ISSN: 0975-3583, 0976-2833 VOL15, ISSUE9, 2024

A MORPHOMETRIC AND MORPHOLOGICAL STUDY OF FORAMEN MAGNUM IN ADULT HUMAN SKULLS

Dr. Nilofer Mulla[1], Dr. Sarika Dakare[2], Dr. Mehera Bhoir[3], Dr. Meenakshi Borkar [4]

Assistant professor[1], Department of Anatomy, HBTMC, Mumbai, India

Assistant professor [2], Department of Anatomy, Seth GSMC, Mumbai, India

Professor & Head[3], Department of Anatomy, HBTMC, Mumbai, India

Associate professor[4], Department of Anatomy, HBTMC, Mumbai, India

Corresponding author: Dr. Nilofer Mulla, Department of Anatomy, HBTMC& Dr. RNCH, Mumbai

Abstract

Background: The shape and morphology of the foramen magnum play a crucial role in identifying the cause and formulating the treatment approach for neurological conditions such as Arnold Chiari malformation. Transcondylar approach enables neurosurgeons to access the brainstem and cervico medullary junction region with minimum retraction and it requires thorough knowledge of different parameters of foramen magnum.

Aim: To study the morphometric characteristics of foramen magnum in dry human skulls.

Material and method: This study was conducted on hundred skulls, obtained from Department of Anatomy from various teaching Institutions of Mumbai.

Result: Most common shape of foramen magnum found in this study was oval shape followed by tetragonal shape. The mean Anterior- Posterior Diameter (APD) and Transverse Diameter (TD) of foramen magnum calculated were 33.8 ± 3.5 mm and 28.8 ± 3.1 mm respectively. Fifty-five skulls (out of hundred) were having FM index more than 1.2, while forty-five skulls (out of hundred) were having FM index less than or equal to 1.2. Mean of foramen magnum areas calculated by method of Routalet al and by Teixeira's method were 770.56 ± 143.06 mm^2 and 777.83 ± 143.77 mm^2 respectively.

Conclusion: The data collected in this study will be valuable for neurosurgeons in examining the Craniovertebral junction's anatomy for preoperative planning and skull base surgery management. These results will also provide insights for Radiologists, Orthopedicians, Anthropologists, Anatomists, anesthesiologist and forensic specialists.

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE9, 2024

Key words: Morphometry**,** Foramen magnum, index, area

Introduction:

The foramen magnum lies in an anteromedian position of posterior part of inferior surface of skull and leads into the posterior cranial fossa. It is oval and wider behind, with its greatest diameter being anteroposterior. It contains the lower end of the medulla oblongata, meninges, cerebrospinal fluid, vertebral arteries and veins, and the accessory nerves. The apical ligament of the dens and the tectorial membrane also pass through foramen magnum to attach to the internal basiocciput. Anteriorly, the margin of the foramen magnum is slightly overlapped by the occipital condyles, which project down to articulate with the superior articular facets on the lateral masses of the atlas[1].

The base of the skull, shielded by a substantial mass of soft tissue, provides protection to the foramen magnum. In instances of severe trauma, fires, explosions, etc., preserved foramen magnum morphometry proves invaluable in determining gender, contributing to the identification of an individual[2].

The assessment of the dimensions of the foramen magnum is essential for diagnosing and management of malformations such as Arnold Chiari syndrome, foramen magnum meningioma, achondroplasia and other posterior fossa lesions. Outcomes of surgeries in this region depend on size and variations of foramen magnum. Knowledge of the bony anatomy of this region is also very important for transcondylar approach which enables neurosurgeons to access the brainstem and cervico medullary junction region with minimum retraction. These observations hold significance not just for neurosurgeons but also for anesthesiologists, orthopedists, radiologists, forensic specialists, anatomists, and anthropologists[3].

Materials and methods:

This study was conducted on hundred adult dry human skulls, obtained from Department of Anatomy from various teaching Institutions of Mumbai. The skulls were of undetermined age and sex. Damaged skulls and skulls with broken foramen magnum were excluded from this study.

All measurements of the foramen magnum were taken by using a digital Vernier caliper (0-200 mm with precision of 0.01 mm). The different shapes of the foramen magnum were observed and classified as oval, round, tetragonal pentagonal, hexagonal and irregular.

