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RESEARCH ARTICLE

FORAMEN MAGNUM IN NORTH INDIAN DRY SKULLS: A MORPHOLOGICAL AND MORPHOMETRIC ANALYSIS

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Abstract

Introduction:-

The foramen magnum is the largest foramen in the occipital bone at the base of the skull, forming a crucial anatomical component of the craniovertebral junction (CVJ) [1-2]. It transmits several important structures, including the medulla oblongata, vertebral arteries, anterior and posterior spinal arteries, membrana tectoria, alar ligaments, and the spinal component of the accessory nerve into the cranial fossa [2]. Additionally, significant neural elements, such as the 7th to 12th cranial nerves, cervical spinal nerves, brainstem, rostral aspect of the spinal cord, cerebellum, and vermis, along with various vascular structures like the vertebral artery and its branches, meningeal vessels, and venous sinuses, are closely associated with the posterior cranial fossa (PCF) and the foramen magnum (FM) [3,4].

The foramen magnum holds a critical importance in anatomy, anthropology, forensic medicine, and neurosurgery. Its dimensions and shape are pivotal in neurosurgery, where precise knowledge of its size is essential for procedures involving the craniovertebral junction. Variations in shape and size that result in a smaller foramen magnum aperture can compress neurovascular structures, particularly in conditions such as basilar invagination. Conversely, a larger foramen magnum may provide more space through which the brainstem can protrude.

Understanding the morphometric anatomy of the foramen magnum is therefore vital for assessing associated pathologies and planning surgical interventions in this region. Additionally, forensic scientists and anthropologists rely on morphometric data of the foramen magnum for sex estimation and population studies.

The present study aimed to observe the variations in the shape of the foramen magnum and to assess its anteroposterior and transverse diameters, calculate the area of the foramen magnum and determine the foramen magnum index in North Indian dry skulls.

Materials and Methods:-

Study type- It is a quantitative cross-sectional observation study.

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Sample Collection
The study sample comprised100 dry, intact adult fully ossified human skulls from the Anthropology Museum of the Department of Anatomy, G.S.V.M. Medical College, Kanpur. All the measurements were done by digital vernier caliper.

Inclusion Criteria-
Intact skulls were included in the studies.

Exclusion Criteria-
Broken skulls were excluded from the studies.

Methodology:-
The study included nonmetric and metric parameters of foramen magnum as follows-

Non MetricParameter:
Shapeof foramen magnum for variations- The shape of FM was observed on the inferior basal view of the skull.The shape of the foramen magnum was classified based on visual inspection into five categories: oval, round, hexagonal, pentagonal, tetragonaland egg-shaped.

Metric Parameters-
1. Anteroposterior Diameter/ McRae line (ML)- distance between basion and opisthion.
2. Transverse Diameter-the maximum distance between two lateral margins
3. Area of the foramen magnum (FMA): The area ofthe Foramen magnum was calculated using a formula derived by Radinsky [4,5,6].
   Radinsky's Formula (FMA): 1/4 x 3.14 x FML x FMW mm^2
   Where, (mathematical constant) = 3.14,
   FML = Foramen magnum length
   FMW = Foramen magnum width.
4. Foramen magnum index (FMI) : Calculated by

Foramen magnum width x 100 / Foramen magnum length [5,7].Statistical Analysis of the data was done.Non-Metric parameter was analysed in percentage while Metric parameters were analysed in range, mean, and standard deviation.

Results:-
Shape Classification-
The distribution of shapes of the foramen magnum was Hexagonal 22%, Pentagonal 18%, Tetragonal 18%, Egg Shaped 16%, Round 14% and Oval 12 %. (Table 1); (Fig 1-6)

Morphological variants of the shape of foramen magnum	Number of skulls (n=100)	Percentage
Hexagonal Shape	22	22%
Pentagonal Shape	18	18%
Tetragonal Shape	18	18%
Egg Shape	16	16%
Round Shape	14	14%
Oval Shape	12	12%

Table 1:- Showing the shape of the Foramen Magnum in north Indian skulls.

The mean Anteroposterior Diameter of Foramen Magnum was 33.90 mm with a standard deviation (SD) of 2.20 mm. The range of APD was 29.24-37.88 mm. It had a mean Transverse Diameter (TD) of 27.82 mm with a standard deviation (SD) of 2.25mm. The range of TD was 23.59-32.20mm.The mean area of Foramen Magnum was 742.91±99.95 $mm^2$and a range of 560.72-946.78 mm^2.The mean Foramen Magnum Index (FMI) was 82.10±4.84 with a range of 72.10-92.82. (Table 2)

Parameters	Range	Mean
Anteroposterior Diameter (mm)	29.24-37.88	33.90 ± 2.20

Transverse Diameter (mm)	23.59-32.20	27.82 ±2.25
Foramen Magnum Area (mm^2)	560.72-946.78	742.91±99.95
Foramen Magnum Index	72.10-92.82	82.10±4.84

Table 2: - Showing morphometric parameters of Foramen Magnum.

