

## MORPHOMETRIC AND MORPHOLOGICAL STUDY OF FORAMEN MAGNUM IN DRY HUMAN SKULL

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### Abstract

**Background:** Foramen magnum is a clinically important landmark present at the skull base due to its close association with brain stem and spinal cord. It is oval in shape, wider behind and the largest diameter is antero-posterior. The dimensions of the foramen magnum are clinically important because of the vital structures passing through it. The objective is to determine and analyse the morphological types and diameters of the foramen magnum in adult skull of Indian population. **Materials and Methods:** Morphological and morphometric study was done on 59 dry human skulls. Digital Vernier calliper was used for measurement. The shape of foramen magnum was noted and classified as oval, round, tetragonal, pentagonal, hexagonal and irregular in shape. Morphometric measurements like antero-posterior diameter, transverse diameter were measured and Foramen magnum index was calculated. **Result:** The most common shape was oval in 22 (37.2%) skulls; followed by round shape in 12 (20.3%). The mean anteroposterior diameter of the foramen magnum was  $32.25 \pm 2.55$  mm, and the mean transverse diameter of the foramen magnum was  $27.94 \pm 2.10$  mm. The mean surface area of the foramen magnum was  $712.51 \pm 110.65$  mm<sup>2</sup>. The mean foramen magnum index was found to be  $83.99 \pm 6.75$ . **Conclusion:** The knowledge of size and shape of foramen magnum is helpful to neurosurgeons in crani-vertebral surgical approaches as well as in posterior cranial fossa surgeries. Data of present study may be helpful to neurosurgeons, anthropologist or forensic persons.

## INTRODUCTION

The foramen magnum is the largest foramen in the skull.<sup>[1]</sup> It is a wide opening in the posterior cranial fossa connecting the cranial cavity with the vertebral canal. It allows the passage of vital structures of brain through it.<sup>[2]</sup> It is oval in shape, wider behind and the largest diameter is antero-posterior. It contains lower end of medulla oblongata, meninges, cerebro-spinal fluid, vertebral arteries and veins, and spinal accessory nerve.<sup>[3]</sup>

The dimensions of the foramen magnum are clinically important because the above mentioned vital structures passing through it may endure compression such as in cases of foramen magnum herniation, foramen magnum meningiomas and foramen magnum achondroplasia.<sup>[4]</sup> Vital structures passing through the foramen magnum are affected by the variations in shape of foramen magnum. Irregular shape of foramen magnum is featured by the formative cranial anomalies.<sup>[5]</sup>

Irregular shape of foramen magnum is accentuated by the developmental anomalies of the bone and soft

tissues at the craniovertebral junction.<sup>[6]</sup> Due to high chances of morbidity and mortality during various surgical procedures at the skull base, this area is having higher clinical importance. The morphometric analysis of foramen magnum and its variations is important not only for anatomists but also to the anesthetist, neurosurgeons, orthopedicians and radiologist. It has also has important clinical implications in the prognosis and treatment of various neurological pathologies like Arnold Chiari syndrome, and posterior cranial fossa lesions.<sup>[4]</sup> Thus, understanding of the variations in its normal anatomy is essential for accurate diagnosis and treatment of same. Hence, the present study was done to determine and analyse the morphological types and diameters of the foramen magnum in adult skull of Indian population.

## MATERIALS AND METHODS

**Study Population:** A total of 30 dry adult human skulls of unknown age and sex were collected from Department of Anatomy Zoram Medical College

Falkawn over a period of six months from January 2023 to June 2023. The study was approved by the Institute Ethics Committee.

#### Inclusion Criteria

Fully ossified, dried, macerated and thoroughly cleaned skull

#### Exclusion Criteria

Deformed and damaged bones related with foramen magnum

**Methodology:** Various morphometric measurements like antero-posterior diameter and transverse diameter of foramen magnum were taken using the Digital Vernier sliding caliper which is accurate to 0.01 millimeter. The mean and standard deviation of the foramen magnum in various dimensions were calculated<sup>7</sup>.

**Antero-posterior Diameter (APD):** Measured from the end of anterior border (basion) to the end of posterior border (opisthion) of foramen magnum.

**Transverse Diameter (TD):** Measured from the point of maximum concavity on the right margin to the maximum concavity on left margin of foramen magnum.

**Foramen Magnum Index (FMI):** was calculated by dividing the transverse diameter by AP diameter and multiplied by hundred.

**Area of the Foramen Magnum:** It is surface area of the foramen magnum calculated by the following formula.<sup>[8]</sup>

$$\text{AREA (A)} = \frac{1}{4} \times p \times w \times h$$

w = Width, transverse diameter

h = Height, longitudinal diameter

$\pi = 22/7$ , mathematical constant.

