Scholars Journal of Applied Medical Sciences (SJAMS) **ISSN 2320-6691 (Online)**
Sch. J. App. Med. Sci., 2016; 4(3F):1071-1074 **ISSN 2347-954X (Print)**

(An International Publisher for Academic and Scientific Resources)
www.saspublisher.com

Original Research Article

Role of Foramen Magnum in Sex determination: A Computed Tomographic Study

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Abstract: The foramen magnum (FM) is an important landmark of the base of skull and is of particular interest to many fields of medicine. In literature, many authors have reported the usefulness of the FM in gender determination. The focus of this study was to evaluate the morphological differences of foramen magnum for sex determination in human individuals using computed tomography scan. Ninety five subjects (55 males, 40 females) between 20-70 years were included in the study. The most appropriate images of foramen magnum were selected for study purpose. The measurements of anteroposterior diameter and transverse diameter of foramen magnum available by the cranial CT were noted and foramen magnum index was calculated. Data was collected and compiled using Microsoft Excel Sheet (Microsoft Office 2007). Statistical analysis was done using the statistical package for the social science (SPSS 17.0) and $p< 0.05$ was considered statistically significant. Mean age in male and female subjects was 39.98±14.26 and 42.65±10.83 years respectively. The overall mean TD, APD and FMI was 30.25±3.14 mm, 36.20±3.19 mm and 83.72±6.63 respectively. There was significant difference in mean transverse diameter ($p=0.0159$) and antero-posterior diameter ($p=0.0000$) between male and female subjects. However, no significant difference in mean foramen magnum index in between male and female was noted ($p=0.2418$). In our study, the sexual dimorphism is present in the foramen magnum. Analysis of the foramen magnum diameters may be statistically useful in determining sex of the unknown skull.
Keywords: Foramen Magnum, Computed Tomographic Scan, Transverse Diameter, Antero-posterior Diameter, Foramen Magnum Index, Sex Determination

INTRODUCTION:

The foramen magnum (FM) is an important landmark of the base of skull and is of particular interest to many fields of medicine [1].Sex determination from skull morphology is challenging and important task in medico-legal cases and it is considered as one of the most reliable bones for sex determination [2].The basal region of the occipital bone is likely to survive the physical insults than the other parts of skull owing to the abundant soft tissue cover, skull thickness in the region, and its relatively well-protected anatomical position [3].Thus, there is an increased possibility of recovering this part of skull even in cases of severe trauma, and studies on the occipital bone may provide useful clues in identification of significantly disrupted remains [4].

In literature, many authors have reported the usefulness of the FM in sex determination. Significant craniometric differences exist in the FM between the two sexes. The FM measurements in males are greater because they tend to have larger heads than females. Such studies have been conducted using Computed Tomographic (CT) scans of living individuals and dried skull and the studies have reported that all dimensions of FM were larger in males than females. The advantage of studying sex determination by measurements with the help of CT scan in living subjects over human dried skull is that sex of the living individuals is already known with 100% accuracy whereas sex of the dried skull needs to be confirmed by

other osteometric measurements/morphological characteristics.

The focus of this study was to evaluate the morphological differences of foramen magnum for sex determination in human individuals using computed tomography scan.

MATERIAL & METHODS:

After getting approval from Institutional Ethical Committee, 95 subjects comprising of 55 males and 40 females between 20-70 years were included in the study. Informed and understood valid consent was taken from the subjects/relatives of the subjects undergoing computed tomographic study in the department of Radiodiagnosis, Rohilkhand Medical College & Hospital, Bareilly, U.P., and India. Study subjects with cranial deformities and structural abnormalities which could affect foramen magnum dimensions were excluded from the study. GE 16 slice bright speed CT scanner was used to obtain imaging. A consecutive CT slices were parallel to orbito-meatal line in 5 mm thickness in axial mode. The most appropriate images of foramen magnum were selected for study purpose. The measurements of anteroposterior diameter (APD) and transverse diameter (TD) of foramen magnum available by the cranial CT were noted in millimetres.

APD of the foramen magnum was the distance between opisthion to basion along the midsagittal plane while TD was the maximum distance along the transverse plane. Foramen magnum index (FMI) was calculated by the following formula [5]:

Foramen Magnum Index = Transverse diameter x 100/ Antero-posterior diameter

Data was collected and compiled using Microsoft Excel Sheet (Microsoft Office 2007). The differences in length and width of foramen magnum between males and females were assessed statistically. Statistical analysis was done using the statistical package for the social science (SPSS 17.0) using independent t-test and $p< 0.05$ was considered statistically significant.