Discussion:-

The foramen magnum is the largest opening in the occipital bone at the base of the skull, transmitting the medulla and its meninges, vertebral arteries, spinal vessels, and ligaments [1,2,3]. Normal morphological variations of the posterior cranial fossa (PCF) and foramen magnum (FM) exist across different geographical areas, races, and religions. Factors such as gender, genetics, and the environment also influence the morphometry of these structures [4,8,9]. The morphological features of the foramen magnum have undergone evolutionary changes, giving this region special anthropological significance [10,11,12]. Measurements of the FM are crucial when addressing lesions in the PCF and craniovertebral junction (CVJ) regions. During surgical procedures, information about the morphometry, morphology, and variations of the FM can impact surgical outcomes [4].

The foramen magnum is formed by the four portions of the occipital bone (two lateral, one squamous, and one basal) and can present different shapes [5]. It is formed by sclerotomes of the first four somites, which eventually fuse to form the occipital bone and the posterior element of the foramen magnum. The fourth sclerotome (proatlas) consists of three portions: the hypocentral, the centrum, and the neural arch, which divides into ventro-rostral and dorsal-caudal components. The ventro-rostral portion gives rise to the occipital condyles and the anterior margin of the FM. This process involves distinct ossification: the superior part of the squamous portion undergoes intramembranous ossification, while the other portions go through endochondral ossification. Any anomaly or malformation during the process of formation of foramen magnum can result in different shapes of the foramen magnum [13].

The shape variation of the FM holds potential for forensic and anthropological applications, such as sex estimation from skeletal remains. This study observed variations in the shape of the foramen magnum, including hexagonal, pentagonal, tetragonal, egg-shaped, round, and oval forms. Previous researchers, such as Zaidi and Dayal, Murshid et al., and Radhakrishna et al., also described these variations in their studies [14,15,16]. The shape of the FM is clinically significant regarding various surgical approaches. Differences in the frequency of FM shapes have been reported, potentially due to geographical, gender, and racial variations. Most literature describes the commonest shape as oval [17,18,19,20,21] amongst the other shapes as. However, in this study, the distribution of FM shapes was hexagonal (22%), pentagonal (18%), tetragonal (18%), egg-shaped (16%), round (14%), and oval (12%), with the most common shape being hexagonal (22%). Another study [4] also reported the most common shape as hexagonal (32.5%), followed by oval (22.5%). The study reported the occurrence of round (20%), tetragonal (5.83%), pentagonal (6.67%), irregular (7.50%), and egg-shaped (5%) foramen magnum as well [4]. Muthukumar et al. reported that if the FM is oval, a wider resection is required compared to a circular shape during surgeries [18].

Measures of the foramen magnum are relevant in cases of achondroplasia (due to the high risk of spinal cord stenosis at the base of the skull), Arnold-Chiari malformation (downward herniation of the cerebellar tonsils), foramen magnum meningioma, plagiocephaly, basilar invagination, and other cranial deformities. The expansion of the transverse diameter is observed in Arnold-Chiari syndrome [5]. Although studies have reported that FM measures are higher in males than in females [22,23,24], Kamath et al. (2015) [25] stated that FM measures may overlap and should not be used alone for gender determination, as other authors found no sexual dimorphic characteristics regarding the FM [26]. The size of the FM in patients with achondroplasia and other neurological problems was reported to be smaller at all ages, with the basichondrocranium of fetuses with hindbrain malformations (such as Arnold-Chiari malformation) being shorter and smaller than in normal fetuses [27,28].

The anteroposterior and transverse diameters of the FM are valuable parameters for analyzing its morphometric variations. In this study, the mean anteroposterior diameter of the FM was 33.90 ± 2.20 mm, while the transverse diameter was 27.82 ± 2.25 mm. In another study, the mean diameters were 34.6 ± 3.46 mm (anteroposterior) and 29.3 ± 3.47 mm (transverse) [Natsis et al., 2016]. Catalina-Herrera [29] reported a sagittal diameter of 35.2 mm and a transverse diameter of 30.3 mm for the FM, while Schmeltzer [30] reported a sagittal diameter of 35 mm and a transverse diameter of 30 mm. Murlidhar et al. (2014) [31] reported the AP diameter as 33.4 mm and the transverse diameter as 28.5 mm. The diameters of the FM in this study are comparable to the data reported in the literature.

