Original Article

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Morphometric Analysis of Foramen Magnum in Dry Adult Human Skull

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Abstract

Background and Objective: Foramen magnum is a large opening in the occipital bone of human skull. Its morphometry is of outmost importance for neurosurgeons, radiologists, forensic experts, anatomists and anthropologists. Our study aims at measuring the morphometric measurements of foramen magnum in dry adult human skull and analyse the observation. *Materials and Methods:* One hundred dry adult human skulls of unknown age and sex were collected from the museum of the department of Anatomy of Navodaya Medical College, Raichur. The morphometric analysis of the foramen magnum was done using vernier calipers. *Results:* The mean antero-posterior diameter (APD) of the foramen magnum was found to be 34.1 mm. The mean transverse diameter (TD) of the foramen magnum was found to be 28.68 mm. The mean surface area of the foramen magnum was found to be 774.17 sq.mms. The mean foramen magnum index (FMI) was found to be 84.18. *Conclusion:* The knowledge of the dimensions of the foramen magnum helps the neurosurgeons, radiologists, forensic experts, anatomists and anthropologists during their analysis or surgery. This study is worthwhile because of this importance.

Keywords: Foramen Magnum; Skull; Human; Anatomy; Morphometry.

Introduction

The foramen Magnum (FM) (Latin: 'great hole') is a large opening in the occipital bone of the cranium. Foramen magnum lies in antero-median position. It is oval and wider behind, with its greatest diameter in antero-posterior direction. Its anterior border is formed by the basilar process of the occipital bone. Its lateral borders are formed by the left and right ex-occipitalis. Its posterior border is formed by the supra-occipital part of the occipital bone. Anteriorly, margins of foramen magnum are overlapped by the occipital condyles, that project downwards [1]. The foramen magnum, as a transition zone between spine and skull, plays an important role as a landmark because of its close relationship to key structures such as the brain and the spinal cord. Through this outlet, the medulla and spinal cord pass from the skull to the vertebral column. It contains lower end of medulla oblongata, meninges, vertebral arteries and spinal accessory nerve. The cranio-vertebral junction refers to the occipital bone that surrounds foramen magnum and atlas and axis vertebrae [2]. The abnormalities of the cranio-vertebral junction can be congenital, developmental, acquired, traumatic, tumours, inflammatory, occurring either alone or in combination. All these abnormalities are of importance to anatomists as well as clinicians as they produce clinical symptoms [3]. The measurements of the foramen magnum are helpful for neurosurgeons for performing lateral trans-condylar surgical approaches for reaching lesions in the middle and posterior part of cranial base [4]. The morphometry of the foramen magnum is important because diseases in this region like achondroplasia (as there is a high risk of spinal cord stenosis in the base of the skull due to the small size of the foramen magnum in patients with achondroplasia at all ages) [5] and Arnold-Chiari malformation (downward herniation of the cerebellar tonsils and a resultant foramen magnum which shows expansion of transverse diameter) [6,7] may compress the vital structures passing through it. Measurements of foramen magnum are also important in conditions like foramen magnum meningioma, plagiocephaly, basilar

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invagination, and others cranial deformities [8,9,10]. The diameters and area of the foramen magnum are found to be greater in males than in females. This fact helps forensic experts determine the sex in situations like explosions, aircraft accidents and war fare injuries [11,12]. Thus, it is obvious that morphometric knowledge of the foramen magnum is of outmost importance. Hence, our study is aimed at establishing a database for the measurements of the dimensions of foramen magnum.

Materials and Methods

Our study group included 100 dry adult human skulls with intact base chosen irrespective of age and sex from the museum of the department of Anatomy of Navodaya Medical College, Raichur of Karnataka state. Pathological, fractured, deformed and developmental disturbances of the skull were excluded from the study. Vernier calipers was used to measure the antero-posterior diameter (APD), transverse diameter (TD). The two authors recorded the above measurements independently and a mean of the two recordings was taken for final statistics. Measurements were recorded to the nearest millimetre. The antero-posterior diameter of the foramen magnum was measured from the anterior border (basion) through the centre of the foramen magnum until the end of the posterior border (opistion), towards the median plane while the transverse diameter was measured from the end of the right border with concavity stronger, through the centre of the foramen magnum to the opposite end of the lateral border of concavity, with transverse directions (Figures 1 and 2). This was followed by measurement of the surface area of the foramen magnum (FMA) which was calculated using formula derived by Radinsky [13].

Radinsky's Formula (FMA): $1/4 \times \pi \times APD \times TD$

Where, π (mathematical constant) = 22/7,

APD = Foramen magnum antero-posterior diameter and TD = Foramen magnum transverse diameter.

This was followed by measurement of the Foramen magnum index (FMI) which was calculated using following formula:

FMI = FM transverse diameter X 100 / FM antero-posterior diameter.

After each parameter was measured, calculated, and assessed, the mean value and standard deviation were computed using Microsoft Excel of Microsoft Office 2000.

Results and Observations

In our study, a total of 100 foramina were studied. The mean antero-posterior diameter (APD) of the foramen magnum was 34.1$\pm$3.36 mm. The maximum value for APD was 42 mm and the minimum value for APD was 26 mm. The mean transverse diameter (TD) of the foramen magnum was 28.68 $\pm$ 2.93 mm. The maximum value for TD was 34 mm and the minimum value for TD was 21 mm. The mean surface area of the foramen magnum (FMA) was 774.17 square mms. The maximum value for FMA was 1040.91 square mms and the minimum value for FMA was 428.61 square mms. The mean value for the foramen magnum index (FMI) was 84.18. The maximum value of the FMI was 91.18 and the minimum value of the FMI was 71.43 (Table 1).

