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Original Research Article

MORPHOLOGY AND MORPHOMETRIC ANALYSIS OF FORAMEN MAGNUM IN ADULT HUMAN SKULLS

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ABSTRACT

Background: The Foramen magnum is an important landmark present at the base of the skull, it serves as a transitional zone between spine and skull. It is closely related to vital structures such as medulla oblongata, meninges, anterior and posterior spinal arteries, vertebral arteries and spinal accessory nerve, passing through it hence thorough knowledge of foramen magnum is required. These structures passing may undergo compression in case of foramen magnum herniation, meningiomas and foramen magnum achondroplasia.

Aims: The present study aims in performing the morphometric analysis foramen magnum and to classify it based on its shape.

Materials and methodology A total number of 64 adult dry human skulls were evaluated from the Department of Anatomy, ESIC MC & PGIMSR, Rajajinagar, Bengaluru, Karnataka.

Results: The mean antero-posterior diameter was found to be 34.10 ± 2.63 mm, mean transverse diameter was 28.07 ± 1.87 mm, with mean area of 752.07 ± 111.97 mm^2 and foramen magnum index was 1.21 ± 0.12. The foramen magnum shapes were classified as oval (30%), circle (12%), hexagonal (3%), pentagonal (5%), egg (17%), leaf (6%), irregular (27%).

Conclusion: The morphometry along with other parameters can be used for sex determination in partially damaged skull bones of unknown individuals. The obtained data is useful not only for anatomists but also the neurosurgeons, otorhinolaryngologist and radiologists.

Keywords: Foramen Magnum, Morphometry, Meningioma, Achondroplasia, Antero-Posterior Diameter, Transverse Diameter, Foramen Magnum Area, Foramen Magnum Index.

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INTRODUCTION

Foramen magnum is the most prominent structure situated in the floor of the posterior cranial fossa in the occipital bone [1]. The major structure passing through this foramen are medulla oblongata, vertebral arteries,

anterior and posterior spinal arteries and the spinal accessory nerve [2,3]. It is surrounded by basilar part clivus anteriorly, the squamous part posteriorly, and condyles are present on right and left lateral side [4].

Spinal osteometry is a vital aspect of research in anthropology and basic medical sciences. Foramen magnum serves as an important landmark as it is a transitional zone between spine and skull [5]. As several developmental variations are observed many of which resemble deformities, thorough knowledge of its morphometric and morphological variation is required for reliable radiological diagnosis. Its morphometry is also helpful for lateral surgical approaches for reaching lesions in the middle and posterior cranial fossa [6]. During mass disasters, air accidents, fire explosions, the craniofacial skeletal structures are damaged, resulting in difficulty in determining the gender and consequent identification. As foramen magnum is protected by a large amount of soft tissue, the anatomical structure is useful in such cases [7]. In Arnold Chairi malformation, expansion of the transverse diameter is noted. The foramen magnum index and cranial index with other parameters are utilized in comparing races [8]. This study aims to conduct the morphometric and morphological analysis on foramen magnum.

MATERIALS AND METHODS

A total number of 64 adult dry human skulls were evaluated from the Department of Anatomy, ESIC MC & PGIMSR, Rajajinagar, Bengaluru, Karnataka.

Inclusion criteria: Completely ossified dry human skull bones irrespective of age and sex.

Exclusion criteria: Skull of children, incomplete, damaged were excluded. Skull showing gross deformity were considered for bony variation but excluded for morphometry.

All measurements were recorded using the Digital Vernier Calliper with with least count of 0.01mm by the same observer to eliminate inter-observer variability. Two measurements were taken and then averaged, in case of difference of more than 0.1mm, a third reading was done.

The following parameters were measured as shown in Figure 1 (**Figure 1).**

1) Antero-posterior diameter: Maximum distance in the mid-Sagittal plane between the median point on the anterior margin (Basion) to the median point in the posterior margin (Opisthion).

2) Transverse diameter: maximum distance between the two lateral margins at the point of greatest lateral curvature.

3) Foramen magnum area:

calculated using the Radinsky formula:

$$¼ \times \pi \times w \times h$$ [9,10]

where π = mathematical constant, 22/7

w = transverse diameter

h = antero-posterior diameter

4) Foramen Magnum index: transverse diameter x 100/Antero-posterior diameter.

The shapes of Foramen Magnum were classified as Pentagonal, Hexagonal, Circular, Irregular, Oval, Egg and Leaf shaped.

RESULTS

In our study the mean Antero-posterior diameter was found to be 34.10 ± 2.63 mm. The maximum antero-posterior diameter was 39.34mm and the minimum antero-posterior diameter was 28.33mm. The mean transverse diameter was 28.07 ± 1.87mm. The maximum transverse diameter was 33.69mm and the minimum transverse diameter was 25.44mm. The mean area was 752.07 ± 111.97 mm^2 and Foramen Magnum index was 1.21 ± 0.12. (Table.1).

