COMPUTED TOMOGRAPHY

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ABSTRACT

Introduction: Forensic anthropology involves scientific techniques to identify human remains and detect crimes. Sex determination is the first step in forensic identification followed by age and stature. The skull base is the thickest part of the cranium and hence relatively protected against trauma or inhumation. The foramen magnum is the largest foramen of the skull base and is hence reported to be a sex discriminator in some populations.

The study aimed to find the sexual dimorphism of the foramen magnum in the Yobe population by analyzing its morphometry and morphology.

Materials and Method: The anteroposterior length and transverse diameter of the foramen magnum were measured and various shapes of the foramen magnum were determined using CT images of the Yobe population who underwent CT examination at Yobe State University Teaching Hospital. Radinsky's formula was used to calculate the area of the foramen magnum. Binary logistic regression was used to analyze the sexual discrimination accuracy of the foramen magnum.

Results: Mean values of anteroposterior length, transverse diameter, and area of the foramen magnum were determined and are found to be greater in males than in females. The morphometric of the foramen magnum and the area calculated showed a significant difference ($p<0.05$) between males and females. The shapes of foramen magnum show a significant association ($P<0.05$) between males and females. ROC curve analysis for the morphometric data shows 86.1% overall sex predictive accuracy.

Conclusions: Considering the predictive accuracy of the foramen magnum in sexual discrimination, it can be used to predict the sex of the Yobe population

Keywords: Sex, Foramen magnum, Computed tomography, Forensic, Morphology, Morphometric

INTRODUCTION

Forensic anthropology is the use of physical anthropology through scientific techniques to identify human remains and also in detecting crimes (1). Sex is the first step in forensic identification followed by age and stature which all depend on sex (2) Sex determination is a significant parameter in a forensic context and requires much attention in detecting human remains. Forensic anthropologist often adopts morphological and morphometric methods in the human sex identification process despite the advent of molecular techniques (3). The morphological assessment is based on subjective analysis through physical inspection whereas the morphometric is based on statistical analysis by comparing measurements (4). The anthropological method of determining sex has an accuracy rate of 94.7% when compared with DNA typing results with increasing accuracy as more skeletal remains are available(5).

The use of radiological modalities has widely been used in forensic anthropology as a guide or a source of data for determining sex, especially in countries where a collection of ancestral skeletal remains are not available (6). With the advent of PACs, medical images are easily retrieved and analyzed to evaluate human anatomy(1).

Computed tomography gives a reliable and accurate measurement, it also helps in viewing a three-dimension of human body without resection, hence time consumption is reduced(7).

The Pelvic and skull are the two best sex dimorphic region in the body. The Pelvic has superior sex dimorphic characteristics due to its reproductive potential and hormonal factors, however as human remains are found incomplete, the skull is the best replaceable region to determine sex due to its thickness and resistance to physical damage(8).

The foramen magnum is the largest foramen located at the base of the skull which allows passage of neurovascular structures. Meningioma, achondroplasia, and herniation of the cerebellum tonsils can affect the normal morphology of the foramen "(9). The dimension of the foramen magnum help in sex determination, diagnosing malformations such as Arnold charity's syndrome and serve as a reference point before the cutting off of the foramen magnum in the posterior cranial fossa lesion (10). Therefore, measurement of normal dimensions of the foramen magnum is recommended as a referencing index in forensic cases as well as clinical diagnoses of lesions associated with the foramen magnum.

In Nigeria, crime rate such as bomb blast, armed robbery, murder, rape, human and drug trafficking has increased over the years (11). Such crimes could lead to death and the body can be fragmented, decomposed, or unidentified. Forensic identification is a multi-disciplinary approach. Nevertheless, the DNA test was widely used but it is associated with several challenges such as the weak amount of DNA, degraded nature of nucleic acid, enzymatic inhibitors during extraction, faint amplification of band, and risk of contamination during excavation or manipulations of the sample (12). Hence the need to determine sex through the morphometry and morphology of foramen magnum of the Yobe population.

MATERIALS AND METHOD

The study is a retrospective correctional study consisting of 126 cranial CT images of the Yobe population that underwent CT examination at the radiology department of Yobe state university teaching Hospital (YSUTH), 63 samples were recruited for males and females each. CT images of Subjects with congenital and acquired diseases that can cause cranial deformities, as well as poorly acquired images, were excluded from the study. The anteroposterior length and transverse diameter of the foramen magnum were measured and the area was calculated using Radisky`s formula–(13). Data obtained were analyzed using Medcalc version 20. An Independent T-test was used to determine the statistical significance difference among the sexes, a P-value of 0.05 is considered significant. Logistic regression was applied to predict the sex.

RESULT

The APL, TD and FMA were measured; all morphometric of foramen magnum were normally distributed when subjected to Shapiro-Wilk test.

The mean APL, TD and FMA were significantly larger in males than females (40.15mm ± 2.30mm and 36.04mm ± 3.00mm), (32.25mm ± 2.40 and 29.69mm ± 2.93mm) and (1017.763mm ± 108.88mm and 843.59mm^2 ± 135.07 mm^2) values for males and females respectively as shown in table 1.

