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Original Article

A morphometric and comparative study of foramen magnum in North Indian population

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ABSTRACT

Introduction: Cranial base, especially the foramen magnum (FM), is of particular interest for anatomists, anthropologists, and neurosurgeons due to its complex relations with vital structures in this region. It is important as well as mandatory to have knowledge about its normal and variant dimensions for better transcondylar surgical approach.

Materials and methods: Various diameters of foramen magnum of 120 adult North Indian dry skulls of unknown age and gender were examined using an electronic digital sliding caliper.

Results: The commonest FM shape was oval and rarest was irregular. The mean antero-posterior (AP) and transverse diameters were 34.68 ± 2.88 mm and 27.24 ± 2.4 mm, respectively. The mean surface area was 757.09 ± 115.82 mm^2. The mean Foramen Magnum Index (FMI) was 78.71 ± 5.94.

Discussion: Results provide a baseline data for anatomists and important information for neurosurgeons to approach the cranial base with maximum safety and minimum mortality and morbidity.

1. Introduction

The foramen magnum (from the Latin, meaning ''great hole'') is the largest opening in the base of the skull through which the spinal cord exits the cranial vault. It is found in the occipital bone and formed around the base of the brainstem (the medulla oblongata), separating the brain above from the spinal cord below. The foramen magnum in humans is formed by the fusion of the four individual parts of the occipital bone (pars squama, left and right pars lateralis, and pars basilaris). The base of the cranium is complex as well as very interesting.[1] The foramen magnum is an important landmark of the skull base and is of particular interest for anthropology, anatomy, and forensic medicine.[2] Moreover, the study of the diameters of the foramen magnum (FM), from a descriptive and topographic point of view (due to the important relations of the FM with its contents), is also noteworthy. Additionally, the dimensions of the FM have clinical importance because the vital structures that pass through it may suffer compression such as in cases of FM achondroplasia[2] and FM brain herniation.[3,4]

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This opening indicates the exact angle of the spinal column which will decide whether our body is horizontal (resembling that of a horse) or vertical (like in case of humans). The position of this passage has been used by several anthropologists to determine the ability to walk upright in human ancestors. Besides the spinal cord, spinal accessory nerve, vertebral arteries, anterior and posterior spinal arteries, and ligaments like membrana tectoria and alar ligaments also pass through it.[3,4]

The transcondylar approach is being increasingly used to assess lesions ventral to the brainstem and cervico-medullary junction.[5] In a transcondylar surgical approach to the FM, such as in the resection of tumors of this region, the anatomic features of the FM and variations in the condylar resections to improve the exposure of this region have been considered in several studies.[6–8] Wanebo et al. stated that longer antero-posterior dimensions of FM permitted greater contralateral surgical exposure for condylar resection. Understanding the bony anatomy of this region is important for this approach.[9]

Despite its anatomical and clinical relevance, literature is still lacking in evaluating the basic measurements of this foramen. In the present study, the shape of foramen magnum and its anatomic metric values were evaluated which is an attempt to find out the possible correlations between the parameters studied in order to provide a baseline data for better surgical approach in this region.

2. Materials and methods

The study was conducted on 120 adult non-pathological dry human skulls of unknown age and sex procured from the Department of Anatomy, King George's Medical University, Lucknow, Uttar Pradesh for the duration of one year. According to the ethnicity, the population under study belonged to North India.

All the parameters were obtained with an electronic digital sliding caliper to the nearest 0.1 mm by one observer only to avoid inter-observer error. At least two repeated measurements were taken and the mean was calculated.

If there was a difference of more than 0.1 mm, a third measurement was done. Descriptive statistics (mean, minimum, maximum, and standard deviation) were evaluated for all the parameters collected. Pearson's correlation (r) value was calculated between the metric variables. For all the analyses, $p < 0.05$ was accepted as statistically significant. The following parameters were measured:

1. The antero-posterior (AP) diameter of the FM was defined as the distance from basion to opisthion and measured.
2. The transverse diameter (TR) of the FM was defined as the distance between the lateral margins of the foramen at the point of greatest lateral curvatures and measured.
3. FM index (FMI) was calculated by using the following formula[33]:

$$\text{Foramen Magnum Index} = \frac{\text{Maximum transverse diameter}}{\text{Maximum AP diameter}} \times 100$$

The shape of the foramen magnum was also assessed and classified as oval, round, pyriform, and irregular.

