

## ***Original Article***

### **Morphometric Study of Foramen Magnum of Adult Dry Skull**

SM Akram Hossain,<sup>1</sup> A S M Ashrafuzzaman,<sup>2</sup> Pervez Shake<sup>3</sup>

Revised : January 20, 2016      Accepted : April 03, 2016

---

#### ***Abstract***

***Introduction:*** The foramen magnum is a large opening in the occipital bone of cranium and is a unique and complex neuroanatomical structure. This is an important landmark of skull base for neurosurgical procedures. The dimensions of the foramen magnum are clinically important because vital structures passing through it may endure compression such as in cases of foramen magnum herniation, foramen magnum meningiomas and foramen magnum achondroplasia. So, the aim of this study was to analyze the morphometry pertaining to comparing antero-posterior and transverse diameters available in literature and to bring out associated clinical implications.

***Methods:*** In this cross sectional study, one hundred thirty eight dry, adult human skull of unknown sex were examined and measured antero-posterior and transverse diameters with the help of Vernier-caliper. Additionally, surface area of foramen magnum was also calculated.

***Results:*** The mean antero-posterior diameter of the foramen magnum was 31.3 mm (range 20.0-41.2mm) and the transverse diameter was 26.92 mm (range 19.2-36 mm). The mean surface area of foramen magnum was 674.7 mm<sup>2</sup>. The mean of foramen magnum index was 86.31%.

***Conclusion:*** The dimensions of foramen magnum have been evaluated in the Bangladeshi population for the first time. This analysis will be of paramount importance for skull base surgery and also helpful for radio-imaging diagnosis. Considering the above mentioned importance, this study is worthwhile.

***Key words:*** Foramen magnum, Skull base, Morphometry, Sexual dimorphism

North Bengal Med. Coll.J. 2016; 2 (2) : 07-13

---

1. Professor and Head, Department of Anatomy, North Bengal Medical College, Sirajganj

2. Lecturer in Anatomy, North Bengal Medical College, Sirajganj

3. Lecturer in Anatomy, North Bengal Medical College, Sirajganj

***Correspondence*** S M Akram Hossain, Email: akhossain\_09@yahoo.com

## Introduction

The Foramen Magnum (FM) in Latin: 'great hole' is a large opening in the occipital bone of the cranium and it is an important landmark in the posterior part of the cranial base. Its transverse diameter is rather less than one third of the distance between the mastoid processes. The anterior border of the foramen magnum is formed by the basilar process of the occipital bone, the lateral border by the left and right exoccipitalis and posterior border is formed by the supra-occipital part of occipital bone.<sup>1</sup> It lies in an antero-median position and leads into the posterior cranial fossa. It transmits the lower end of the medulla oblongata, meninges, vertebral arteries and spinal accessory nerve; the apical ligament of the dens and the tectorial membrane pass through it 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.<sup>2</sup> A fundamental knowledge of the normal anatomy of the cranial base, specially the foramen magnum and associated structures, is important to the clinician for accurate diagnosis and treatment of various diseases.<sup>3</sup> The dimensions of FM have clinical importance because the vital structures that pass through it may suffer compression such

as in cases of FM achondroplasia<sup>4</sup> and FM brain herniation.<sup>5,6</sup> These may result into life-threatening respiratory complications, lower cranial nerve palsies, and paresis of upper and lower extremities. In a computerized tomographic study of Catalina & Herrera, dimensions of the foramen magnum of 63 achondroplastic individuals were compared to standards established for non-achondroplastic individuals. The size of the foramen magnum in patients with achondroplasia was small at all ages, particularly in those with serious neurological problem.<sup>7</sup> In neurosurgical practice, the transcondylar approach is commonly used to access the lesions which are ventral to the brainstem and cervicomedullary junction. It was reported that understanding the bony anatomy of the condylar region is important for this approach.<sup>8</sup> Furthermore, it was stated that longer FM antero-posterior dimensions permitted greater contralateral surgical exposure for condylar resection.<sup>9</sup> The knowledge of foramen magnum diameters is needed to determine some malformations such as Arnold Chiari syndrome, which shows expansion of transverse diameter.<sup>10</sup> It can be used in the field of forensic identification and anthropology for determination of the gender of human skulls.<sup>11-13</sup> This knowledge can be applied in its morphometric analysis to determine sex

