



ORIGINAL ARTICLE

Morphometric Study of Foramen Magnum and Its Clinical Significance in Adult Human Dry Skulls

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Abstract

Background: The foramen magnum is an important anatomical land-mark situated in the occipital bone at the base of the skull. It trans-mits the lower medulla, meninges, vertebral arteries, spinal accessory nerves, anterior and posterior spinal arteries, and venous plexus. Mor-phometric evaluation of the foramen magnum is useful in anatomy, an-thropology, forensic identification, radiology, neurosurgery, and cran-iovertebral junction procedures.

Aim: To study the morphometry and shape variations of the foramen magnum in adult human dry skulls and to assess its anatomical and clinical significance.

Materials and Methods: A descriptive observational study was con-ducted in the Department of Anatomy using 80 adult human dry skulls of unknown sex. Skulls with damaged occipital bone, broken margins of the foramen magnum, deformity, or gross pathology were excluded. Anteroposterior diameter, transverse diameter, and foramen magnum index were measured using a digital Vernier caliper. The shape of the foramen magnum was classified as oval, round, tetragonal, hexagonal, irregular, or egg-shaped. Data were analyzed using descriptive statis-tics.

Results: The mean anteroposterior diameter of the foramen magnum was 34.82 ± 2.46 mm, while the mean transverse diameter was 29.76 ± 2.18 mm. The mean foramen magnum index was 85.52 ± 5.74 . Oval shape was the most common type, observed in 32.5% skulls, followed by round shape in 21.3%, tetragonal shape in 16.3%, hexagonal shape in 12.5%, irregular shape in 10.0%, and egg-shaped foramen magnum in 7.5%. The anteroposterior diameter was greater than the transverse diameter in most skull **Conclusion:** The foramen magnum shows considerable variation in dimensions and shape. Morphometric knowledge of the foramen magnum is important for neurosurgical approaches to the craniovertebral junction, radiological interpretation, forensic anthropology, and anatomical teaching. The data generated may serve as a regional reference for anatomical and clinical applications.

Keywords: Anatomy, Craniovertebral Junction, Dry Skull, Foramen Magnum, Morphometry, Occipital Bone.

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1 | INTRODUCTION

The foramen magnum is the largest opening in the base of the skull and is located in the occipital bone. It forms a vital communication between the posterior cranial cavity and the vertebral canal. The structures passing through it include the lower medulla oblongata, meninges, vertebral arteries, anterior and posterior spinal arteries, spinal accessory nerves, tectorial membrane, apical ligament of dens, and venous plexus. Because of its central location at the craniovertebral junction, it has considerable anatomical and clinical importance. (1)

The occipital bone develops from membranous and cartilaginous components. The squamous part above the superior nuchal line develops in membrane, whereas the basal and lateral parts around the foramen magnum develop mainly in cartilage. Developmental variations in ossification may influence the size and shape of the foramen magnum. Knowledge of such variations is important during interpretation of skull base anatomy. (2)

Morphometry of the foramen magnum is useful in physical anthropology and forensic medicine. Measurements of the cranial base are relatively resistant to postmortem damage and may help in identification of sex and population affinity when other skeletal parts are incomplete or fragmented. The anteroposterior and transverse diameters of the foramen magnum are commonly used parameters in morphometric studies. (3)

The foramen magnum also has importance in radiology and neurosurgery. Lesions around the craniovertebral junction, Chiari malformation, basilar invagination, atlanto-occipital assimilation, tumors, and traumatic injuries may alter or involve this region. Accurate anatomical knowledge is essential during imaging assessment and surgical planning. (4)

The shape of the foramen magnum may vary considerably. It has been described as oval, round, tetragonal, hexagonal, pentagonal, irregular, or egg-shaped in different studies. Shape variation may influence the available surgical corridor during posterior fossa and craniovertebral junction procedures. (5)

In neurosurgical procedures involving the posterior cranial fossa and craniovertebral junction, the dimensions of the foramen magnum are relevant for planning decompression, avoiding injury to neurovascular structures, and understanding the relationship of surrounding bony landmarks. Foramen magnum decompression is commonly performed in selected cases of Chiari malformation and other compressive pathologies. (6)

Regional morphometric data are useful because cranial dimensions may vary with ethnicity, geography, genetic background, and population characteristics. Therefore, anatomical studies on dry skulls provide baseline data for comparison with radiological and forensic studies. (7)

The present study was conducted to assess the anteroposterior diameter, transverse diameter, foramen magnum index, and shape variations of the foramen magnum in adult human dry skulls and to discuss their anatomical and clinical significance.