3. Observations and results

The incidence of different shapes of FM was evaluated of which the commonest was oval (66.66%) followed by round (16.6%), pyriform (12.5%), and irregular (4.01%) [Fig. 1(a–d), Table 1]. The mean antero-posterior (AP) and transverse diameters of foramen magnum were found to be 34.68 $\pm$ 2.88 mm and 27.24 $\pm$ 2.4 mm, respectively. The minimum and maximum values for AP diameters were 29.10 mm and 39.82 mm, respectively. The minimum and maximum values for transverse diameters were 23.08 mm and 32.90 mm, respectively (Table 2). Pearson Correlation coefficient ($r = 0.604$) was slightly higher and p-value was <0.05. Thus, a strong positive correlation existed between AP and transverse diameters of this foramen (Table 3). Foramen Magnum Index (FMI) was 78.714 $\pm$ 5.94. The minimum and maximum values for FMI were 65.29 and 92.3, respectively. Mean surface area of the foramen was 757.09 $\pm$ 115.82 mm^2. The minimum and maximum surface areas were observed as 538.44 mm^2 and 978.45 mm^2, respectively.

4. Discussion

The lesions in the cervico-medullary region pose a surgical challenge and have been associated with high mortality and morbidity.[10] Many surgical approaches and their several modifications have been developed to approach these lesions safely and effectively.[11] The lateral approach and its modifications are used to reach the foramen magnum ventrally and ventro-laterally.[12] In these procedures and specially the lateral approach, vital anatomical structures are jeopardized and the knowledge of the morphometry of this region and its variations can affect the surgical outcome.[13–15]

The foramen magnum dimensions in our (Indian) population are very close to the dimensions taken by other authors in different population groups. It is an important fact to be noted that though, other authors have used different methods for measurements, yet the findings are approximately similar. For example, in contrast to our technique, Govsa et al.[16] and Ozer et al.[14] have used the 3-D doctor computer program while Avci et al.[17] have used both the digital caliper and the radiologic method (3D CT).

4.1. *Shape of foramen magnum*

Few reports on the area of the FM and its variations in shape are available.[1] The FM is usually described as oval in shape.[18,19] The most common shape of foramen magnum in our study was also found to be oval (66.66%) while least common was irregular (4.01%). Round shape was present in 16.6% of skulls and pyriform in 12.5%. It is mentioned that the round-shaped foramen provides a larger operative angle for better approach and thus need of bone extraction becomes less.[17] Thus, in Indian population, the neurosurgeons have to go for some osteotomy for better transcondylar approach, as the shape of this foramen is oval in most of the subjects.

Similar findings were observed by Natis et al.,[11] who found the commonest shape as two semicircles and most unusual as