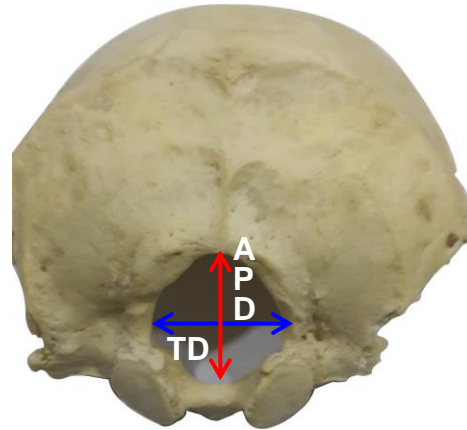
in medicolegal purpose, when there is involvement of other parts of the craniofacial skeleton, as in severe injuries, aircraft accidents, fire or explosion.<sup>14,15</sup>

It is obvious that, FM evaluation was very important to ascertain the appropriate surgical techniques, and also to obtain the useful data for unknown sex determination and age estimation for medicolegal purpose. So, the aim of the present study was to evaluate the dimensions of foramen magnum.

### Materials and Method

This is a cross-sectional type of study. In this study the samples were included by random collection of 138 adult human dry skulls from departments of anatomy, North Bengal Medical College, Sirajganj, Shahid M. Mansur Ali Medical College, Sirajganj, Barind Medical College, Rajshahi and Rajshahi Medical College, Rajshahi. The skulls that have been damaged, eroded, deformed and those of children were excluded from the study. They were used for tutorial teaching for medical students. With the help of simple Vernier-caliper antero-posterior (APD) and transverse diameters (TD) of foramen magnum were measured. The length of foramen magnum was measured from the anterior border (basion) through the center of the foramen magnum until the end of the posterior (opisthion). The transverse diameter was measured from

the point of maximum concavity on right and left margins (Figure 1).



**Figure 1 : Measurement of diameters of Foramen Magnum in Skull**

The area of foramen magnum (FMA) was calculated using formula derived by Randinsky.<sup>16</sup> Surface area of foramen magnum was calculated by using formula stated below.

$$\text{AREA} = 1/4 \times \pi \times h \times w$$

Where,  $\pi$  (mathematical constant) = 22/7 (3.14)

$h$  = antero-posterior diameter

$w$  = transverse diameter

Foramen magnum index (FMI) was calculated by: Foramen magnum width (TD)  $\times$  100/ Foramen magnum length (APD).

### Results

In this study, the dimensions and surface area of foramen magnum are shown in Table-I.

**Table I: Dimensions and surface area of Foramen Magnum**

Values	Antero-Posterior diameter (APD) (mm)	Tansverse diameter (TD) (mm)	Surface area (mm <sup>2</sup> )
<b>Maximum</b>	41.2	36.0	1015.5
<b>Minimum</b>	20.0	19.2	329.7
<b>Mean</b>	31.3	26.9	674.7

After proper verification regarding consistency and validity, data were entered into computer by using SPSS 16 version programme. Statistical significance was found by applying relevant statistical test at appropriate probability level ( $p < 0.01$ ).

The mean dimension of foramen magnum in APD was 31.3 mm, whereas it was 26.9 mm in TD. APD of foramen magnum had highly significant in compared to TD ( $p < 0.01$ ). The mean surface area of foramen magnum was 674.7 mm<sup>2</sup> (range 329.7 mm<sup>2</sup>-1015.5 mm<sup>2</sup>). Mean foramen magnum index (FMI) was 86.31% (range 65.29% -109.15%).

## Discussion

Foramen magnum is morphologically variable osteological feature in the skull which has undergone evolutionary changes.<sup>17</sup> The dimensions of the foramen magnum are clinically important because vital structures passing through it. In the present study the average antero-posterior diameter (APD) of the foramen magnum was 31.3 mm (range 20.0-41.2 mm) and transverse diameter (TD) was 26.9 mm (range 19.2-36 mm) respectively. The mean