2 | MATERIALS AND METHODS

This descriptive observational study was conducted in the Department of Anatomy. A total of 80 adult human dry skulls of unknown sex were included.

Adult skulls with intact occipital bone and clearly defined margins of the foramen magnum were selected. Skulls with broken margins of the foramen magnum, damaged occipital bone, congenital deformity, gross pathology, or postmortem damage affecting measurement were excluded.

The skulls were examined macroscopically. The foramen magnum was identified at the base of the skull. Measurements were taken using a digital Vernier caliper with accuracy of 0.01 mm. Each measurement was taken twice, and the average value was recorded to reduce observational error.

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The following parameters were measured:

Anteroposterior diameter: Maximum distance from the basion to the opisthion

Transverse diameter: Maximum width of the foramen magnum measured perpendicular to the anteroposterior diameter

Foramen magnum index: Calculated using the formula: transverse diameter divided by anteroposterior diameter multiplied by 100.

The shape of the foramen magnum was assessed by direct visual inspection and classified as oval, round, tetragonal, hexagonal, irregular, or egg-shaped.

All data were entered in Microsoft Excel and analyzed using descriptive statistics. Mean, standard deviation, range, frequency, and percentage were calculated.

Ethical permission was obtained from the concerned institutional authority. Since the study was conducted on dry human skulls available in the Department of Anatomy and did not involve living participants, individual consent was not applicable.

3 | RESULTS

3.1 | Total of 80 adult human dry skulls were studied

The mean anteroposterior diameter was greater than the mean transverse diameter. This indicates that the foramen magnum was longer in the anteroposterior direction in most skulls. The mean foramen magnum index was 85.52 ± 5.74 .

Oval shape was the most common type, observed in 26 (32.5%) skulls. Round shape was observed in 17 (21.3%) skulls. Tetragonal and hexagonal shapes were found in 13 (16.3%) and 10 (12.5%) skulls respectively. Irregular shape was observed in 8 (10.0%) skulls, while egg-shaped foramen magnum was seen in 6 (7.5%) skulls.

Most skulls had an anteroposterior diameter between 32 and 36 mm. Only 12 (15.0%) skulls had an AP diameter less than 32 mm, while 20 (25.0%) had an AP diameter greater than 36 mm.

The majority of skulls had transverse diameter between 28 and 32 mm. Transverse diameter greater than 32 mm was observed in 12 (15.0%) skulls.

4 | DISCUSSION

The present study evaluated the morphometry and shape variations of the foramen magnum in 80 adult human dry skulls. The mean anteroposterior diameter was 34.82 ± 2.46 mm, and the mean transverse diameter was 29.76 ± 2.18 mm. The most common shape was oval, followed by round and tetragonal forms. These findings support that the foramen magnum shows measurable anatomical variation.

Murshed et al. studied morphometric evaluation of the foramen magnum using computed tomography and reported that the anteroposterior diameter is generally greater than the transverse diameter. (8) The present study showed a similar pattern, with the AP diameter exceeding the transverse diameter in most skulls.

Routal et al. examined the morphology of the foramen magnum and observed different shapes, including oval, round, tetragonal, pentagonal, and irregular forms. (9) In the present study also, multiple shapes were identified, with oval being the most common.

Muthukumar et al. emphasized the surgical anatomy of the foramen magnum region and its relevance in transcondylar and posterior craniovertebral approaches. (10) The dimensions recorded in the present study are clinically important for planning procedures around the craniovertebral junction.

Radhakrishna et al. conducted a morphometric analysis of the foramen magnum and observed population-specific variations in its dimensions. (11) The present study adds regional anatomical data that may be useful for comparison with other Indian and international studies.

Kanchan et al. evaluated sex differences in foramen magnum dimensions and highlighted its forensic relevance. (12) Although sex determination was not performed in the present study because the skulls were of unknown sex, the measured parameters may still provide baseline morphometric data.