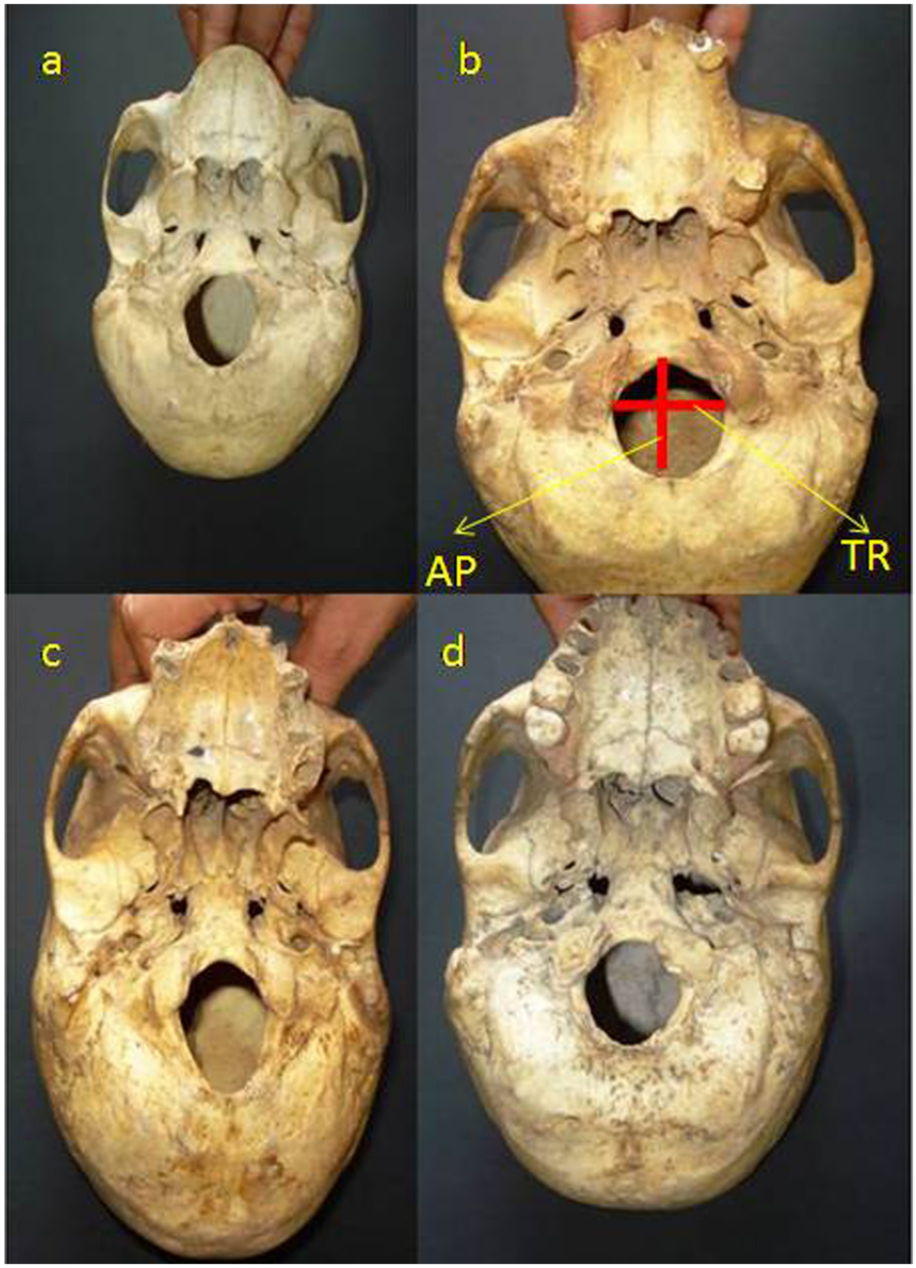

Fig. 1 – Different shapes of foramen magnum. (a) Oval. (b) Round. (c) Pyriform. (d) Irregular.

irregular. Mursheed et al.[1] in a Turkish population observed 8.1% oval FM, egg-shaped in 6.3%, round in 21.8%, and irregular in 19.99% of skulls. In addition, Radhakrishna et al.,[20] in South Indian population observed 39% oval and 28% round FM which were significantly larger than the results of this study. As reported by Zaidi and Dayal,[21] foramen magnum was irregular in 3.5% and round in 0.5% of the skulls whereas in the skulls studied by Sindel et al.,[22] it was irregular in 6.31% and round in 15.78%. Lang et al.[23] identified round FM in 7.05% of subjects. The differences observed can be explained on the basis that primarily, different authors have followed different methods of classifications for identification of shape of FM; secondly, the racial factors and ethnicity also affect the shape and lastly the sample size which can affect the results.

Table 1 – Showing distribution of shape of FM.

Shape	N (120)	%
Oval	80	66.66
Round	20	16.6
Pear-shape	15	12.5
Irregular	05	4.01

4.2. *Mean AP and transverse diameters, their correlation, and foramen magnum index*

Classically, the anatomic diameters have been found to be about 35 mm for the sagittal diameter and 30 mm for the

Table 2 – Showing the metric variables.