surface area of foramen magnum was 674.7 mm<sup>2</sup>. Other researchers were observed that the average APD of the foramen magnum was 33.3 mm (range 27-39 mm) and the TD was 27.9 mm (range 23-32 mm).<sup>8</sup> There is statistically significant difference between present study and observation done by previously reported by researchers ( $p < 0.01$ ). It was found that the mean APD was 3.1cm, and mean TD was 2.7cm and mean surface area of the foramen magnum was 558 mm<sup>2</sup>.<sup>2,18</sup> In Catalina-Herrera's<sup>7</sup> anatomic study of FM, the diameters were 35.2 mm for APD and 30.3 mm for TD and the means of the FM in male and female skulls were 888.4 mm<sup>2</sup> and 801 mm<sup>2</sup> respectively. It was reported by Berg and Bergmann in their study, the average APD of 34 mm and TD of 29 mm.<sup>19</sup> A study was conducted on skulls of Karnataka showed that, the mean APD in male was 33.4 mm, female was 33.1 mm and by CT imaging method in male was 38.5 mm and female was 35.2 mm. The mean TD of FM in male was 28.5 mm and female was 27.3 mm but by CT imaging method in male was 29.1 mm and female was 27.6 mm.<sup>15</sup> In Western Europe, a study was carried on skulls confirmed that APD

ranges 30 mm to 43 mm with the mean of 36.6 mm but TD ranges from 25 mm to 39 mm with the mean of 31.1 mm.<sup>20</sup> Similarly, another study on Brazilian individuals in relation to gender established that mean APD was 35.7 mm in male and 35.1 mm in female but the TD was 30.3 mm in male, 29.4 mm in female.<sup>14</sup> In a cadaveric CT images measurements conducted by Wanebo & Chicoine<sup>9</sup> showed that, mean area of the FM is  $820.0 \pm 100.0 \text{ mm}^2$ , the mean length (SD)  $36.0 \pm 2.0 \text{ mm}$  and the mean width (TD)  $32.0 \pm 2.0 \text{ mm}$ . A study was conducted on fifty-four cranial CT scans obtained from the archives of Department of Radiology and observed that mean APD of FM was 35.58 mm and TD was 29.84 mm. The mean APD in male and female was 30.75 mm and 29.98 mm respectively. The mean TD in male and female was 36.95 mm and 34.41 mm respectively. There was a significant difference between the APD of male and female cases.<sup>21</sup> There was a significant difference in mean of FM area among male and female ( $p < 0.001$ ) which were  $909.91 \text{ mm}^2$  in males,  $819.01 \text{ mm}^2$  in females.<sup>22</sup> Our study revealed the mean foramen magnum index (FMI) was 86.31% whereas in a Brazilian study conducted by Pires et al.<sup>23</sup> it was 83.75%.

As it has been mentioned, the FM includes specific neuroanatomic structures<sup>24-27</sup> and lesions occupied in that area needs special microsurgical intervention.<sup>27</sup> A meticulous planning mainly based on the FM sizes is very essential for choosing and establishing

the most appropriate surgical techniques to refrain from any neurological impairment.<sup>27,28</sup> In addition, it is quite difficult to detect many pathological lesions not only by neurological examination but also needs support from the radiological findings.<sup>23,27</sup>

## Conclusion

The knowledge of diameters of the foramen magnum are needed to determine the radiological malformations (Arnold Chiari's syndrome) and prior to cutting off of foramen magnum or posterior cranial fossa lesions, or sex determination of skulls medico-legal purpose. So, the knowledge of dimensions of foramen magnum are important for neurosurgeons, radiologist as well as anthropologists.

## Acknowledgements

We are very much grateful and express our deep gratitude to the authority of North Bengal Medical College Sirajganj, Shaheed M. Monsur Ali Medical College, Sirajganj, Barind Medical College, Rajshahi and Rajshahi Medical College, Rajshahi, for their cordial supports during sample collection.

## Contribution of the Authors

The first author was the principal researcher, while the second and third were involved in data collection, computer composing and data analysis.