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TABLE 1: Morphometric Dimensions of Foramen Magnum

Parameter	Mean $\pm$ SD	Range
Anteroposterior diameter	34.82 $\pm$ 2.46 mm	29.40–39.80 mm
Transverse diameter	29.76 $\pm$ 2.18 mm	25.20–34.10 mm
Foramen magnum index	85.52 $\pm$ 5.74	74.60–96.20

TABLE 2: Distribution of Foramen Magnum Shape

Shape	Number	Percentage
Oval	26	32.5%
Round	17	21.3%
Tetragonal	13	16.3%
Hexagonal	10	12.5%
Irregular	8	10.0%
Egg-shaped	6	7.5%

TABLE 3: Distribution Based on Anteroposterior Diameter

AP Diameter Group	Number	Percentage
<32 mm	12	15.0%
32–36 mm	48	60.0%
>36 mm	20	25.0%

TABLE 4: Distribution Based on Transverse Diameter

Transverse Diameter Group	Number	Percentage
<28 mm	16	20.0%
28–32 mm	52	65.0%
>32 mm	12	15.0%

Uthman et al. studied foramen magnum dimensions using CT and reported its usefulness in sex estimation. (13) The relative protection of the cranial base makes the foramen magnum useful in forensic identification, especially when other skeletal remains are damaged.

Chethan et al. studied the morphology of the foramen magnum in dry human skulls and reported oval shape as one of the common types. (14) The present study similarly found oval shape as the most common type, observed in 32.5% skulls.

Berge and Bergman described variations in size and shape of the foramen magnum and emphasized the importance of anatomical knowledge of the skull base. (15) The present study supports that shape variations are frequent and should be considered during anatomical teaching and clinical interpretation.

Ganapathy et al. reported morphometric data of the foramen magnum and discussed its significance in neurosurgical and radiological practice. (16) The present study findings may be useful during interpretation of skull base imaging and planning of craniovertebral junction procedures.

Natsis et al. studied anatomical variations of the foramen magnum and highlighted their clinical relevance in posterior cranial fossa procedures. (17) Variations in shape and dimensions may influence the available surgical space and relationship with surrounding neurovascular structures.

The predominance of oval shape in the present study may be related to normal developmental growth patterns of the occipital bone. Oval and round shapes provide relatively regular margins, while irregular shapes may reflect developmental asymmetry or variation in bony remodeling.

The mean AP diameter recorded in the present study was within the range reported in previous morphometric studies. A larger AP diameter may be relevant in assessing space available at the craniovertebral junction. Reduced dimensions may be clinically important in conditions associated with compression at the foramen magnum level.

The transverse diameter is also important because it indicates the width of the foramen magnum. It has relevance during surgical decompression and posterior fossa approaches. Narrowing or asymmetry may affect the relationship of the medulla, vertebral arteries, and surrounding structures.

The foramen magnum index provides an estimate of overall shape by comparing transverse and anteroposterior diameters. Higher index values indicate a relatively wider foramen, whereas lower values indicate a more elongated form. In the present study, the mean index was 85.52 ± 5.74 , suggesting predominance of an elongated oval configuration.

Foramen magnum measurements are useful in forensic anthropology, particularly in fragmented skeletal remains. Since the base of the skull is relatively protected, it may remain preserved when other skeletal elements are damaged. However, sex estimation based only on foramen magnum dimensions should be interpreted cautiously and preferably combined with other skeletal parameters.

In radiology, knowledge of normal variation helps differentiate anatomical variants from pathology. Imaging of the craniovertebral junction is commonly performed in cases of trauma, congenital anomalies, Chiari malformation, basilar invagination, tumors, and degenerative disease.

In neurosurgery, the foramen magnum region is surgically important because it contains vital neurovascular structures. Procedures involving decompression or tumor removal require detailed knowledge of bony anatomy and variations. Morphometric data may assist in preoperative planning.

The present study has certain limitations. The sex and age of skulls were unknown. The sample size was moderate, and the study was limited to dry skulls. Radiological correlation was not performed. Future studies including larger samples, known sex, CT correlation, and population comparison may provide

more comprehensive data.

5 | CONCLUSION

The foramen magnum shows significant variation in size and shape. In the present study, the mean anteroposterior diameter was greater than the transverse diameter, and oval shape was the most common type. Knowledge of foramen magnum morphometry is important for anatomists, radiologists, neurosurgeons, and forensic experts. The findings provide useful baseline data for anatomical teaching, craniovertebral junction surgery, radiological assessment, and forensic identification.

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