The area of the FM is another morphometric tool for analyzing its variations, with values ranging from 560.72 to 946.78 mm² in this study, and a mean value of 742.91 ± 99.95 mm². A CT-based study by Chaudhary P et al. [4] found the FM area to be 691 ± 30.35 mm². Another study on skulls calculated the area as 772.4 ± 116.7 mm² [5]. Murlidhar et al. (2014) [31] reported the FM area as 748.6 mm². In another study, the mean FM area was 772.4 mm² with an SD of 116.7 mm [5].

The mean foramen magnum index (FMI) in this study was 82.10 ± 4.84, with a minimum value of 72.10 and a maximum value of 92.82. Kanchan et al. (2014) reported an FMI of 79.70 ± 6.98 mm in South Indians [26]. Another study reported a mean FMI of 83.75 mm with an SD of 7.23 mm [5]. In our study, we calculated the FMI as (transverse diameter / anteroposterior diameter) x 100. Some authors have calculated the FMI as anteroposterior diameter / transverse diameter [13,18,31]. In the latter case, the mean FMI was reported as 1.2 ± 0.1 [18,31].

Clinically, the dimensions of the FM are crucial for neurosurgical interventions involving the craniovertebral junction. Muthukumar et al. emphasized the importance of anatomical knowledge of the FM for surgical approaches like the transcondylar approach, where drilling of the posterior margin is essential to access lesions [18]. Accurate knowledge of foramen magnum dimensions can assist in planning surgical approaches and avoiding complications.

Limitation of the Present Study

One limitation of this study is that the sex of the skulls was unknown, preventing analysis of sexual dimorphism based on the foramen magnum. Additionally, the study was conducted on only 100 skulls, which is not sufficient to establish definitive benchmarks for the measurements of the foramen magnum in North India. Future studies with larger sample sizes and more diverse populations are recommended to validate these findings and explore additional clinical implications**.**

Hexagonal shape ofForamen Magnum

Pentagonal shape of ForamenMagnum.

Tetrahedral shape of Foramen Magnum

Oval shape of Foramen Magnum

Egg shaped Foramen Magnum

Round ShapedForamen Magnum

Conclusion:-

The data collected in this study of the foramen magnum provide an important database for neurosurgeons, forensic medicine experts, radiologists, and anthropologists. The dimensions of the foramen magnum are clinically and surgically significant, as vital structures may be compressed in conditions such as brainstem herniation, meningiomas, and achondroplasia.

Conflict of Interest-

None.

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None.

References:-

1. Oberman DZ, Baldoncini M, Rabelo NN, Ajler P. Morphometric analysis of posterior cranial fossa and surgical implications. J Craniovertebr Junction Spine. 2021;12(2):178–82. https://doi.org/10.4103/jcvjs.jcvjs_205_20.
2. Nishikawa M, Sakamoto H, Hakuba A, Nakanishi N, Inoue Y. Pathogenesis of Chiari malformation: a morphometric study of the posterior cranial fossa. J Neurosurg. 1997;86(1):40–7. https://doi.org/10.3171/jns.1997.86.1.0040.
3. Wen HT, Rhoton AL Jr, Katsuta T, de Oliveira E. Microsurgical anatomy of the transcondylar, supracondylar, and paracondylar extensions of the far-lateral approach. J Neurosurg. 1997;87(4):555–85. https://doi.org/10.3171/jns.1997.87.4.0555.
4. Chaudhary P, Verma R, Mishra P, Goyal A. Morphometric analysis of posterior cranial fossa and foramen magnum and its clinical implications in craniovertebral junction malformations: a computed tomography based institutional study in a tertiary care hospital of the northern part of India. Egypt J Neurosurg. 2023;38(1):1-8.
5. Pires LAS, Teixeira ÁR, Leite TFO, et al. The morphometric aspect of the foramen magnum and the orbit in Brazilian dry skulls. Int J Med Res Health Sci. 2016;5(4):34-42.
6. Radinsky L. Relative brain size is a new measure. Science. 1967; 155:836-83.
7. Kumar A, Dave M, Anwar S. Morphometric evaluation of foramen magnum in dry human skulls. Int J Anat Res. 2015; 3:1015-23. https://doi.org/10.16965/ijar.2015.154.
8. Relethford JH. Population-specific deviations of global human craniometric variation from a neutral model. Am J Phys Anthropol. 2010;142(1):105-11. https://doi.org/10.1002/ajpa.21207.