The above parameters were recorded as an average of two observations which were measured independently by two different people. The mean and

standard deviation for each parameter was calculated and expressed as mean  $\pm$  standard deviation.

In addition the shapes of the foramen magnum were also noted and classified as oval, round, tetragonal, hexagonal, pentagonal and pear shaped.

**Statistical Analysis:** The qualitative data were expressed in proportion and percentages and the quantitative data expressed as mean and standard deviations. The difference in proportion was analyzed by using chi square test. Significance levels for tests were determined as 95% ( $P < 0.05$ ).

## RESULTS

The various parameters related to the foramen magnum were measured and demonstrated in this study.

In this study various shapes of foramen magnum were observed. The most common shape was oval in 22 (37.2%) skulls; followed by round shape in 12 (20.3%), tetragonal shape was 10(16.9%), skulls and hexagonal in 06 (10.1%) skulls, hexagonal was 5 (8.4%). Round shaped FM was present in 16 (13.3%) skulls, pentagonal FM in 16 (13.3%) and pear shaped was present in 8 (6.6%) skulls. [Table 1]

In this study the anteroposterior diameter of the foramen magnum was in a range of 27.30-37.20 mm with a mean of  $32.25 \pm 2.55$  mm, and the transverse diameter of the foramen magnum was in a range of 23.11 – 32.78 mm with a mean of  $27.94 \pm 2.10$  mm. The mean surface area of the foramen magnum was  $712.51 \pm 110.65$  mm<sup>2</sup>, range being from 486.74 mm<sup>2</sup> to 880.28 mm<sup>2</sup>. The mean foramen magnum index was found to be  $83.99 \pm 6.75$ . [Table 2]

**Table 1: Shapes of foramen magnum.**

Shape	Number	Percentage
Oval	22	37.2
Round	12	20.3
Tetragonal	10	16.9
Hexagonal	06	10.1
Pentagonal	05	8.4
Pear	04	6.7
Total	59	100

**Table 2: Dimensions of foramen magnum.**

Parameter	Mean $\pm$ SD	Minimum	Maximum
Anteroposterior diameter (APDfm) (mm)	$32.25 \pm 2.55$	27.30	37.20
Transverse diameter (TDfm) (mm)	$27.94 \pm 2.10$	23.11	32.78
Foramen magnum area (Afm) (mm <sup>2</sup> )	$712.51 \pm 110.65$	486.74	880.28
Foramen magnum index (Ifm)	$83.99 \pm 6.75$	72.79	95.20

**Table 3: Mean dimensions of foramen magnum according to shape.**

Parameter	Various shape of foramen					
	Oval	Round	Tetragonal	Hexagonal	Pentagonal	Pear
Mean Anteroposterior diameter	$30.15 \pm 2.48$	$33.20 \pm 2.50$	$32.56 \pm 2.46$	$34.19 \pm 2.24$	$31.25 \pm 2.16$	$33.25 \pm 2.14$
Mean Transverse diameter	$29.45 \pm 2.10$	$28.56 \pm 1.98$	$31.14 \pm 2.15$	$30.24 \pm 2.18$	$26.27 \pm 2.10$	$27.36 \pm 2.15$
Mean Foramen magnum area	$684.23 \pm 111.23$	$681.53 \pm 110.54$	$682.37 \pm 112.34$	$683.58 \pm 110.81$	$685.95 \pm 110.56$	$684.20 \pm 110.84$
Mean Foramen magnum index	$82.65 \pm 6.84$	$81.74 \pm 6.40$	$85.34 \pm 6.48$	$84.36 \pm 6.10$	$86.47 \pm 6.14$	$84.37 \pm 6.45$

## DISCUSSION

Foramen magnum is morphologically variable osteological feature in the skull which has undergone evolutionary changes.<sup>[9]</sup>

In this study we found that the most common shape of foramen magnum was oval shape in 22 (37.2%) skulls; followed by round shape in 12 (20.3%), tetragonal shape was 10(16.9%), skulls and hexagonal in 06 (10.1%) skulls, pentagonal was 5 (8.4%) and the least was pear shaped in 8 (6.6%) skulls. [Table 1] Our findings are accordance with Vinutha SP et al,<sup>[11]</sup> who also reported the most common shape of foramen magnum was oval shape in 36.5% skulls. Many other researchers Nagwani M et al,<sup>[10]</sup> Kumar A et al,<sup>[11]</sup> Singh R and Kumar R,<sup>[12]</sup> also observed oval as most common type. However Chethan P et al,<sup>[13]</sup> found round shape was the most common. In another study Aragao JA et al,<sup>[14]</sup> reported pear shape was the most common foramen magnum while Sindel M et al,<sup>[15]</sup> reported tetragonal shape as a common shape of foramen magnum.

