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Original Article

CLINICAL SIGNIFICANCE OF MORPHOLOGICAL AND MORPHOMETRICAL ANALYSIS OF FORAMEN MAGNUM

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ABSTRACT

Introduction: The foramen magnum is a transitional zone between cranial cavity and spinal canal, and it is related with the very important neuro-vascular structures like vertebral arteries, spinal accessory nerves and spinal arteries and terminal part of medulla oblongata. Thus, cranio-cervical junction surgeries require a thorough knowledge about the variations in the morphometry and morphology of the foramen magnum.

Materials and Methods: This study analyzed 70 dried human skulls from the Departments of Anatomy at TS Misra Medical College & Hospital, Era's Lucknow Medical College & Hospital, and KGMU, Lucknow. The shape of the foramen magnum was classified, and its transverse and anteroposterior (AP) diameters were measured using a vernier caliper. The foramen magnum index (FMI) and the foramen magnum area (FMA) were also calculated.

Results: The foramen magnum showed six distinct shapes: oval (47%), round (30%), tetragonal (10%), triangular and irregular (10% each), pentagonal (2%), and hexagonal (1%). The average AP diameter was 34.3±2.90 mm, and the average transverse diameter was 28.9±2.80 mm. The average FMI was 77.80±27.80, while the average FMA was 845.90±87.50 mm^2.

Conclusions: The data from this study are valuable for neurosurgeons performing surgeries at the cranio-cervical junction and posterior cranial fossa. Understanding the morphometric and morphological characteristics of the foramen magnum is crucial for the prognosis and treatment of neurological conditions like Arnold Chiari syndrome, achondroplasia, and posterior cranial fossa lesions.

Keywords: Foramen magnum, Transcondylar approach, Foramen magnum index, Foramen magnum area, Transverse diameter (TD), Anteroposterior diameter, Trigonal

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INTRODUCTION

The foramen magnum is an intraosseous foramen which is located at antero-median position in the occipital bone of skull.[1] It provides passageway to the lower end of the medulla oblongata with its meninges, vertebral arteries and veins, spinal accessory nerves, spinal arteries, apical ligament of the dens and the tectorial membrane [1]. The knowledge of anatomical variations of foramen magnum are important in terms of its morphology as well as morphometry because in cases of congenital abnormalities and pathologies at cranio-cervical junction, the morphometry and morphology of foramen magnum is greatly affected.

Therefore, the neurosurgeons should know about the anatomical variations of foramen magnum and its related structures, prior to surgery and the knowledge of anatomical variation of foramen magnum also help to the physical anthropologist and forensic experts for identification of mutilated bodies in the conditions of war fare, nuclear explosions or natural disasters. Very less work is done on basic morphometric and morphological variations of foramen magnum [2].

In addition to the best of our knowledge, till date there is only one research done by Philipp Guber et. al., where they tried to explore any change in biological characters of foramen magnum that occurs from generation to generation [2].

The aim of present study was to determine and analyze the morphometric and morphological variations of foramen magnum which will help the neurosurgeons, prior to surgeries done at cranio-cervical junction in the cases of cerebellar herniation or Achondroplasia.

MATERIALS AND METHODS

This observational study was carried out on 70 dried adult human skulls of unknown age and gender. The skulls were obtained from the Department of Anatomy, TS Misra Medical College, Era's Lucknow Medical College & Hospital and KGMU, Lucknow. The approval from Institutional Ethics Committee was obtained prior to the study. The fully cleaned, undamaged skulls were selected whereas deformed and damaged skulls were excluded. The shape of foramen magnum was observed. The anteroposterior and transverse diameters were measured with the help of digital vernier caliper. The precision of measurement of caliper was 0.01mm. The FMI (foramen magnum index) and FMA (Foramen magnum Area) were also calculated and registered in the tabulated form.

Antero-posterior diameter (AP) was measured from basion (midpoint of anterior margin of foramen magnum) to opisthion (midpoint of posterior margin of foramen magnum). Transverse diameter (TD) was measured between the maximum concavity of right and

left lateral margins of foramen magnum (figure-1). The following formulae were used to calculate the Foramen magnum Index (FMI) and Foramen magnum area (FMA)-

- FMI = Transverse diameter × 100/ Antero-posterior diameter [3]
- Radinsky formula- FMA= ¼ × π × TD × AP^3

Where "π" was accepted as 3.14 in both formulas.

Statistical Analysis: All the data was expressed as mean ± SD and all the statistical analysis was done by using the SPSS software version16.0.

Fig. 1. Landmarks and dimensions of foramen magnum

RESULTS

In the current study, the morphometric and morphological parameters were studied in 70 dried adult human skulls of unknown age and gender of North Indian population.

The most common shape was oval shaped foramen magnum found in maximum skulls (in 33 skulls) and its percentage was 47.1%. The second most common shape was round shaped foramen magnum which was 22.8% (in 16 skulls). The tetragonal shaped foramen magnum was found in 14.2 % (in 10 skulls). The irregular shaped foramen magnum was 7.1 % (in 5 skulls), and hexagonal shaped foramen magnum was only 1.7 % (in single skull). The new variant "trigonal" shaped foramen magnum was 7.1 % (in 5 skulls). The data is presented in table 1 and figure 2 which shows the different shapes of foramen magnum observed in the current study.

Table 2 shows all the morphometric and morphological parameters of foramen magnum according to the different shapes of foramen magnum which were found in this study.

The mean AP and TD diameter of oval shaped foramen magnum was 35.0±3.1 mm and 28.7±2.2 mm respectively and the mean FMA and FMI was 826.7±84.0 mm^2 and 78.8±28.0 respectively.

