Section: Anatomy

Original Research Article

MORPHOMETRIC ANALYSIS OF FORAMEN MAGNUM IN ADULT HUMAN DRY SKULL OF UTTARAKHAND REGION

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ABSTRACT

Background: The foramen magnum, positioned at the base of the cranium, serves as a crucial junction between the spine and skull. It is in close proximity to essential structures, including the medulla oblongata, the membranes surrounding the brain and spinal cord, vertebral arteries, and the spinal accessory nerve. Understanding the anatomy and function of the foramen magnum is vital, as disorders like herniation, tumour's such as meningioma's, or achondroplasia can result in the compression of these critical elements, leading to serious medical complications. **Aims:** This study aimed to analyze specific cranial measurements to better understand anatomical variations and standard morphometric values of the foramen magnum in the adult dry human skull of Uttarakhand region.

Materials and methodology: A total of 65 adult dry human skulls were examined from the Department of Anatomy at Soban Singh Jeena government institute of medical sciences, Almora. Antero-posterior (APD) and transverse diameters (TD) were measured by using stainless steel electronic digital callipers.

Results: The mean antero-posterior diameter was found to be 32.27 ± 2.80 mm, mean transverse diameter was 27.07 ± 2.49 mm, with mean area 689.85 ± 109.18 mm^2 and foramen magnum index was 84.14 ± 6.89. The foramen magnum shapes were classified as Oval (40%), Circle /round (20%), Hexagonal (13%), Irregular (27%).

Conclusion: Based on this study, we conclude that the anatomical data obtained hold substantial value for clinical practice and neurosurgical procedures. These population-specific findings improve the accuracy of diagnosing and treating craniovertebral junction disorders, leading to better patient outcomes while advancing anatomical research specific to the region.

Keywords: Foramen Magnum, Morphometry, Meningioma, Achondroplasia, Antero-Posterior Diameter, Transverse Diameter, Foramen Magnum Area, Foramen Magnum Index.

INTRODUCTION

The foramen magnum, a prominent oval aperture located within the occipital bone, exhibits a notable asymmetry in its dimensions, being wider towards its posterior aspect compared to its anterior portion. This variance is attributable to the presence of the occipital condyles, which encroach upon its anterolateral margin. Functionally, the foramen magnum serves as a crucial conduit, facilitating communication between the posterior cranial fossa and the vertebral canal. This anatomical arrangement is integral to various physiological processes, including the passage of the spinal cord, blood vessels, and other neural structures between the cranial and vertebral regions.[1] The basion and opisthion are significant craniometric landmarks within the craniocervical junction. Flanking the foramen magnum are the occipital condyles, which articulate with the first cervical vertebra to form

joints. The foramen magnum is generally larger in males, both in transverse and anteroposterior measurements. For surgical approaches, the foramen magnum is divided into three regions: the basal (clival or anterior compartment), the squamosal (posterior compartment), and the condylar (lateral) compartment. An imaginary coronal plane, which extends from the first dentate ligaments and intersects cranial nerves IX to XII, separates the clival part from the squamosal part. The clival (anterior) compartment, an osseoligamentous area, includes the dens' tip, the apical ligament, and the upper portion of the cruciate ligament of the C1 vertebra. The posterior (squamous) compartment is a neurovascular region that contains or transmits the vertebral and spinal arteries, cranial nerve XI, sympathetic plexuses, the medulla and its surrounding meninges, and the cerebellar tonsils when herniated due to pathological conditions. The lateral (condylar) compartment features the hypoglossal canal, occipital condyle, and the posterior edge of the jugular foramen. Most decompression surgeries are performed through the squamous (posterior or suboccipital) approach.[2] The dimensions of the foramen magnum are particularly important in clinical contexts due to their potential implications for vital structures that traverse this opening. Conditions such as foramen magnum herniation, meningiomas located in this region, and achondroplasia affecting the foramen magnum can all lead to compression of these crucial anatomical elements. Consequently, understanding and monitoring the dimensions of the foramen magnum are essential for diagnosing and managing such conditions effectively, as compression of these structures can result in various neurological symptoms and complications.[3]

MATERIALS AND METHODS

A total of 65 adult dry human skulls were examined from the Department of Anatomy at Soban Singh Jeena government institute of medical sciences, Almora. This study aimed to analyze specific cranial measurements to better understand anatomical variations and standard morphometric values.