The foramen magnum shapes were classified as Oval (30%), Circle (12%), Hexagonal (3%), Pentagonal (5%), Egg (17%), Leaf (6%), Irregular (27%). In one skull out of the 64 skull studied, we noted a bony tubercle at the posterior margin of foramen magnum. **(Figure 2) (Figure 3).**

Table 1: Descriptive statistics of antero-posterior and transverse diameter and foramen magnum index.

Number of skulls= 64	Antero-posterior diameter of foramen magnum(mm)	Transverse diameter of foramen magnum(mm)	Foramen magnum index
Mean	34.1	28.07	1.214
Standard deviation	2.63	1.87	0.12
Minimum	28.33	25.44	1.06
Maximum	39.34	33.69	1.42

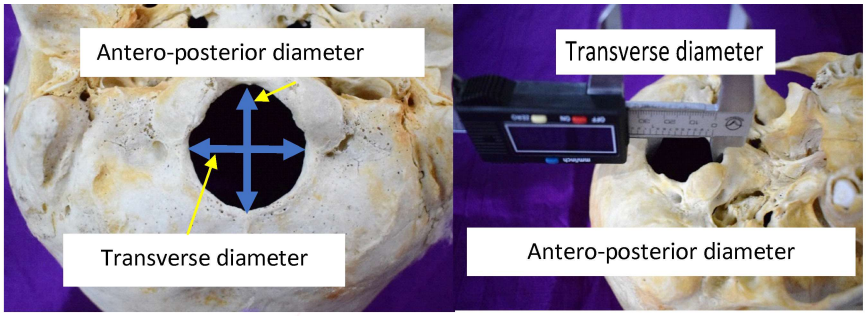


Fig. 1: Showing measurement of Antero-posterior diameter and Transverse diameter.

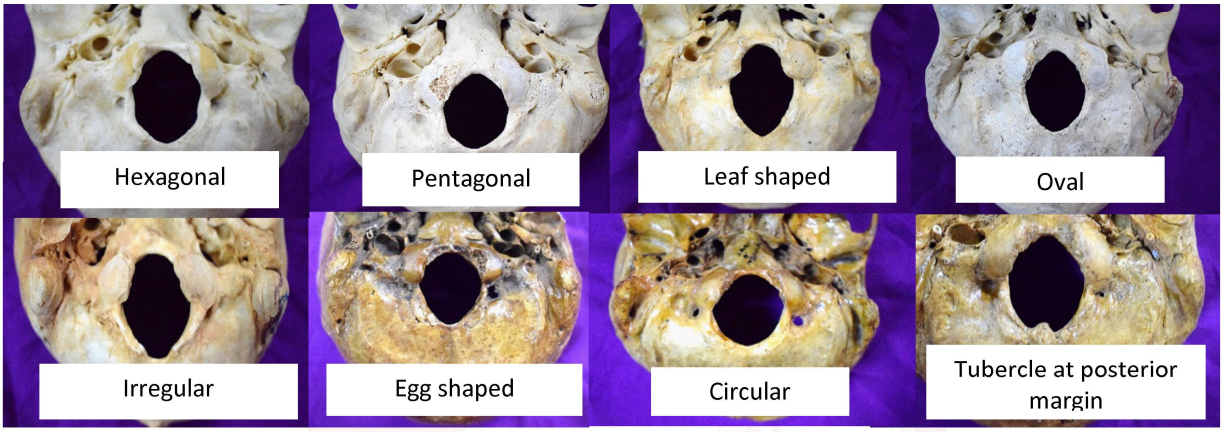


Fig. 2: Showing different morphology of foramen magnum.

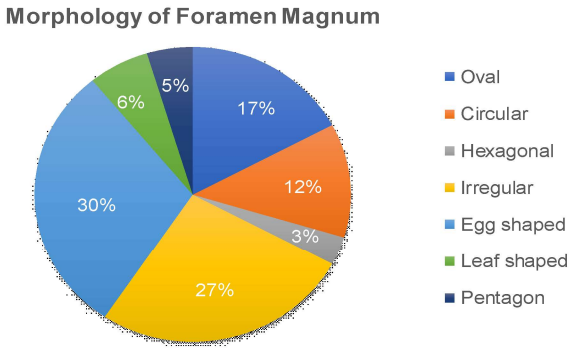
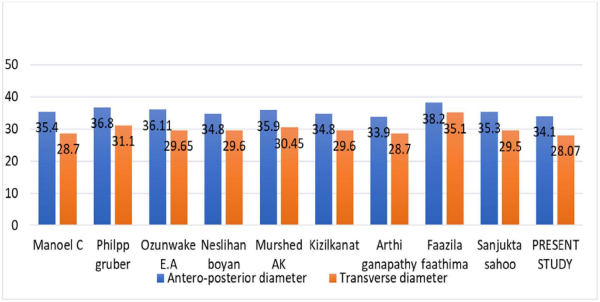


Fig. 3: Showing percentage of occurrence of different morphology in foramen magnum.