Fig. 1: Measurement of the antero-posterior diameter of the foramen magnum using vernier callipers

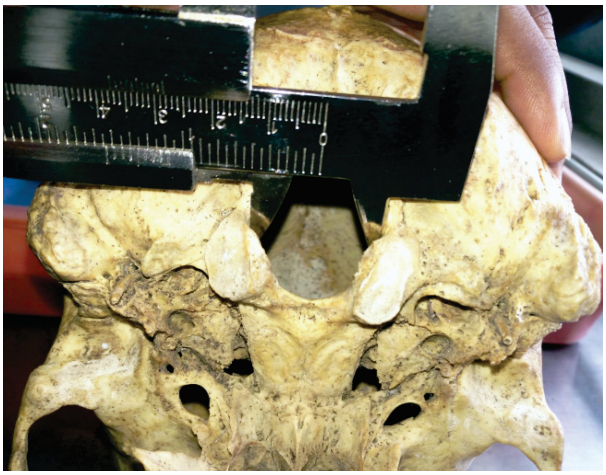

Fig. 2: Measurement of the transverse diameter of the foramen magnum using vernier callipers

Table 1: Morphometric measurements of the foramen magnum

Sl. No	Variable	APD (mm)	TD (mm)	FMA (sq. mm)	FMI
1	Mean	34.1	28.68	774.17	84.18
2	Maximum	42	34	1040.91	91.18
3	Minimum	26	21	428.61	71.43

[APD= Antero-posterior diameter, TD= Transverse diameter, FMA= Surface area of foramen magnum, FMI= Foramen magnum index]

Discussion

The FM is formed by sclerotomes of the first 4 somites that eventually fuse to form the occipital bone and the posterior element of the foramen magnum. The fourth sclerotome (proatlas) contains 3 portions: the hypocentrum, the centrum, and the neural arch, the latter divides into ventro-rostral and dorsal-caudal components. The ventro-rostral portion originates the occipital condyles and the anterior margin of the FM. As such, morphological anomalies and malformations in this process can result in different types and forms of foramen magnum [14]. Foramen magnum is morphologically variable osteological feature in the skull which has undergone evolutionary changes [15]. Embryologically, the length of the foramen magnum increases more rapidly during prenatal period when compared to its width[16]. A greater degree of cerebellar tonsillar herniation is associated with a wider antero-posterior diameter of foramen magnum [17]. Also, a longer antero-posterior dimension of foramen magnum permits greater contralateral surgical exposure for condylar resection in transcondylar approach [4].

Morphometric knowledge of the foramen magnum is important because pathological conditions like achondroplasia, occipital vertebra, basilar invagination, condylar hypoplasia, and atlas assimilation, Jeune's asphyxiating, thoracic dystrophy, Marchesani's syndrome, foramen magnum meningioma, Arnold-Chiari malformation, and plagiocephaly bring changes in the morphology of the foramen magnum [8-10, 18-20]. These diseases can cause compression of the structures that traverses the FM and produce symptoms like respiratory complications, lower cranial nerve dysfunctions; upper and lower extremity paresis, hypo or hypertonia, hyperreflexia or clonus, and general delay during motor development can appear [14]. Some studies suggest that foramen magnum measurements are higher in male subjects than in females [21-23]. However, study by Kamath et al. states that the measurements of foramen magnum may overlap and should not be used by itself for the determination of genre [9].

In our study, the mean antero-posterior diameter of the foramen magnum was 34.1 mm (range- 26 mm to 42 mm). This is similar to the reports of studies by Coin and Malkasian (34 mm), Schmeltzer et al (34 mm), Sayee et al (34.2 mm), Berge and Bergmann (33.8 mm), Kizilkant et al (34.8mm), Deshmukh and Devershi (34 mm), Avci et al (34.5 mm), Damiani et al (34.78 mm), Radhakrishna et al (34.04 mm), Kanchan et al (34.51mm), and Santhosh et al (34.37mm) [24]. Our finding matches most accurately with that of Coin and Malkasian (34 mm), Schmeltzer et al (34 mm), Deshmukh and Devershi (34 mm) and Radhakrishna et al (34.04 mm).

In our study, the mean transverse diameter of the foramen magnum was 28.68 mm (range- 21 mm to 34 mm). This is similar to the reports of studies by Coin and Malkasian (29 mm), Sayee et al (28.5 mm), Berge and Bergmann (28.3 mm), Damiani et al (28.69 mm), Radhakrishna et al (28.63 mm), Santhosh et al (28.98 mm), Patel and Mehta (28.29 mm), Ganapathy et al (28.7 mm) and Muralidhar et al (28.5 mm) [24]. Our finding matches most accurately with that of Damiani et al (28.69 mm).

In our study, the mean foramen magnum area was 774.17 square millimetres (range- 428.61 sq.mm to 1040.91 sq.mm). This is similar to the reports of studies by Acer et al (760 sq mm) and Milhorat et al (787.7 sq mm) [24]. Our finding matches near to that of the study by Milhorat et al.

In our study, the mean foramen magnum index was 84.18 (range- 71.43 to 91.18). This is similar to the reports of studies by Chaturvedi and Harneja (83.81) and Howale et al (84.85) 24. Our finding matches near to that of the study by Chaturvedi and Harneja.

Conclusion

The present study illustrates the morphometric data and the variations in the morphology of the FM with emphasis on their clinical implications. The morphometric knowledge of the foramen magnum is of importance to neurosurgeons, radiologists, forensic experts, anatomists and anthropologists. This study was undertaken because of the significance of this knowledge. However, our reports are limited by the

sample size. Hence, to obtain more robust conclusions, larger samples should be included.

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