## References

1. Scheuer L, Black S. The juvenile skeleton. Elsevier. London 2004;p1-19.
2. Standarding S. Gray's anatomy. The anatomical basis of clinical practice. 39<sup>th</sup> ed. London: Elsevier Churchill Livingstone, 2005;p.460.
3. Gautam K, Vijay P, Yad RY, Pushp RB, Dhananjay S. Morphometric analysis of posterior fossa and foramen magnum. J Neurosci Rural Pract. 2012;3(3): 261-266.
4. Hecht TJ, Horton WA, Reid CS, Pyeritz RE, Chakraborty R. Growth of the foramen magnum in achondroplasia. AJMG. 1989;32: 528-535.
5. Reich JB, Sierra J, Camp W, Zanzonico P, Deck MD, Plum F. Magnetic resonance imaging measurements and clinical changes accompanying transtentorial and foramen magnum brain herniation. Annals of Neurology. 1993;33: 159-170.
6. Ropper AH. MRI demonstration of the major features of herniation. J Neurol Neurosurg Psychiatry. 1993;56: 932-935.
7. Catalina-Herrera CJ. Study of the anatomic metric values of the foramen magnum and its relation to sex. Acta Anat. 1987;130: 344-347.
8. 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: 889-895.
9. Wanebo JE, Chicoine MR. Quantitative analysis of the transcondylar approach to the foramen magnum. Neurosurgery. 2001;49: 934-941.
10. Sgouros S, Goldin JH, Hockely AD, Wake MJ, Natarajan K. Intracranial volume change in childhood. J Neurosurg. 1999;91: 610-616.
11. Tanuj K, Anadi G, Kewal K. Craniometric analysis of foramen magnum for estimation of sex. Int J Med, Health, Biomed and Pharm Eng. 2013;7(7): 111-113.
12. Suazo GIC, Russo PP, Zavando MDA, Smith RL. Sexual Dimorphism in the foramen magnum dimensions. Int J Morphol. 2009;27(1): 21-23.
13. Edwards K, Viner MD, Schweitzer W, Thali MJ. Sex determination from foramen magnum. J Forensic Radiol and Imaging. 2003;1(4): 186-192.
14. Manoel C, Prado FB, Caria PHF, Groppo FC. Morphometric analysis of the foramen magnum in human skulls of brazilian individuals: its relation to gender. Braz J Morphol Sci. 2009;26(2): 104-108.
15. Muralidhar P, Magi M, Nanjundappa B, Pavan PH, Premalatha G, Shaik HS.

- Morphometric analysis of foramen magnum. *Int J Anat Res.* 2014;2(1): 249-255.
16. Randinsky L. Relative brain size is a new measure. *Science.* 1967;155: 836-838.
  17. Nevell L, Wood B. Cranial base evolution within the hominin clade. *J Anat.* 2008;212: 455-468.
  18. Tubbs RS, Griessenauer CJ, Loukas M, Shoja MM, Cohen-Gadol AA. Morphometric analysis of the foramen magnum: an anatomic study. *Neurosurgery* 2010;66(2): 385-388.
  19. Berg JK, Bergmann RA. Variation in size and in symmetry of the foramina of the human skull. *Clin Anat.* 2001;14: 406-413.
  20. Gruber P, Henneberg M, Boni T, Ruhli FJ. Variability of human foramen magnum size. *Anat Rec.* 2009;292: 1713-1719.
  21. Erdil FH, Sabancıoğlu V, Cimen M, İpyk O. Morphometric analysis of the foramen magnum by computed tomography. *Erciyes Med J.* 2010;32(3): 167-170.
  22. Gunay Y, Altınkok M. The value of the size of foramen magnum in sex determination. *J Clin Forensic Med.* 2000;7(3): 147-149.
  23. Lucas AS Pires, Álvaro R Teixeira, Tulio FO Leite, Marcio A Babinski, Carlos AA Chagas. Morphometric aspects of the foramen magnum and the orbit in Brazilian dry skulls. *Int J Med Res Health Sci.* 2016;5(4): 34-42.
  24. Williams PL, Warwick R. *Gray's Anatomy*, 7<sup>th</sup> Ed. New York: Churchill Livingstone. 1989;p.342-361.
  25. Snell RS. *Clinical Anatomy for Medical Student*, 4<sup>th</sup> edition. Boston Little, Brown and Company. 1992;p.808-812.
  26. De Oliveira E, Rhoton AL Jr, Peace D. Microsurgical anatomy of the region of the foramen magnum. *Surg Neurol.* 1985;24: 293-352.
  27. Coin CG, Malkasian D R. Foramen magnum. In Newton TH, Potts DG, editors. *Radiology of the Skull and Brain: The Skull*. Vol. 1, book 1 St. Louis: Mosby. 1971;p.275-286.
  28. George B, Lot G, Boissonnet H. Meningioma of the Foramen Magnum: a series of 40 cases. *Surg Neurol.* 1997;47: 371-379.