Section: Miscellaneous

Original Research Article

A COMPARATIVE STUDY OF FORAMEN MAGNUM DIMENSIONS THROUGH MORPHOMETRY AND CT SCAN

Areeba Nasar[1], Mah Paiker[2], Tarim Usmani[3], Anchal Katiyar[4], Anas Ahmad Khan[5]

[1]*Associate Professor, Department of Anatomy, Rama Medical College Hospital & Research Center, Rama University, Kanpur, India.*
[2]*Associate Professor, Department of Anatomy, Integral Institute of Medical Sciences& Research, Integral University, Lucknow, India.*
[3]*Associate Professor, Department of Radio Diagnosis, Career Institute of Medical Sciences, Lucknow, India.*
[4]*MSc (Medical Anatomy) Student, Department of Anatomy, Rama Medical College Hospital & Research Center, Rama University, Kanpur, India.*
[5]*Professor, Department of Community Medicine, Rama Medical College Hospital & Research Center, Rama University, Kanpur, India.*

Received : *19/10/2025*
Received in revised form : *07/11/2025*
Accepted : *29/11/2025*

Corresponding Author:
Dr. Anas Ahmad Khan,
Professor, Department of Community Medicine, Rama Medical College Hospital & Research Center, Rama University, Kanpur, India.
Email: anas.ahmad.khan@gmail.com

DOI: 10.70034/ijmedph.2025.4.476

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2025; 15 (4); 2649-2653

ABSTRACT

Background: The foramen magnum (FM) which is situated in the posterior cranial fossa of skull plays a vital role in transmitting neurovascular structures and is clinically significant in neurosurgery, radiology, orthopaedics, and forensic anthropology. Variations in its size and shape influence outcomes in medical conditions such as achondroplasia, craniovertebral junction anomalies and posterior fossa malformations. With increased dependence on imaging modalities, correlating osteological and CT-based measurements is essential for accurate morphometric assessment. **Objectives:** (1) To measure the anteroposterior (AP) and transverse (TD) diameters of the FM; (2) To assess the morphological shapes of the FM; (3) To correlate CT-based measurements with morphometric parameters of dry skulls.

Materials and Methods: A prospective, cross-sectional study was conducted from December 2023 to November 2024 on 75 dry skulls of unknown sex and 75 CT scans of known age and sex at Rama Medical College, Kanpur. AP and TD dimensions were measured using a digital Vernier caliper for skulls and Radiant DICOM Viewer for CT images. Shapes were categorized as circular, oval, or irregular. Statistical comparisons examined differences between CT and skull measurements and gender-based variations.

Results: Dry skulls showed higher mean AP (31.07 mm) and TD (29.20 mm) diameters compared to CT scans (AP: 25.09 mm; TD: 26.17 mm). The oval shape was most common (52%). No statistically significant gender differences were observed for CT-derived dimensions ($p > 0.05$). CT and dry skull measurements exhibited good agreement, with minor underestimation in CT values.

Conclusion: CT imaging provides reliable, non-invasive assessment of FM morphology, closely correlating with dry skull measurements. The study contributes essential baseline morphometric data valuable for surgical planning, radiological evaluation, and forensic identification.

Keywords: Foramen magnum, Morphometry, CT scan, Craniovertebral junction.

INTRODUCTION

The posterior cranial fossa is made up of occipital and temporal bones with minor contributions from the sphenoid and parietal bones. The brain stem and the cerebellum are located in posterior cranial fossa which is largest and deepest among three cranial fossa. The dorsum sellae and the clivus comprise the anterior limits of the posterior cranial fossa located in the midline. The superior border of the petrous portion of the petromastoid component of the temporal bone makes up the lateral limits of the posterior cranial fossa. Minor portions of the occipital and parietal bones, as well as the petromastoid portion of the temporal bone, border the fossa laterally.[1]

The foramen magnum being the largest foramen is found in the base of the skull centrally in the deepest area of the posterior cranial fossa. Posteriorly, it is composed by the squamous part of the occipital bone whereas anteriorly and on the eithersides by the lateral and basilar parts of the same respectively. It provides a passage to vertebral arteries, spinal roots of accessory nerve [XI], lower part of the medulla oblongata along with the meninges, anterior and posterior spinal arteries, apical ligament of dens and tectorial membrane.[2]