Table 4.1: Mean morphometric diameters and area of foramen magnum

	Mean APL(mm) ± SD		Mean TD(mm) ± SD		FMA (mm) ± SD	
	Male	Female	Male	Female	Male	Female
	40.15±2.3	36.040±3.0	32.25± 2.4	29.68± 2.9	1017.8±108.9	843.6± 135.1
T	4.925		3.194		4.544	
P value	P<.0001		P<.001		P<.0001	

SD= standard deviation, APL=anteroposterior length, TD=transverse diameter, FMA= foramen magnum area, T= student T -test, P = significant level at alpha = 0.05

The ROC analysis graph for APL, TD, and FMA respectively are shown in Figure 4.1, Figure 4.2, and Figure 4.3. The area under curve of APL is the highest (AUC=0.865) followed by FMA (AUC=0.846) and the least is TD (AUC=0.758) this signifies discriminating accuracy for APL, FMA and TD to be 86.5%, 84.6% and 75.8% respectively. However, the ROC curve analysis for multivariate logistic regression area under curve (AUC=0.861) denoting 86.1% accuracy of discriminating sex when all the variables (APL, TD and Area) are used. Table 4. Shows the ROC table for the multivariate analysis.

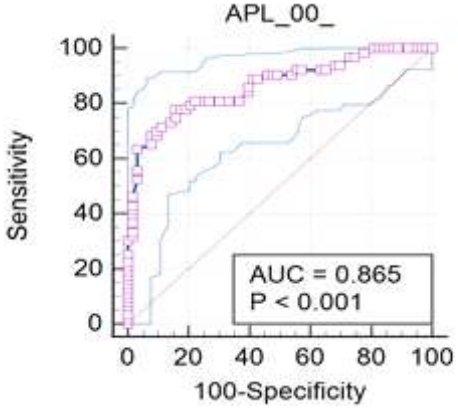

Figure 4.1: ROC curve graph of APL

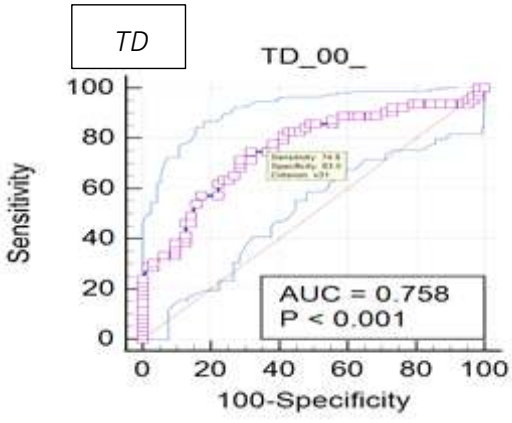

Fig. 4.2: ROC curve graph of TD

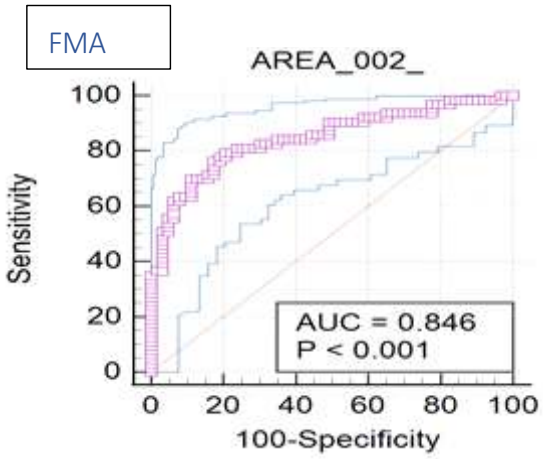

Fig.4.3: ROC curve graph of FMA

Table 4.2: Multivariate ROC curve table

Area under the ROC curve (AUC)	0.861
Standard Error	0.0329
95% Confidence interval	0.788 to 0.916

Regarding the morphological analysis of foramen magnum; hexagonal {n=54(42%)}, egg shape {n=33 (26.2%)}, pentagonal {n=15(11.9%)}, round {n=11 (8.7%)}, irregular {n=5 (4%)}, oval {n=6(4.8%)} and tetragonal {n=2(2%)}. Hexagonal is the most common shape among males accounting for 61% of hexagonal shapes while egg shape is the most common among females accounting for 72% of total egg shape. Tetragonal shape is the least shape among both sexes. Frequency distribution of foramen magnum shape in relation to sex is shown in table 4. The association of foramen magnum shape and sex was tested using Pearson chi-square and hence significant Chi-square value at P=0.0251 which is less than the alpha value P=0.05.