9. Kanodia G, Parihar V, Yadav YR, Bhatele PR, Sharma D. Morphometric analysis of posterior fossa and foramen magnum. J Neurosci Rural Pract. 2012;3(3):261-6. https://doi.org/10.4103/0976-3147.102602.
10. Kanchan T, Krishan K, Gupta A, Acharya J. A study of cranial variations based on craniometric indices in a South Indian population. J Craniofac Surg. 2014; 25:1645-9.
11. Shanthi CH, Lokanadham S. Morphometric study on foramen magnum of human skulls. Med Sci. 2013;2(4):792-8.
12. 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.
13. Tubbs RS, Griessenauer CJ, Loukas M, Shoja MM, Cohen-Gadol AA. Morphometric analysis of the foramen magnum: an anatomic study. Neurosurgery. 2012;66(2):385-8. https://doi.org/10.1227/01.NEU.0000366106.31469.C1.
14. Zaidi SH, Dayal SS. Variations in the shape of foramen magnum in Indian skulls. Anat Anz Jena. 1988;167:338-4.
15. Murshed K, Çiçekcibasi A, Tuncer I. Morphometric evaluation of the foramen magnum and variations in its shape: a study on computerized tomographic images of normal adults. Turk J Med Sci. 2003;33:301-6.
16. Radhakrishna S, Shivarama C, Ramakrishna A, Bhagya B. Morphometric analysis of foramen magnum for sex determination in South Indian population. Nitte Univ J Health Sci. 2012;2(1):20.
17. Natsis K, Piagkou M, Skotsimara G, Piagkos G, Skandalakis P. A morphometric anatomical and comparative study of the foramen magnum region in a Greek population. Surg Radiol Anat. 2013;35(10):925-34. https://doi.org/10.1007/s00276-013-1119-z.
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(8):889-95. https://doi.org/10.1007/s00701-005-0555-x.
19. Alaftan M, Alkhater S, Alhaddad F, et al. Morphological variations and morphometry details of the foramen ovale in the Saudi population: a retrospective radiological study. J Med Life. 2023;16(3):458-62. https://doi.org/10.25122/jml-2022-0265.
20. Prakash KG, Saniya K, Honnegowda TM, Ramkishore HS, Nautiyal A. Morphometric and anatomic variations of the foramen ovale in the human skull and its clinical importance. Asian J Neurosurg. 2019;14(4):1134-7. https://doi.org/10.4103/ajns.AJNS_243_19.
21. Bahşi İ, Adanır SS, Orhan M, et al. Anatomical evaluation of the foramen magnum on cone-beam computed tomography images and review of literature. Cureus. 2021;13(11):e19385. https://doi.org/10.7759/cureus.19385.
22. Gapert R, Black S, Last J. Sex determination from the occipital condyle: discriminant function analysis in an eighteenth and nineteenth century British sample. Am J Phys Anthropol. 2009;138:384-94. https://doi.org/10.1002/ajpa.20943.
23. Uthman AT, Al-Rawi NH, Al-Timimi JF. Evaluation of foramen magnum in gender determination using helical CT scanning. DentomaxillofacRadiol. 2012;41:197-202. https://doi.org/10.1259/dmfr/16366786.
24. Catalina-Herrera CJ. Study of the anatomic metric values of the foramen magnum and its relation to sex. Acta Anat. 1987;130(4):344-7. https://doi.org/10.1159/000146481.
25. Kamath VG, Asif M, Shetty R, Avadhani R. Binary logistic regression analysis of foramen magnum dimensions for sex determination. Anat Res Int. 2015;2015. https://doi.org/10.1155/2015/459428.
26. Kanchan T, Gupta A, Krishan K. Craniometric analysis of foramen magnum for estimation of sex. Int J Med Health Biomed Pharm Eng. 2013;7(7):111-3.
27. Leikola J, Haapamäki V, Karppinen A, Koljonen V, Hukki J, Valanne L, et al. Morphometric comparison of the foramen magnum in non-syndromic craniosynostosis patients with or without Chiari I malformation. Acta Neurochir. 2012;154:1809-13. https://doi.org/10.1007/s00701-012-1440-7.
28. Furtado SV, Thakre DJ, Venkatesh PK, Reddy K, Hedge AS. Morphometric analysis of foramen magnum dimensions and intracranial volume in pediatric Chiari I malformation. Acta Neurochir. 2010;152:221-7. https://doi.org/10.1007/s00701-009-0544-4.
29. Catalina-Herrera CJ. Study of the anatomic metric values of the foramen magnum and its relation to sex. Acta Anat. 1987;130(4):344-7. https://doi.org/10.1159/000146481.
30. Schmeltzer A, Babin E, Wenger JJ. Measurement of the foramen magnum in children and adults. Neuroradiology. 1971;2:162-3.
31. Pereira GAM, Lopes PTC, Santos AMP, Duarte RD, Piva L, Pozzobon A. Morphometric analysis related to the transcondylar approach in dry skulls and computed tomography. Int J Morphol. 2012;30(2):399-404. https://doi.org/10.