The morphometric analysis of the foramen magnum and its variations is important not only for anatomists but also for anaesthetists, neurosurgeons, orthopedicians, and radiologists. There are various applications of the morphometric analysis of the foramen magnum. The length and breadth of the foramen find their clinical importance in patients suffering from achondroplasia, where in the cervicomedullary junction gets compressed due to marked foramen magnum stenosis, becoming evident through neurologic manifestations.[3] Achondroplasia is a genetic disorder manifesting in dwarfism and abnormal endochondral bone formation at the base of the cranium resulting in a narrow cervical spinal canal and stenosis of foramen magnum.[4] The knowledge of size and shape of foramen magnum is helpful to neurosurgeons in cranio-vertebral surgical approaches as well as in posterior cranial fossa surgeries.[3] Irregular shape of foramen magnum is accentuated by the developmental anomalies of the bone and soft tissues at the craniovertebral junction. Due to high chances of morbidity and mortality during various surgical procedures at the skull base, this area is having higher clinical importance. It has also had important clinical implications in the prognosis and treatment of various neurological pathologies like Arnold Chiari syndrome, and posterior cranial fossa lesions.[5]

Recent evidences through the Computed Tomographic (CT) / Magnetic Resonance Imaging (MRI) of cranial structures shows that the clustering of the hind brain because of the poor development of the posterior cranial fossa is the reason for various disorders of the craniovertebral junction. Therefore, a fundamental knowledge of the basic anatomy around the region is essential to the clinician for further diagnostic and treatment purposes.[6]

The foramen magnum is a large opening in the occipital bone at the base of the skull. Its development is closely associated with the overall growth of the skull and vertebral column during embryogenesis and postnatal development.

1. Embryonic Development The foramen magnum is a part of the occipital bone, developing from both endochondral and intramembranous ossification. The four different cartilaginous centers that give rise to the occipital bone are as follows
   - Basioccipital forming the anterior aspect of the foramen magnum.
   - Exoccipitals (paired) forming the lateral aspect of foramen magnum including the occipital condyles.
   - Supraoccipital surrounding the foramen magnum posteriorly.
2. Neural Tube Influence The foramen magnum is closely related to the developing neural tube and notochord. The notochord contributes to the organization of the cartilaginous precursors around the foramen magnum. The shape and size of the foramen magnum are influenced by the growth and development of the medulla oblongata and spinal cord.[7]
3. Fetal Stage Ossification of cartilaginous bone precursors begins around the third month of fetal development. In the case of the occipital bone, its various parts start to unite near the foramen magnum during the later stages of gestation, but full fusion is only completed after birth.
4. Postnatal Development

The foramen magnum continues to grow in size to accommodate the brainstem and spinal cord. By 5-7 years of age, the occipital components surrounding the foramen magnum are completely fused.[8]

Objectives

1. To measure the anteroposterior and transverse dimension of foramen magnum
2. To examine the shape of Foramen magnum.
3. To correlate CT findings with morphometric parameters done on dry skulls, irrespective of gender & age.

MATERIALS AND METHODS

Study Setting

This study was conducted at the Department of Anatomy, in association with the Department of Radio Diagnosis, Rama Medical College Hospital and Research Centre, Kanpur.

Ethical Clearance

The ethical clearance was taken from institutional medical ethical committee.

Inclusion Criteria: All the skulls used for the study were dried, complete, showed normal anatomical features

Exclusion Criteria: Skulls with broken and deformed foramen magnum were excluded from this study.

Types of Study: Prospective study and Cross-sectional study

Duration of Study: This study was conducted from December 2023 to November 2024.

Study Design: This study was conducted in Department of Anatomy in association with the Department of Radiodiagnosis, Rama Medical College Hospital and Research Centre, Mandhana, Kanpur.

Morphometric parameters were measured on 75 dry skulls in Department of Anatomy of unknown sex and age and 75 CT scans from Department of Radiodiagnosis of known sex and age.

All individuals participating in the study had given their informed consent.