Inclusion Criteria: Fully ossified dry human skull bones were included in the study, regardless of the age and sex of the individuals. This criterion ensured that the sample consisted of mature bones suitable for accurate morphometric analysis.

Exclusion Criteria: Skulls of children were excluded to avoid the influence of incomplete ossification and developmental changes. Additionally, any incomplete or damaged skulls were excluded to ensure the accuracy and reliability of the measurements. Skulls showing significant deformities were considered for studying bony variations but were excluded from the morphometric analysis to avoid skewing the data.

All measurements were meticulously recorded using a Digital Vernier Caliper with a least count of 0.01mm to ensure high precision. To eliminate inter-observer variability and ensure consistency, all measurements were taken by the same observer. For each measurement, two readings were taken and then averaged. If the difference between the two readings exceeded 0.1mm, a third reading was taken to ensure accuracy.

Measurement of the anteroposterior distance (APD) of the foramen magnum, optimally viewed on the sagittal section, defined as a line drawn from the basion to the opisthion.[2]

- Measurement of the transverse diameter (TD), optimally viewed on the axial section, defined as a line connecting both lateral margins of the foramen magnum at its widest point.[4]
- FM area-FM area was calculated by Radinsky's formula; (πWL/4) (mm2),[5]

Foramen magnum index (FM) was calculated using the formula: (TD/ APD) × 10.[6]

These measurements were essential for understanding the anatomical variations and providing baseline data for surgical approaches and anthropological studies. The data collected were entered into spreadsheets, compiled, and analyzed using descriptive, inferential, and comparative statistical methods. This comprehensive approach provided valuable insights into the morphometric characteristics of the adult human skull.

RESULTS

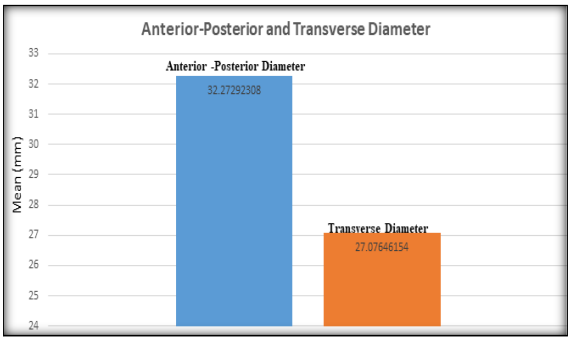

Figure 1: Histogram illustrating the mean antero-posterior and transverse diameter of foramen magnum

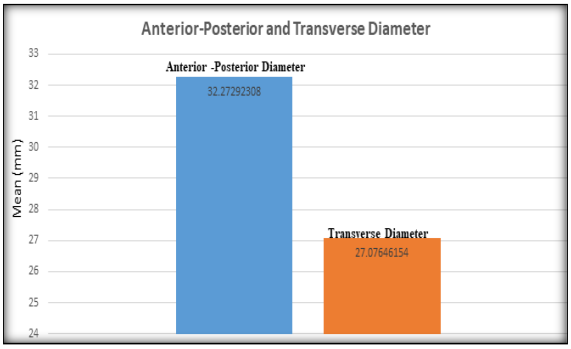

Figure 2: Showing percentage of occurrence of different morphology in foramen magnum

In our study the mean Antero-posterior diameter was found to be 32.27 ± 2.80 mm. The maximum antero-posterior diameter was 39.41mm and the minimum antero-posterior diameter was 25.9mm. The mean transverse diameter was 27.07 ± 2.49 mm. The maximum transverse diameter was 32.11 mm and the minimum transverse diameter was 20.7 mm. The mean area was 689.85 ± 109.18 mm2 and Foramen Magnum index was 84.14 ± 6.89. [Table1, Figure 1]