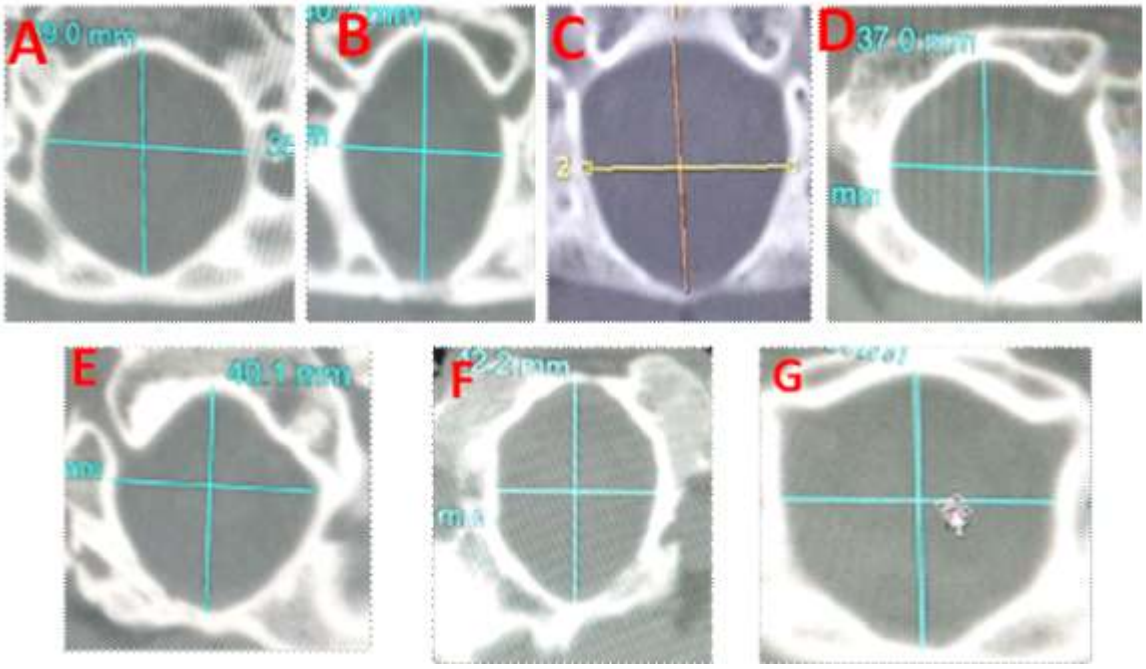

Fig. 4.4: Morphological variations of foramen magnum. Key: A-Round-shaped; B- Oval; C- Egg; D- Irregular; E-Tetragonal; F- Pentagonal; G- Hexagonal

Table 4.4: Shapes frequency distribution of sex

SEX	EGG	HEXAGONAL	IRREGULAR	OVAL	PENTAGONAL	ROUND	TETRAGONAL
Male	9	33	3	2	11	4	1
Female	24	21	2	4	4	7	1
Total	33 (26.2%)	54 (42.9%)	5 (4.0%)	6 (4.8%)	15 (11.9%)	11 (8.7%)	2 (1.6%)
Chi-squared	14.436						
DF	6						
Sig. level	P = 0.0251*						

DISCUSSION

Several studies have been conducted on different population around the world to determine sex through foramen magnum due to its robustness and resistivity. However, the determination of sex is population specific.

In the present study, the mean APL is significantly larger in males than females ($p<0.05$), this is in agreement with the study by Ukoha *et al* (14) in Southern Ngeria. Similarly, researches by Patricia *et al.,* 2020'(15); El-Barany *et al.,* 2016;—(16) Abo EL-atta *et al.,* 2020(17) and Tellioglu *et al.,* 2018'"–(18) reported the mean APL to be significantly larger in males than females.

Likewise studies by Bello *et al.,* 2013(19) and ; Moodley *et al.,* 2019 '(20) also reported larger APL in males than females, however, no statistical significance was noted among the sexes.

The foramen magnum TD was significantly larger in males than females in the present study. This is in keeping with the studies by Ukoha *et al.,* 2011 (14) Bello *et al.,* 2013(19); El Barany *et al.,* 2016—(16); Abo El-atta *et al.,* 2020;(17) Tellioglu *et al.,* 2018'"–(18).

More also, Patricia *et al.,* 2020 '(15) report larger TD in males although no statistical significance was noted among the sexes.

Foramen magnum area is significantly larger in males than females with AUC =0.846 when subjected to ROC curve. This is in agreement with studies by Abo-eletta, Patricia et al; Singh et al; Moodley et al; Lashin et al; and Toneva et al. Wani et al(21) reports larger foramen magnum in males than females. However, no statistical significant difference between them.

Morphological variations of foramen Magnum exist since from foetal life development '"(22).

The present study reveals hexagonal, egg, irregular, oval, pentagonal, round and tetragonal shapes as the shape of the foramen magnum with hexagonal and egg shapes as the most common shapes among the males and female sexes respectively.

This is contrary to studies by conducted outside Nigeria by Moodley et al 2019'(20) and Patricia et al 2020 '(15) in which the former found egg shape to be the most commonly observed shape among both sexes whereas the latter reported oval and hexagonal as the most common foramen magnum shapes in males and females sexes respectively.

There is no published work that has been conducted in Nigeria to assess sexual dimorphism based on shape according to the researcher's best knowledge as at the time of the study.

A Significant association ($P=0.0251 < 0.05$) was found between the shapes of foramen magnum and both sexes. This is contrary to a study in South Africa by Moodley et al. 2019 '(20) ($p=0.736$) and Patricia *et al.,* 2020'(15) ($p=0.48$) who reported no association between foramen magnum shape and sex

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