Study Tool:

G Wipro Ct scan machine, Digital Vernier caliper, thread.

Radi Ant DICOM Viewer software is used for study scan images.

Methods

1. AP diameter/Length of the FM (Foramen Magnum): Distance in a straight line from the end of the anterior border(basion) through the center of the FM until the end of the posterior border (opisthion), toward the median sagittal plane.

2. Transverse diameter/Width of FM (foramen magnum): Maximum distance between two lateral margins.

3.Shape of FM (foramen magnum): Circular, oval, irregular shapes were observed.

Figure 1: Showing the transverse diameter of foramen magnum

Figure 2: Showing anteroposterior diameter of foramen magnum

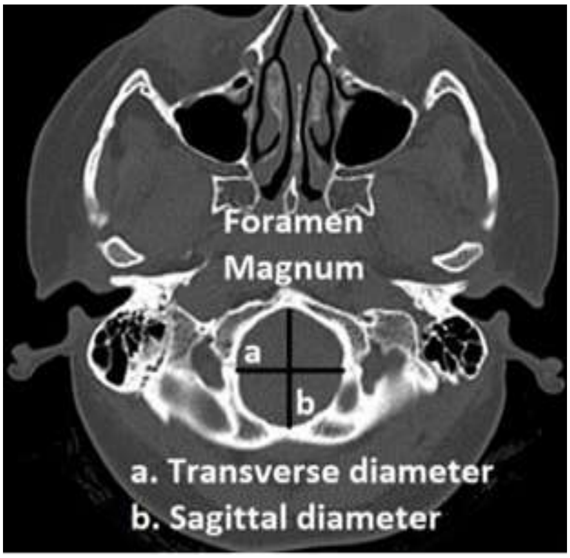

Figure 3: Measuring the anteroposterior and transverse diameter of foramen magnum on CT Images

RESULTS

Table 1: AP diameter of Foramen magnum on dry skulls & CT Scan

	Minimum	Maximum	Mean		Std. Deviation
			Statistic	Std. Error	Statistic
Dry Skulls	24.85	38.31	31.07	.43	3.09
CT Scan	16.20	35.20	25.0967	.54169	4.69120

Dry skulls show a larger anteroposterior diameter (Mean = 31.07 mm) compared to CT scan measurements (Mean = 25.0967 mm). CT scan values have a wider range (16.20–35.20 mm) compared to dry skulls (24.85–38.31 mm), indicating more variability in in-vivo imaging measurements.

Dry skull measurements are more consistent, as reflected by the lower standard deviation (3.09 mm) compared to CT scans (4.69120 mm). The difference in mean values suggests that CT scan measurements tend to underestimate the actual anteroposterior diameter, which is commonly observed due to soft-tissue effects and imaging limitations.

Table 2: Transverse diameter findings of foramen magnum on dry skulls & CT Scan

	Minimum	Maximum	Mean		Std. Deviation
			Statistic	Std. Error	Statistic
Dry Skulls	24.20	33.36	29.20	.45532	1.97
CT Scan	18.30	33.80	26.1652	.45532	3.94317

Dry skulls again show a higher mean transverse diameter (Mean = 29.20 mm) compared to CT scan measurements (Mean = 26.1652 mm). The minimum transverse diameter recorded in CT scans (18.30 mm) is much lower than that of dry skulls (24.20 mm), indicating greater measurement variability in CT imaging. Standard deviation is higher in CT scans (3.94317 mm) versus dry skulls (1.97 mm), showing that dry skull measurements are more uniform. Similar to Table 1, CT scan measurements appear to underestimate the true transverse diameter, possibly due to image resolution and anatomical factors.

Table 3: Showing the shape of foramen Magnum on dry skulls

Shape	Number	Percentage
Circular	28	37
oval	39	52
irregular	8	11

Total three shapes were observed in the study. The most common shape of foramen magnum on dry skulls is oval as shown in table no 3.