The difference in shapes of the foramen magnum from various reports indicates racial variability among the morphology. These variations might have been attributed by the factors such as sexual dimorphism,<sup>[16]</sup> types of population<sup>13</sup> and ethnic groups.<sup>[17]</sup> Therefore the variation in the foramen magnum shape should be taken into consideration during clinical and radiological diagnostic procedures and the surgical approach.<sup>[13]</sup>

In this study we found that the mean anteroposterior diameter of the foramen magnum was in  $32.25 \pm 2.55$  mm and the mean transverse diameter was  $27.94 \pm 2.10$  mm. our findings are consistent with Muthukumar N et al,<sup>[18]</sup> who observed that the average anteroposterior length of the foramen magnum was 33.3 mm and the transverse diameter was 27.9 mm. In another study Sampada PK et al,<sup>[19]</sup> reported anteroposterior diameter of foramen magnum was  $34.84 \pm 2.32$  mm and an average transverse diameter of  $29.39 \pm 1.73$  mm. In a study done on 71 skulls of Uttar Pradesh the mean anteroposterior diameter of foramen magnum was  $34.09 \pm 2.23$  mm and transverse diameter was  $28.22 \pm 2.19$  mm.<sup>[20]</sup> However Philipp Gruber,<sup>[21]</sup> in his study on skulls from Western Europe found that the mean anteroposterior diameter of foramen magnum was 36.6 mm and the mean transverse diameter was 31.1 mm which was higher value than our study.

In present study we also found that the mean surface area of the foramen magnum was  $712.51 \pm 110.65$  mm<sup>2</sup>, range being from 486.74 mm<sup>2</sup> to 880.28 mm<sup>2</sup> which is similar with the study conducted by Singh D et al,<sup>[22]</sup> who observed  $728.12 \pm 112.98$  mm<sup>2</sup>. In another study conducted by Praveen T and Singh P,<sup>[23]</sup> reported the mean area of foramen magnum was  $792.61 \pm 91.01$  mm<sup>2</sup>. However Shika et al,<sup>[24]</sup> and Rohinin devi et al,<sup>[25]</sup> reported that the mean area of the foramen magnum was 970.57 mm<sup>2</sup> and 820.53 mm<sup>2</sup> which were higher than present study. The

variations observed in various studies may be due to the ethnic group involved and size of study sample.

In this study we found that the mean foramen magnum index was found to be  $83.99 \pm 6.75$  which is consistent with the study conducted by Archana Singh et al<sup>7</sup> who also reported  $83.91 \pm 6.43$ . Various study conducted by Chaturvedi RP et al., and Howale DS et al. reported the average value of foramen magnum index as 83.81 and  $84.85 \pm 4.77$  respectively, which was concordance with present study.<sup>[26,27]</sup>

The shape of the foramen magnum is morphologically variable. Variations in foramen magnum shape should be taken into consideration during radiological diagnostic procedures and surgical approaches to the region. This is also important for deciding that how much bone must be removed.<sup>[28]</sup> In early fetal development, foramen magnum is one of the centres of ossification and because of evolutionary changes its shapes are variable.<sup>[9,18]</sup> The irregular shape of the FM may be due to developmental anomalies related to bones and soft tissues at the craniovertebral junction.

## CONCLUSION

The analysis of various shapes of foramen magnum is utmost important. This study will become a useful guide for the surgeons, radiologists, orthopedics, anthropologists as well as forensic experts. The present study enhances the knowledge about various shapes of foramen magnum at the base of skulls in Indian populations.