DISCUSSION

The findings recorded from the present study were compared with previous studies as seen in Figure 3 and the following results were noted **(Figure 4).**



In the morphometric analysis of Brazilian skulls and its relation to gender found that the length of the foramen magnum of Brazilian male skulls and female skulls were are 35.7 ± 0.29mm and 35.1 ± 0.33mm respectively. The width of the foramen magnum, the values of the male skulls were 30.3 ± 0.20mm and the female skulls were 27.1 ± 1.6mm [7].

Another study on the variability of foramen magnum size in Central European population with specimens from the Pleistocene to modern times and reported that Sagittal (36.8 ±2.8mm) diameters were signiûcantly greater than transverse (31.1 ± 2.1mm) diameters ($p < 0.001$). Sexual dimorphism could not be established either in the transverse (P = 0.55) or the sagittal (P = 0.08) diameter of the foramen magnum, though both the diameter were slightly smaller in females than male [5].

In southern Nigerian adult skulls, the mean length of Foramen Magnum was 36.11± 2.60mm and the transverse diameter was 29.65 ± 2.60 mm. The study also established that a large foramen magnum is normally associated with a large jugular foramen [11].

In a study of foramen magnum in Turkish skulls the antero-posterior and transverse diameters of the Foramen Magnum were 34.8±2.2mm and 29.6±2.4mm respectively, and a mean Foramen Magnum index of 1.2, similar to that of present study [12].

The mean Sagittal diameter and Transverse diameter of Foramen Magnum in Computerized tomographic images in males, were 37.2 ± 3.43 mm and 31.6 ± 2.99 mm respectively. In females, the mean Sagittal diameter and Transverse diameter were 34.6 ± 3.16 mm and 29.3 ± 2.19 mm, respectively. The study also found that the Sagittal diameter and Transverse diameter of foramen magnum in males were significantly greater than in females ($p < 0.001$) [13].

Another study of morphometry in both dry human skull and CT images and it was found that the mean antero-posterior, transverse, right oblique and left oblique diameters in dry skulls and CT images were 33.9mm, 28.7mm, 29.0mm, 29.2mm and 34.9mm, 29.8mm, 30.4mm, 30.4mm respectively [14]. The results obtained from the present study closely co-related with that of the above mentioned study.

The size of foramen magnum and overlapping of condyles into Foramen Magnum were studied and demonstrated that the mean anteroposterior and transverse diameters of the foramen magnum were 38.22 mm and 35.15 mm respectively. The mean area of Foramen Magnum was found to be 1102.5 mm^2 [15]. The results from the present study were comparable with the results from previous studies.

The most common foramen magnum shape was found to be round (22.2%) in a study conducted by Degno S et al [16], similar results were obtained by Chethan P et al with round shape in 22.6% [17] and K Natsis with circular in 25.9% [18], While in the present study oval shape(30%) was the commonest.

The antero-posterior diameter is always greater than the transverse diameter of the same foramen [4,16] but embryologically when there is disruption during separation of caudal and cranial parts of first sclerotome, the foramen outlet could be distorted and the transverse diameter could be greater than antero-posterior diameter [19].

The measurements of foramen magnum have also been used in sex differentiation where men have a higher average then women [20].

The results obtained is essential to the neurosurgeons to understand the microsurgical anatomy of cranio-vertebral junction and treating foramen magnum meningiomas [17,21,22]. It is necessary to have thorough knowledge of foramen for compression distraction reduction to treat basilar invagination and atlanto-axial dislocation [23]. It has been observed that far-lateral approach provides effective means to approach intradural anterior and antero-lateral craniovertebral junction [24-26]. While the posterolateral transcondylar approach has been found to be versatile avenue to encounter the lesions ventrolateral to the brain stem [27].

Embryologically the failure of distal occipitoblasts to fuse can form an abnormal bony formation around foramen magnum, a phenomenon called manifestation of occipital vertebra which was observed in one of our specimens as a posterior tubercle [28].

CONCLUSION

The present provides a morphometric data and morphological differences in foramen magnum and its clinical importance. The data obtained along with other parameters can be used in sex differentiation. The thorough knowledge helps radiologists to differentiate anatomical variation from deformities such as Arnold-Chiari malformation and neurosurgeons for better approach to treat foramen magnum meningiomas and other posterior cranial fossa lesions. Thus, the knowledge of foramen magnum is useful not only for anatomists but also for radiologists, neurosurgeons, ENT surgeons and orthopaedicians.

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Conflicts of Interests: None

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