The foramen magnum shapes were classified as Oval (40%), Circle /round (20%), Hexagonal (13%), Irregular (27%). In one skull out of the 64 skull studied, we noted a bony tubercle at the posterior margin of foramen magnum. [Table 2]

Table 1: Demographic details

Number of skulls= 65	Antero-posterior diameter of foramen magnum(mm)	Transverse diameter of foramen magnum (mm)	Foramen magnum index
Mean	32.27	27.07	84.14
Standard Deviation	2.8	2.49	6.89
Minimum	25.9	20.7	67.1
Maximum	39.41	32.11	98.46673

DISCUSSION

In the present study, mean anteroposterior diameter of foramen magnum in 65 skulls was found to be 32.27± 2.80 mm, range being 25.9¬- 39.41 mm and the standard deviation of 2.80. the mean transverse diameter of foramen magnum was 27.07± 2.49 mm with the range being 20.7 - 32.11 mm and standard deviation of 2.49. In present study mean foramen magnum area was found to be 689.85± 109.18 mm2, with range being minimum 440.10 to maximum 898.0 with standard deviation of 109.18. the mean index of foramen Magnum 84.14 ± 6.89 while comparing our study with Singh R et al, the mean antero- posterior diameter was 32.47±1.65 mm with maximum diameter 40.48 mm and minimum it was 26.48, Transverse diameter: the mean transverse diameter was 26.49±12 mm with maximum diameter 35.85 mm and minimum it was 24.45mm. Foramen magnum area: the mean area of foramen magnum was 749.04 ± 101.45 mm2, Foramen Magnum index: the index of foramen Magnum was 1.45 ± 0.15. that the most common shape of for amen magnum is oval which is 43%, hexagonal 8% circular 28%, irregular 21%.[7] Another study of Bhardwaj K et al, the mean anteroposterior diameter of foramen magnum male and female skull bones were found to be 37.17±1.76 mm and 33.92±3.50 mm respectively. The average transverse diameter of the foramen magnum in male skulls was measured at 29.49±2.68 mm, while in female skulls, it was 29.38±2.47 mm. The average area of the foramen magnum in male and female skulls was found to be 818.05±119.66 mm² and 847.57±105.85 mm², respectively. Additionally, the mean foramen magnum index for male skulls was 84.00±5.41, while for female skulls it was 80.27±5.79 in 30 skull bones, they are: oval, round, tetragonal, hexagonal and irregular. Oval shape (33.33%) was the most common type and irregular (3.33%) was the least common type.[8] The base of the cranium presents a compelling area of study, particularly in examining the diameters of the foramen magnum from both descriptive and topographic viewpoints, owing to its critical relationship with the structures it encloses. The radiological and anatomical dimensions of the foramen magnum have been the focus of numerous investigations. While anatomical measurements reported by different authors are generally consistent, radiological measurements often display greater variability across studies.[9] Dasegowda G et al, the mean antero-posterior diameter was found to be 34.10 ± 2.63 mm, mean transverse diameter was 28.07 ± 1.87 mm, with mean area of 752.07 ± 111.97 mm2 and foramen magnum index was 1.21 ± 0.12. The foramen magnum shapes were classified as oval (30%), circle (12%), hexagonal (3%), pentagonal (5%), egg (17%), leaf (6%), irregular (27%) (10). Hemant Ashish Harode, Anteroposterior Diameter (APD)34.41mm, Transverse Diameter 29.24 mm, foramen index 1.17.[11] Rajkumar et al, studies show that the mean anteroposterior and transverse diameter of the foramen magnum were 34.13±2.44 mm and 28.32±2.042mm. The mean area and index of the foramen magnum were 754.32±105.6 mm2 and 83.14±6.33mm. The shape of the foramen magnum -oval 66%, rounded 24.83%, hexagonal 4.02%, tetragonal 3.35%, pentagonal 2.68%, shapes.[12] The development of the foramen magnum's unique shape is closely linked to embryological processes. During early development, the shape is influenced by the ossification of primordial cranial structures, which connect with specific endochondral ossification centers at various locations within the cranium. This complex interaction results in a range of foramen magnum shapes observed in different individuals. Furthermore, the irregularities in the shape of the foramen magnum can be exacerbated by developmental anomalies affecting the bone and soft tissues at the craniovertebral junction. Such anomalies can arise from disruptions in the normal pattern of ossification, leading to further deviations from the typical shape of the foramen magnum. Understanding these developmental factors is crucial, as they have significant implications for both anatomical variations and potential clinical concerns related to the craniovertebral region.[13] Sharma S et al, study concluded the mean antero-posterior and transverse diameters of the foramen