## REFERENCES

1. Vinutha SP, Suresh V, ShubhaR. Discriminant function analysis of foramen magnum variables in South Indian population: A study of computerized tomographic images. *Anat Res Int.* 2018;2018:1-8.
2. Kumar A, Potdar P, Singh K, Dhakar JS. A study of foramen magnum and its clinical relevance. *Santosh Uni J of Health Sci.* 2019;5(2):72-7.
3. Standring S, editor. *Gray's Anatomy.* 41sted. Elsevier; 2016.p.422
4. Murshed K A, Cicekeibasi A E, Tuncer I. Morphometric evaluation of the foramen magnum and variations in its shape. A study of computerized tomographic images of normal adults. *Tur J Med Sci* 2003;33:301-6
5. Furtado SV, Thakre DJ, Venkatesh PK et al. Morphometric analysis of foramen magnum dimensions and intracranial volume in pediatric Chiari I malformation. *Acta neurochirurgica.* 2010;152(2):221-7
6. K. Edwards, M.D. Viner, W. Schweitzer, M.J. Thali. Sex determination from the foramen magnum. *Journal of forensic radiology and imaging.* 2013;1(4):186-92
7. Singh A, Agarwal P, Singh A. Morphological and Morphometric Study of Foramen Magnum in Dry Human Skull and Its Clinical Significance. *International Journal of Anatomy, Radiology and Surgery.* 2019,8(3):10-12
8. Radinsky L. Relative brain size: a new measure. *Science* 1967;155:836-8
9. Nevell L, Wood B. Cranial base evolution within the hominin clade. *J Anat.* 2008;212:455-68
10. Nagwani M, Rani A, Rani A. A morphometric and comparative study of foramen magnum in North Indian population. *J of the Anat Soc of India.* 2016; 65(1):11-5.

11. Kumar A, Potdar P, Singh K, Dhakar JS. A study of foramen magnum and its clinical relevance. *Santosh Uni J of Health Sci.* 2019; 5(2):72-7.
12. Singh R, Kumar R. Analysis of morphology of foramen magnum in Indian population. *J of the Anat Soc of India.* 2015;64(2):107-12
13. Chethan P, Prakash KG, Murlimanju BV, Prashanth KU, Prabhu LV, Saralaya VV et al. Morphological analysis and morphometry of the foramen magnum: an anatomical investigation. *Turk Neurosurg.* 2012;22(4):416-9.
14. Aragão JA, de Oliveira Pereira R, da Cruz de Moraes RZ, Reis FP. Morphological types of foramen magnum. *Annual Research & Review in Biology.* 2014;4(9):1372-8.
15. Sindel M, Özkan O, Uçar Y, Demir S. Foramen Magnum'un Anatomik Varyasyonları. *Akdeniz Üniversitesi Týp Fakültesi Dergisi.* 1989;44(6):97-102
16. Ukoha U, Egwu O, Okafor I, Anyabolu A, Ndukwe G, Okpala I. Sexual Dimorphism in the Foramen Magnum of Nigerian Adult. *Int J Biol Med Res.*, 2011;2(4): 878-81.
17. Espinoza E, Ayala C, Ortega L, Collipal E, Silva H. Morfometría tomográfica del foramen magno y su relación con el sexo y la etnia mapuche. *Rev. ANACEM (Impresa).* 2011;5(1):28-31.
18. Muthukumar N, Swaminathan R, Venkatesh G, Bhanumathy SP. A morphometric analysis of the foramen magnum region as it relates to the transcondylar approach. *Acta Neurochir (Wien.)* 2005;147:889-95
19. Sampada PK, Poornima B, Mallikarjun M, Santosh B Sakri. Morphometric and morphological study of foramen magnum in dried human skull bones. *Int J Anat Res.* 2017;5(2.):3682-6.
20. Mishra AK, Pandey SB, Yadav CK, Haque M, Chandra N. Morphometric study of foramen magnum of skulls in population of Uttar Pradesh. *Int J Anat Res.* 2018;6(2.2):5186-90.
21. Gruber P, Henneberg M, Böni T and Rühli FJ. Variability of Human Foramen Magnum Size. *Anat Rec.* 2009;292:1713-9
22. Singh D, Patnaik P, Gupta N. Morphology and morphometric analysis of the foramen magnum in dried adult skulls in North Indian region. *Int J Health Sci Res.* 2019;9(4):36-42.
23. Praveen T and Singh P. A north Indian skull based study of a morphological and morphometrical measurement of foramen magnum. *Ind J of App Res.* 2018 ;8(7):68-70.
24. Shika S, Sharma AK, Bhawani S M, Arshad M. Morphometric Evaluation of the Foramen Magnum and Variation in its Shape and Size: A Study on Human Dried Skull. *Int J Anat Res.* 2015;3(3):1399-03.
25. Rohinidevi M and Vimala V. Morphometric analysis of foramen magnum and variations in its shape in dried human adult skulls: . *Int J Anat Res.* 2016;4(3):2670-73
26. Chaturvedi RP, Harneja NK. A craniometric study of human skull. *Journal of Anatomical Society of India.* 1963;12:93-6.
27. Howar DS, Bathija D, Pandit DP. Correlation between cranial index and foramen magnum index in human dried skulls. *GJRA.* 2014;3(1):3-6
28. Kizilkanat ED, Boyan N, Soames R, et al. Morphometry of the hypoglossal canal, occipital condyle, and foramen magnum. *Neurosurg Q.* 2006;16(3):121-5