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE9, 2024

Following parameters were studied:

1) **Antero-posterior diameter (APD)**: It is an anteroposterior distance between the basion (the midpoint of the anterior margin of the FM) and opisthion (themidpoint of the posterior margin of the FM) in the mid sagittal plane.

2) **Transverse Diameter (TD)**: It is the widest transverse distance of the foramen magnum. It is the perpendicular to anteroposterior diameter in a coronal plane.

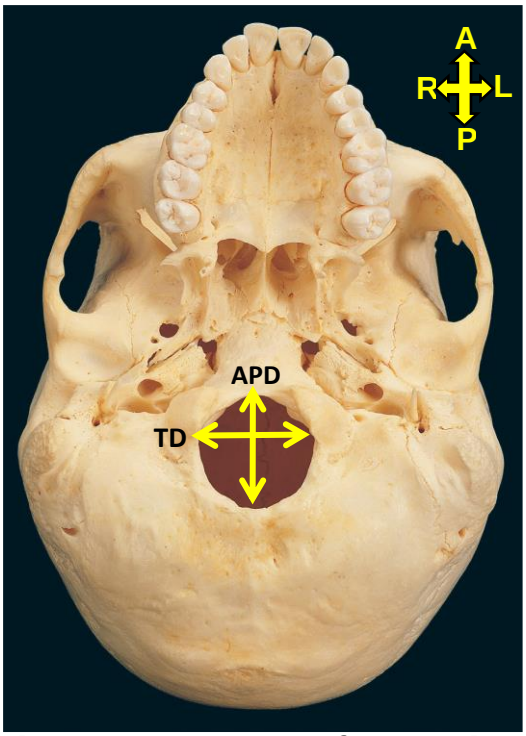


Figure 1: Illustration showing measurement of APD and TD of foramen magnum

3) **Foramen Magnum Index**: It is calculated by dividing the anteroposterior diameter of foramen magnum with its transverse diameter.

4) **Area of Foramen magnum (A)**:

The area of the foramen magnum was calculated by using the two different formulas published by Routal et al. and Teixeira respectively as follows:

a) By using formula by Routal et al.:

Area of Foramen magnum (A) = ¼ x π x TD x APD

TD: Transverse diameter, APD: Anteroposterior diameter

b) By using formula by Teixeira:

$$\text{Area} = \pi \times [(\text{APD} + \text{TD})/4]^2$$

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE9, 2024

TD: Transverse diameter, APD: Anteroposterior diameter

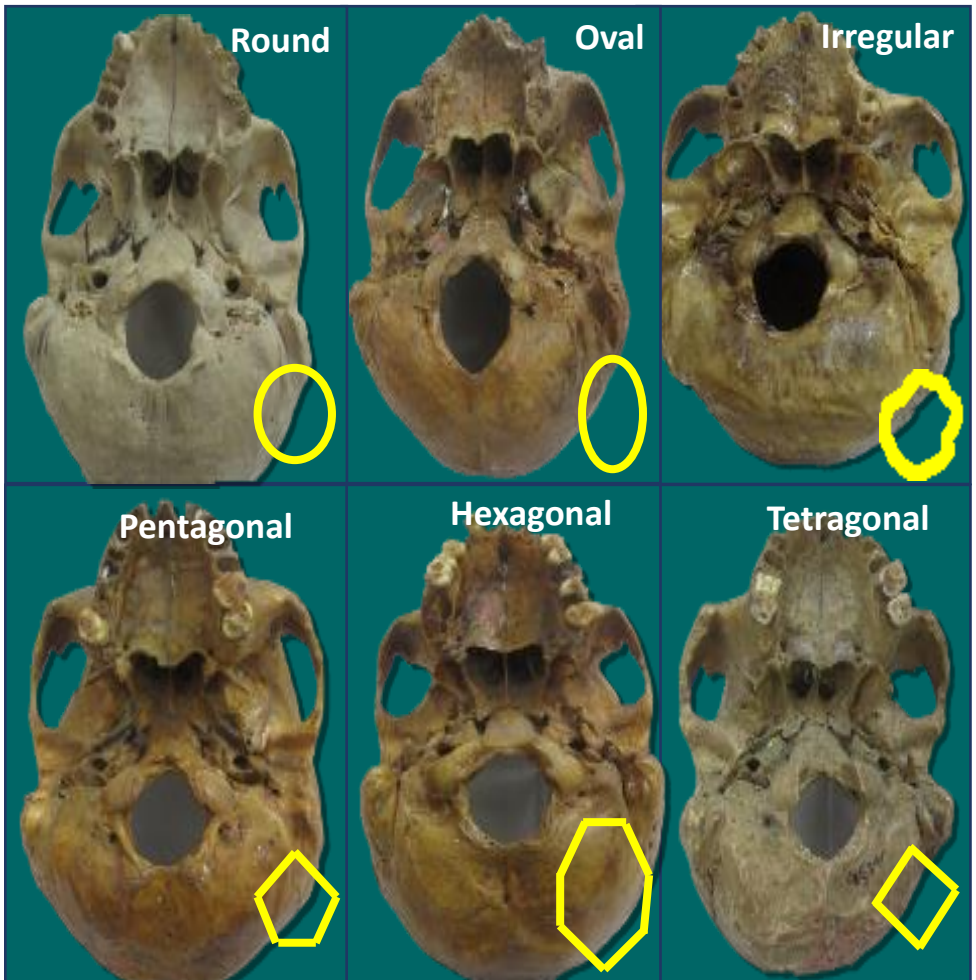
Descriptive statistical methods like mean, standard deviation, Range, standard error of mean and percentage were used for depicting and analyzing data.Microsoft Word and Excel were used to generate graphs and tables.

Results:

Various parameters related to foramen magnum were measured in 100 dry human skulls of undetermined age and gender in the present study. All these measurements and observations are mentioned as follows:

Table 1: Shapes of Foramen Magnum

Foramen Magnum Shape	No. of Specimens	Percentage of specimens
Oval	36	36%
Round	7	7%
Tetragonal	18	18%
Pentagonal	6	6%
Hexagonal	16	16%
Irregular	17	17%



ISSN: 0975-3583, 0976-2833 VOL15, ISSUE9, 2024

Figure 2: Illustration showing variations in the shapes of foramen magnum

Table 2: Parameters of Foramen Magnum

Parameter	Mean +/- S.D (mm)
Anterior- posterior Diameter (mm)	33.8 ± 3.5
Transverse diameter (mm)	28.8 ± 3.1

In this study, we were calculated Foramen magnum index by dividing the anteroposterior diameter of foramen magnum with its the transverse diameter. It was found that 55 skulls (out of 100) were having FM index more than 1.2, while 45 skulls (out of 100) were having FM index less than or equal to 1.2.

In our study, we used two different methods for calculations of area of Foramen magnum, one published by Routalet al and another described by Teixeira. Mean of foramen magnum areas calculated by method of Routal et al was 770.56 ± 143.06mm^2 while mean of areas calculated by Teixeira's method was 777.83 ± 143.77 mm^2

Discussion:

This study was done to analyze about morphological shapes and diameters of foramen magnum in Indian population which will help during surgical procedures in posterior cranial fossa region, especially approaches through foramen magnum. The linear morphometric method of foramen magnum analysis can be a useful tool for gender determination but its effectiveness is enhanced when combined with other anthropological techniques[4].Variations in the morphology of the foramen magnum are observed among diverse populations, influenced by genetic, environmental, and socio-economic factors[3].

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE9, 2024

The significance of variations in the shape of the foramen magnum lies in their impact on vital structures passing through it, and it also plays a crucial role in various surgical approaches. The most common shape of foramen magnum in the present study was oval shape which found in 36 skulls out of 100 (36 %). It is comparable with the previous studies done by Dalvinder Singhet al[3], Archana Singh et al[5], Sanjaykumar Revankar et al[6], Sampada P K et al[7] and Arora Sandeep et al[8]. Second most common shape of foramen magnum found in present study was tetragonal shape followed by irregular and hexagonal shapes with 18%, 17% and 16% respectively. Percentage of these shapes almost resemble with that of previous studies. While round and pentagonal shapes were seen in 7% and 6% respectively which is lesser than most of the previous studies.