Table 4: Association of mean values of foramen magnum of CT findings with gender of study population

Parameters	Male Mean =SD	Female Mean = SD	t-test	p-value
FM (AP)	25.49+ 4.26	24.71 + 5.10	0.72	0.4728
FM (TD)	26.99+ 3.61	25.36 + 4.13	1.82	0.0727

Table no 4 shows that no statistically significant difference was found among males and females for both the diameters that is Anteroposterior (AP) diameter (p = 0.4728) and transverse (TD) diameter (p = 0.0727). However males show slightly larger mean dimensions (both AP and TD), but the difference is not statistically significant, this shows that foramen magnum size is not strongly sexually dimorphic in this sample. CT- Scan measurements do not reliably distinguish gender based on FM dimensions.

Table 5: Comparison of the means of parameters of CT findings with means of Morphometric parameters on dry skulls

Parameters	Dry Skull mean (mm) + SD	CT-Male mean (MM) + SD	CT-Female mean (mm) + SD	T-test	p-value
FM (AP)	25.49+ 4.26	24.71 + 5.10	0.72	0.72	0.47
FM (TD)	26.99+ 3.61	25.36 + 4.13	1.82	1.82	0.07

Table no 5 shows that dry skull morphometric mean measurements are almost similar to CT-Scan mean values, showing good agreement in both AP and TD dimensions. But no statistically significant difference was observed between CT and dry skull AP measurement (p = 0.47) CT and dry skull TD measurement (p = 0.07) this shows that CT scanning is a reliable method for measuring foramen magnum dimensions. CT-derived values can be used as proxies for dry skull measurements in anatomical and forensic studies. The slightly larger dry skull values compared to CT values may be due to, differences in in-vivo vs. ex-vivo measurement conditions, CT image reconstruction limitations, observer or instrument variability.

DISCUSSION

Measurements on dry skulls revealed that the average AP diameter is 31.07 mm, with a standard deviation of ±3.09 mm. This indicates a range of variation among the sample population, providing insights into the typical size of the skulls examined. The average transverse diameter recorded was 29.2 mm, with a standard deviation of ± 1.97 mm.

The most common shape among the skulls analysed was oval, accounting for 52% of the sample. The CT analysis revealed that the average AP diameter for males was 25.49 mm, while for females, it was 24.71 mm. The difference in measurements was not statistically significant (p = 0.4728), indicating that sex does not appear to play a substantial role in the variation of AP diameter in this context. Similarly, the TD for males was 26.99 mm, whereas females exhibited a mean of 25.36 mm. Though the measurements suggest variation between sexes, the statistical analysis yielded a p-value of 0.0727, which suggests a trend but does not reach conventional significance thresholds. On comparing with Previous Studies on dry skull, Rajkumar et al. (2017) indicate that the average AP and TD measurements reported for the Foramen Magnum were significantly larger, at 34.13± 2.44 mm and 28.32± 2.04 mm, respectively. This discrepancy may reflect differences in population characteristics, methodology, or sample size.[9] In the study of Samara O A. et al. (2017), they reported the mean values of anteroposterior distance measuring 35.1±3.2 mm and the transverse diameter measuring 29.3±2.5 mm.[2] Saxena A et al. (2023) conducted a study and reported that the anteroposterior diameter measured was 32.25±2.55 mm, while the transverse diameter was 27.94±2.10 mm. Notably, the majority of the specimens examined exhibited an oval shape, which accounted for 37.2% of the total sample size.[3] In the study of Oberman dz et al. The anteroposterior dimension was noted to be 34.51 mm, while the transverse diameter measured was 29.85 mm. These precise measurements contribute to a better understanding of the anatomical features examined in the study, highlighting the significance of these dimensions in the context of the research findings.[1] The findings of the present study regarding the measurements of anteroposterior and transverse diameter of the foramen magnum remain consistent with the ranges documented in previous literature. However, it is noteworthy that the CT-based measurements for both AP and TD were found to be smaller compared to those derived from dry skull specimens. This discrepancy may be attributed to factors such as soft tissue attenuation during imaging or limitations in scan resolution that can affect the accuracy of the measurements. Furthermore, the observed predominance of an oval shape for the foramen magnum was found to be similar to the findings reported by Saxena et al,[3] and Singh D et al.[6] Akay G et al in their study found that regarding the types of FM shapes, the most frequent type was found to be round (n = 41, 21.6%), while egg shaped (n = 13, 6.8%) and tetragonal type (n = 15, 7.9%) were the least common.[10] Muthkumar N et al in their study found that the average anteroposterior length of the foramen magnum was 33.3 mms and the width was 27.9 mms. When the foramen magnum index was > 1.2, the foramen was found to be ovoid. Forty six percent of the skulls studied exhibited an ovoid foramen magnum.[11] In a study conducted in Saudi Arabia by Aljarrah K et al observed that Eight shapes were seen in foramen magnum, with the hexagonal shape being the most common. However, the shape of the foramen magnum was not found to be a useful variable for sex estimation. However the results indicate a low degree of sexual dimorphism in the basicranium for this population, but the method can be a helpful adjunct in forensic anthropology, particularly when dealing with fragmented skull bases where other skeletal elements are unavailable.[12]