	FMAP (mm)	FMTR (mm)	FMI	FMA (mm^2)
N	120	120	120	120
Mean ± S.D.	34.68 ± 2.88	27.24 ± 2.48	78.714 ± 5.94	757.09 ± 115.82
Minimum	29.10	23.08	65.29	538.44
Maximum	39.82	32.90	92.30	978.45

transverse diameter.[24] Tubbs et al. found the mean antero-posterior diameter to be 3.1 cm, and the mean horizontal diameter as 2.7 cm.[25]

The sagittal diameter is generally larger than the transverse diameter which was also noticed in the present study. Catalina-Herrera[26] reported 35 mm for the sagittal and 30.5 mm for the transverse diameters. Berge and Bergmann[27] in 2001 and Gruber et al.,[2] in 2009, reported an average sagittal diameter of 34 mm and an average transverse diameter of 29 mm. Wackenheim[28] obtained radiographically mean values of 35 mm and 30 mm for the sagittal and transverse diameters, respectively. In an anatomic study of the FM, Testut and Latarjet[24] reported 35.2 mm for the sagittal and 30.3 mm for the transverse diameters. Muthukumar et al.[29] studied South Indian population and found the mean sagittal diameter as 33.3 mm and mean transverse diameter as 27.9 mm. Natis et al.[11] observed the AP diameter as 35.53 ± 3.06 mm and transverse diameter as 30.31 ± 2.79 mm. As far as the correlation is concerned between these two diameters, we observed a strong positive statistically significant correlation. Similarly, Olivier[30] found a correlation between these two variables. This is a useful finding for forensic medicine and paleo-anthropology, because one can, thus, estimate the size and shape of foramen magnum in its fragmented remains. Therefore, one can have an idea about the race and ethnicity of the individual.

Fischgold and Wackenheim[31] reported the minimum radiographic value for the sagittal diameter as 27 mm. According to other authors, the minimum values for sagittal and transverse diameters are 28.5 mm[32] and 21.4 mm[23], respectively. In the present study, the minimum values for both the diameters were 29.10 mm and 23.08 mm, respectively.

Janeczek et al. (2011) calculated the foramen magnum index (FMI = W/H × 100) which was 82.7 mm[33], while in the present study FMI was 78.71 ± 5.94. Howale et al. reported the average value of foramen magnum index as 84.85 ± 4.77.[34] Chaturvedi and Harneja studied Indian skulls and reported the average value of foramen magnum index as 83.81.[35]

Table 3 – Showing correlation coefficients and p-value.

		Correlation	
		Foramen magnum AP diameter (mm)	Foramen magnum transverse diameter (mm)
FM AP diameter (mm)	Pearson correlation	1	0.604**
	p-value (2-tailed)		0.000
FM transverse diameter (mm)	Pearson correlation	0.604**	1
	p-value (2-tailed)	0.000	
Surface area of FM (mm^2)	Pearson correlation	0.909**	0.880**
	p-value (2-tailed)	0.000	0.000

** Correlation is significant at the 0.01 level (2-tailed).

4.3. *Foramen magnum area*

Catalina-Herrera[26] found that the mean area of FM in male and female skulls was 888.4 mm^2 and 801 mm^2 respectively, while in the present study, we found the mean FM area (irrespective of sex) as 757.09 ± 115.82 mm^2 which is lower than that observed by Catalina-Herrera.[26] Tubbs et al.[25] found that the mean surface area of the foramen magnum was 558 mm^2, which is lower than our study. The reason behind such results can be explained on the basis of racial differences in different population groups. On the basis of classification of FM surface area given by Tubbs et al., Type I foramina were identified in none of the dry skulls which exhibited a surface area of less than 500 mm^2. Type II (5%, 6 skulls) was applied to foramina of an intermediate size with surface areas ranging between 500 and 600 mm^2. Type III (85%, 115 skulls) was applied to large foramina with surface areas of more than 600 mm^2. This is an important fact which should be kept in mind by Indian surgeons during operations in this region as wider FM is most common in our population.

5. Conclusions

Results of this study provide a baseline useful data that enable surgeons to perform effective and reliable surgery in FM region with maximum safety. We found the most common shape of foramen magnum being oval indicating a narrower operative field. Thus, Indian population (particularly North Indians) needs more osteotomy for safer approach to FM area. In this study, a strong positive statistically significant correlation between transverse and antero-posterior diameters of FM was observed. Thus, shape and approximate size of FM can be estimated from fragmented remains and race and ethnicity can be known in cases of difficult identification.

Conflicts of interest

The authors have none to declare.

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