magnum was recorded as 38.75mm and 33.44 mm. The mean of area of FM was observed 970.57mm2, and the mean of FM index was 87.68. Round shaped foramen was observed in 22% oval shaped in 16% egg shaped in 16 %, irregular in 18%, tetragonal in 12%, pentagonal and hexagonal 8% each.[14] In cases where the foramen magnum has an ovoid shape, achieving proper exposure of its anterior sportion during surgery can be challenging for the surgeon. If the occipital condyle extends into the foramen magnum, it may require more extensive removal of bone to ensure adequate surgical access.[15] Bharat.j et al,[1] sharma A et al,[16] and Fathima F et al,[17] values of APD, TD, Mean area were founded to be greater than our findings whereas Chethan P et al,[18] and Berjina F et al.[19]

Table 3: Showing the comparison of Antero-posterior, Transverse diameter, FM Area and FM Index of different studies

Name of Author	Population	Sample Size	Anteroposterior Diameter (mm)	Transverse Diameter(mm)	FM Area (mm^2)	FM Index (mm)
Faazila Fathima et al	Chennai	53	38.22	35.15	1102.5	NA
Bharat.j.sarvaiya et al	Gujarat	326	34.18	28.49	766.86	83.6
Anshu sharma et al	Chandigarh	50	34.44	30.46	745.727	88.4
Berjina N et al	Kashmir	25	31.6	26.5	660	83.64
Chetan P et al	India	53	31.6	25	NA	NA
Raveena Singh et al	Pratapgarh/Fatehpur,	100	32.47	26.49	749.04	1.45
Giridhar Dasegowda et al	Bengaluru,Karnataka.	64	34.1	28.07	752.07	1.21
Hemant et al	Bhopal	60	34.41	29.24	NA	1.17.
Rajkumar et al	Kanpur /Lucknow	298	34.13	28.32	754.32	83.14
Shikha Sharma et al	Tundla india	50	38.75	33.44	970.57	87.68
Present study	Uttarakhand	65	32.27	27.07	689.85	98.46

CONCLUSION

From the present study we can concluded that the morphometric analysis of the foramen magnum holds significant implications for both clinical and surgical practices in medicine, particularly in understanding and managing conditions associated with the craniovertebral junction. The foramen magnum, a key anatomical structure, plays a critical role in the passage of vital neural and vascular elements between the cranial cavity and the spinal canal. Variations in its size, shape, and dimensions can be indicative of several congenital and acquired anomalies, such as Chiari malformations, basilar invagination, and atlanto-occipital assimilation.This study highlights the significance of detailed morphometric assessments of the foramen magnum, which are essential for accurately diagnosing these conditions. Precise measurements are crucial for identifying deviations from the norm, enabling early detection of potential pathologies. Furthermore, the data obtained from such analyses can serve as a valuable reference in clinical practice, assisting in the formulation of more individualized and effective treatment plans.

From a surgical perspective, understanding the morphometric variations of the foramen magnum is vital for planning interventions, particularly in neurosurgery and spinal surgery. Accurate knowledge of the dimensions and shape of this structure can help surgeons avoid critical complications, such as damage to the brainstem or spinal cord during procedures like foramen magnum decompression or craniovertebral junction stabilization. Future research in this area should focus on expanding the study population to include a diverse demographic, encompassing various age groups, ethnicities, and genders. This will allow for a more comprehensive understanding of the morphometric variations and contribute to the development of standardized protocols and guidelines in clinical practice, ultimately improving patient care and outcomes in the long term.

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