CONCLUSION

This comparative study of computed tomography (CT) findings with morphometric measurements from dry skulls of the foramen magnum provides crucial insights into cranial base anatomy, revealing consistent morphological patterns and significant bilateral symmetry. The comparative nature of this study enhances its clinical relevance, emphasizing the reliability of CT imaging as a non-invasive tool for assessing cranial base morphology in living individuals. Overall, these findings contribute valuable baseline data for neurosurgeons, radiologists, forensic experts, and anthropologists. The integration of imaging and osteological approaches strengthens diagnostic accuracy, supports surgical planning, and enhances identification protocols, thus underscoring the importance of interdisciplinary anatomical research. It is to acknowledge that the scope of this study remains open to further investigation and research. The findings lay a strong foundation, yet additional studies possibly with larger sample sizes, advanced methodologies, or in different populations are necessary to validate, refine, and expand upon the conclusions drawn here. Continued exploration in this area will help enhance the depth and applicability of the current work in both academic and clinical contexts.

REFERENCES

1. Oberman DZ, Baldoncini M, Rabelo NN, Ajler P. Morphometric analysis of posterior cranial fossa and surgical implications. Journal of craniovertebral junction and spine. 2021 apr 1;12(2):178-82.
2. Samara OA et al. T. Morphometric analysis of the foramen magnum. Int. J. Morphol. 2017; 35(4):1270-1275.
3. Saxena A, Kausar T. Morphometric and morphological study of foramen magnum in dry human skull. Int j acad med pharm. 2023;5(6):573-6.
4. Sharma A, Ramandeep K, Sharma KM. Foramen magnum: morphometry, possible variation in the shape and its clinical implication. Int journal of scientific study. 2019;6(10):13-6.
5. Shrestha B, Paudel RC, Kashichhawa S, Maharjan N. Morphometric analysis of posterior fossa and foramen magnum among pediatric age group 6 to 16 years. Kathmandu univ med journal. 2022; 79(3): 342-5.
6. 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.
7. Tubbs RS, Griessenauer CJ, Loukas M, Shoja MM, Cohengadol AA. Morphometric analysis of the foramen magnum: an anatomic study. Neurosurgery. 2010 feb 1;66(2):385-8.
8. Yadav V, Prasad RS, Sahu A, Mishra MK, Pradhan RS. Morphometric analysis of posterior cranial fossa and foramen magnum and it's clinical implications in craniovertebral junction malformations: a computed tomography based institutional study in a tertiary care hospital of northern part of india. Egyptian journal of neurosurgery. 2024 feb 26;39(1):12.
9. Rajkumar KP, Manik P, Singh V. Morphometric analysis of foramen magnum of dry human skulls in north indian population. Int j anat res. 2017;5(1):3480-4
10. Akay G, Güngör K, Peker İ. Morphometric analysis of the foramen magnum using cone-beam computed tomography. Turk J Med Sci. 2017;47(6):1715-22
11. Muthukumar N, Swaminathan R, Venkatesh G, Bhanumathy SP. A morphometric analysis of the foramen magnum region: implications for transcondylar approaches. Neurosurgery. 2005;56 (2):373-80.
12. Aljarrah K, Aljblawi H, Al-Adawi M, Hamed A, Gammoh O. Morphometric analysis of foramen magnum and occipital condyle using CT for sex determination in a Saudi population. Morphologie. 2022; 106(354):71-6.