RESULTS:

Mean age in male subjects was 39.98±14.26 years and in female it was 42.65±10.83 years. Overall mean age including male and female subjects was 41.11 ± 12.93 years. The overall mean TD, APD and FMI was 30.25±3.14 mm, 36.20±3.19 mm and 83.72±6.63 respectively. [Table - 1]

Tables-1: Morphometric measurements of foramen magnum (n = 95)

Parameters	**Mean ± SD**
Age (Years)	41.11 ± 12.93
Transverse diameter (mm)	30.25 ± 3.14
Antero-posterior diameter (mm)	36.20 ± 3.19
Foramen magnum index	83.72 ± 6.63

The mean transverse diameter (mm) was 30.91±2.93 in male and 29.395±3.22 in female subjects. There was significant difference in mean transverse diameter between male and female (p=0.0159). Mean Antero-posterior diameter in male was 37.32±3.09 mm whereas in female it was 34.66±2.68 mm. There was highly significant difference in mean antero-posterior diameter in between male and female (p=0.0000). Mean foramen magnum index was 83.04±6.98in male and 84.66±6.08 in female individuals. There was no significant difference in mean foramen magnum index between male and female (p=0.2418). [Table - 2]

Table-2: Statistical analysis of foramen magnum measurements in relation to sex

Parameters	**Male (n = 55)**	**Female (n = 40)**	**t- value**	**p-value**
Transverse diameter (Mean ± SD)mm	30.91± 2.93	29.39 ± 3.22	2.4574	0.0159 (Significant)
Antero-posterior diameter (Mean ± SD)mm	37.32 ± 3.09	34.66 ± 2.68	4.3762	0.0000 (Highly significant)
Foramen magnum index(Mean ± SD)	83.04 ± 6.98	84.66 ± 6.08	1.1781	0.2418 (Not significant)

•$p<0.05$ considered statistically significant.

DISCUSSION:

The FM development is regulated by various biological factors and non-biological factors during pre and postnatal period. Genetic and hormonal factors are major players among biological factors [6]. Since FM is a regular structure at the base of the skull and is less

likely to undergo major morphological changes due to it's relatively protected anatomical position, therefore it has been used for sex determination [7]. The first research published on estimation of sex based on the size of foramen magnum was probably by Teixeira in the last quarter of 20th century [8].Many workers in the field have worked on linear diameters of the foramen magnum by using dry skulls or radiological methods like CT scan, magnetic resonance imaging and classic X-ray. Among radiological methods, CT scan has been used more frequently. We also used CT scan to take measurements of FM.

In the study on morphometric analysis of the FM by CT carried out by Erdil *et al.;* [9] the mean age of the 54 subjects was found to be 43.63±21.28 years, TD 29.84±2.90 mm, APD 35.58±4.11 mm and FMI 84.36±8.40 which corresponded well with the findings of our study. The average value of foramen magnum index in human skull obtained by Howale *et al.;* [10] and Chaturvedi & Harneja [11] was 84.85±4.77 and 83.81 respectively which was also well correlated with our study.

While evaluating morphometric measurements of FM according to sex, Erdil *et al.;* [9] noted TD value 30.75±2.81 in male and 29.98±2.78 in female, and APD value 36.95±4.01 in male and 34.41±3.89 in female. Both these diameters were higher in male as compared to female and a statistical difference ($p<0.05$) in both the sexes was observed. However, the FMI was higher (84.94±7.67) in female as compared to male but the value was not statistically different. Their findings were consistent with ours.

A significant positive correlation was found between the length and breadth of the foramen magnum in both males (n=142) and females (n=171) in another study conducted by Burdan *et al.;* [6] while studying morphology of the FM in young Eastern European adults using 3D computer tomography image.

Muralidhar *et al.;* [12] used CT scan images and recorded longitudinal diameter of the foramen magnum of 38.5±3.6mm in male, while in female it was 35.2±3.1mm. The longitudinal diameter of the foramen magnum of male subject was significantly large when compared to female subjects. The transverse diameter of the foramen magnum in male subject was 29.1±2.3mm, whereas in female subjects it was 27.6±2.3mm. Mean transverse diameter of the foramen magnum was not significantly greater than in female subjects.

Other researchers [13, 14] in the field, who used CT scan to study FM diameters, also concluded that the diameters in male were higher as compared to those of females.

The comparison of the morphometric analysis obtained in our study was in agreement with the results of other studies and literatures in the field. Morphometric analysis of FM may provide a statistically useful indication as to sex of the unknown skull in the investigation/research especially in the field of Anthropology and Forensic Medicine.

CONCLUSION:

The results demonstrated that sexual dimorphism is present in the foramen magnum. In incomplete skeletons where only base of skull is available, metric analysis of the foramen magnum diameters may be statistically useful in determining sex of the unknown skull.

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