In cases where the foramen magnum has an ovoid shape, it presents a challenge for surgeons to adequately expose the anterior portion of the foramen. The anatomical variations of the foramen magnum can influence specific surgical procedures, including repairs for vertebral artery and posterior inferior cerebellar artery aneurysms, resections of foramen magnum meningiomas, and decompression procedures[9]. The formation of a specific foramen magnum (FM) shape is elucidated by embryological data, likely arising from the ossification of primordial cranial remnants. This process involves the fusion of these remnants with endochondral ossification points occurring at different locations, leading to diverse shapes. An irregular foramen magnum shape is further emphasized by developmental anomalies affecting both bone and soft tissues at the craniovertebral junction[7].

Accurate measurements of the foramen magnum play a crucial role in surgical resection, facilitating access to the lower clivus and premedullary region in a transcondylar approach. Diseases linked to anomalies of the foramen magnum (FM) encompass occipital vertebra, basilar invagination, condylar hypoplasia, and atlas assimilation. It is widely recognized that the size of the foramen magnum is enlarged in Arnold Chiari malformations and reduced in achondroplasia[2].

The antero-posterior and transverse diameters of the foramen magnum, along with the degree of overriding of the occipital condyle within the foramen magnum are valuable for determining the surgical field's area.

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE9, 2024

Table 3: Comparison of Anteroposterior diameter and Transverse diameter of foramen magnum with previous studies

Study	Year	Country	Material for study	AP diameter of foramen magnum (mm)	Transverse diameter of foramen magnum (mm)
N Muthukumar et al[10]	2005	India	Dry bones	33.3	27.9
Anshu Sharma et al[11]	2019	India	Dry bones	34.44	30.46
Dalvinder Singh et al[3]	2019	India	Dry bones	33.57 ± 2.82	27.49 ± 2.61
Archana Singh et al[5]	2019	India	Dry bones	33.79 ± 2.60	28.25±1.83
Sanjaykumar Revankar et al[6]	2020	India	Dry bones	34.36 ± 3.13	28.48± 3.97
Sampada P K et al[7]	2017	India	Dry bones	34.84 ±2.32	29.39±1.73
P Chethan et al[12]	2012	India	Dry bones	31 ± 2.4	25.2 ± 2.4
Vishal Jasuja et al[13]	2016	India	Dry bones	34.13 ± 2.73	27.82 ± 3.32
Roma Patel et al[14]	2014	India	Dry bones	40.2	28.29
Arora Sandeep et al[8]	2017	India	Dry bones	35.42 ± 3.22	27.81 ± 2.58
Present study	2023	India	Dry bones	33.8 ± 3.5	28.8 ± 3.1

It is said that the shape of foramen magnum can be calculated by using foramen magnum index[10]. Muthukumar et al[10]. has considered foramen magnum to be oval when foramen magnum index was ≥ 1.2 and considered the rest as circular with foramen magnum index < 1.2. A similar sized lesion situated anterior to the brainstem will require more extensive bone removal in a person with an ovoid foramen magnum than in a person with circular foramen magnum[10]. Out of 100 skulls studied by V. Jasuja et al[13]. 71% were found to have the foramen magnum index equal to or more than 1.2 similar to that reported by Muthukumar et al [10].

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE9, 2024

Data obtained by studying the morphological types and diameters of the foramen magnum in the adult skulls aims to enhance the effectiveness and reduce failure rates in surgical procedures involving the posterior cranial fossa, especially those utilizing approaches through the foramen magnum.The area of the foramen magnum can be used as better predictor of the sex of the skulls[15].

Table 4: Comparison of Area of Foramen magnum(calculated by method of Routal et al)(mm2) with previous studies

Study	Year	Country	Material for study	Area of Foramen magnum (mm2)
Anshu Sharma et al[11]	2019	India	Dry bones	745.727
Dalvinder Singh et al[3]	2019	India	Dry bones	728.12 ± 112.98
Sanjaykumar Revankar et al[6]	2020	India	Dry bones	773.53 ± 154.359
Sampada P K et al[7]	2017	India	Dry bones	803.8 ± 83.42
Roma Patel et al[14]	2014	India	Dry bones	755.37
Present study	2023	India	Dry bones	770.56 ± 143.06

In the present study, area of foramen magnum was calculated by using method of Routal et al which was similar with the method used by Radinsky. We found that area calculated in our study by formula, Area = ¼ x π x TD x APD was 770.56 ± 143.06 mm^2 and it was in accordance with most of the previous studies as mentioned in table 4.

Expanding the scope of research by incorporating larger sample sizes and employing some additional bony landmarks could offer comprehensive insight into skull base morphometry. Studies like this would contribute to understanding potential anatomical variations within this region.

Conclusions:

The present study gives a morphometric reference of various types of foramen magnum in Indian population & its clinical significance. The information gathered in this study holds

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE9, 2024

importance for neurosurgeons, offering valuable insights into the anatomy of the Craniovertebral junction for both preoperative planning and the management of skull base surgeries. Additionally, the findings from this research will contribute useful perspectives for Radiologists, Orthopedicians, Anthropologists, Anatomists, anesthesiologists, and forensic specialists.

Abbreviations: FM- Foramen magnum, APD- Anteroposterior diameter, TD- Transverse diameter, A - Area

References:

1. Standring S. Gray's Anatomy: Anatomical Basis of Clinical Practice. 40th ed. Edinburgh: Elsevier Churchill Livingstone, 2008.
2. Vinutha S P, Shubha R. Morphometry and Sexual Dimorphism in Foramen Magnum: A Study of Human Skull Bones. International Journal of Anatomy and Research. 2016; Vol 4(3): 2593-99.
3. Singh D, Patnaik P, Gupta N. Morphology and Morphometric Analysis of the Foramen Magnum in Dried Adult Skulls in North Indian Region. International Journal of Health Sciences & Research. April 2019; Vol 9 (4): 36-42.
4. Manoel C Et al. Morphometric analysis of the foramen magnum in human skulls of brazilian individuals: its relation to gender. Braz J Morphol Sci. 2009; Vol 26(2): 104-108.
5. 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. Jul 2019; Vol 8(3): 10-12.
6. Revankar S Et al. Morphometric Analysis of Foramen Magnum Region in Adult Indian Population. European Journal of Molecular & Clinical Medicine. 2020; Volume 7(10): 2515-8260.
7. Sampada P K Et al. Morphometric and Morphological Study of Foramen Magnum in Dried Human Skull Bones. International Journal of Anatomy and Research. 2017; Vol 5(2.1): 3682-86.
8. Arora S Et al. Morphometry and Surgical Importance of Foramen Magnum. International Journal of Anatomy and Research. 2017; Vol 5(1): 3464-69.
9. Ficke J, Varacallo M. Anatomy, Head and Neck: Foramen Magnum. Stat Pearls Publication. 2023 (Accessed on April 2024). Available from: https://www.ncbi.nlm.nih.gov/books/NBK526041/
10. Muthukumar N Et al. A morphometric analysis of the foramen magnum region as it relates to the transcondylar approach. Acta Neurochir (Wien). 2005, 147: 889–895.
11. Sharma A, Kaur R, Sharma M K. Foramen Magnum: Morphometry, Possible Variation in the Shape and its Clinical Implication. International Journal of Scientific Study. January 2019; Vol 6 (10): 13-16.

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE9, 2024

12. Chethan P Et al. Morphological Analysis and Morphometry of the Foramen Magnum: An Anatomical Investigation. Turkish Neurosurgery. 2012; Vol 22(4): 416-419.
13. Jasuja V R Et al. A Morphometric Study of Occipital Condyles and Foramen Magnum in Adult Skull Base in Western Maharashtra Region of India. International Journal of Anatomy and Research. 2016; Vol 4(1): 1846-50.
14. Patel R, Mehta C D. Morphometric study of Foramen Magnum at the base of human skull in South Gujarat. IOSR Journal of Dental and Medical Sciences. Jun 2014; Volume 13 (6): 23-25.
15. Kanchan T, Gupta A, Krishan K. Craniometric Analysis of Foramen Magnum for Estimation of Sex. International Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering. 2013; Vol 7: 378-380.