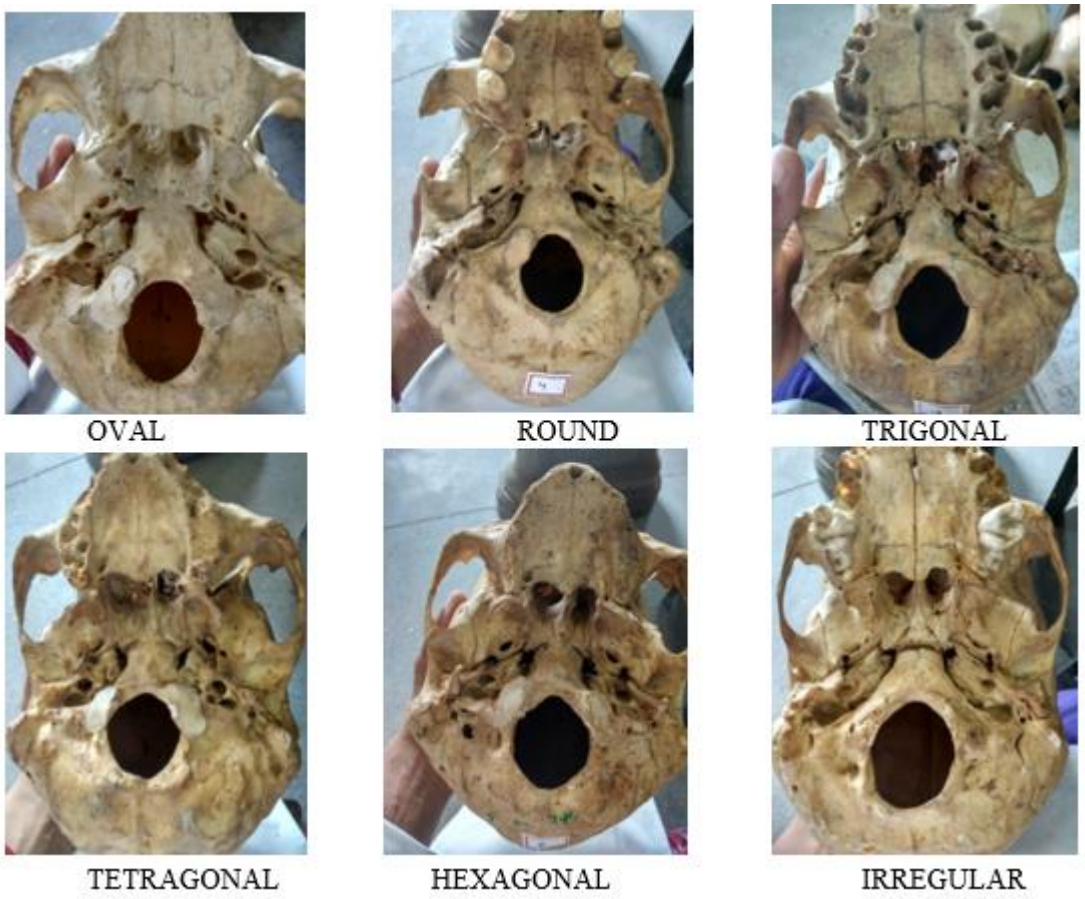

Fig. 2. Different shapes of foramen magnum

S. No.	Shapes of FM	Number of FM	Percentage %
1	Oval	33	47.1%
2	Round	16	22.8%
3	Trigonal	5	7.1%
4	Tetragonal	10	14.2%
5	Hexagonal	1	1.7%
6	Irregular	5	7.1%

Table 1. Number of different shapes of foramen magnum and their percentage

The mean AP and TD of round shaped foramen magnum was 33.5±2.9 mm and 30.9±3.1 mm (transverse diameter) and mean of FMA and FMI was 951.6±39.0 mm^2 (FMA) and 81.2±28.4 (FMI) respectively.

The mean AP, TD, FMA, and FMI of trigonal shaped foramen magnum was 34.6±1.6 mm (AP diameter), 27.6±1.9 mm (transverse diameter), 764.7±25.0 mm^2 (FMA) and 74.9±27.3 (FMI).

S. No.	Shapes of FM	AP diameter (mm) Mean ± SD	Transverse diameter (mm) Mean ± SD	FMI (mm) Mean± SD	FMA (mm^2) Mean± SD
2	Oval	35.0±3.1	28.7±2.2	78.8±28.0	826.7±84.0
2	Round	33.5±2.9	30.9±3.1	81.2±28.4	951.6±39.0
3	Trigonal	34.6±1.6	27.6±1.9	74.9±27.3	764.7±25.0
4	Tetragonal	32.4±2.5	29.0±3.2	73.8±27.1	868.2±77.0
5	Hexagonal	35.0±0.0	24.0±0.0	65.9±25.6	685.7±0.0
6	Irregular	34.6±1.8	26.0±1.0	70.6±26.5	778.7±43.0

Table 2. Dimensions of foramen magnum according to the different shapes

The mean AP, TD, FMA, and FMI of tetragonal shaped foramen magnum were 32.4±2.5 mm (AP diameter), 29.0±3.2 mm (transverse diameter), 868.2±77.0 mm^2 (FMA) and 73.8±27.1 (FMI).

The hexagonal shaped foramen magnum was observed only in single skull (7.1%). The anteroposterior diameter was 35.0±0.0 mm and transverse diameter was 26.0±1.0 mm. The foramen magnum index of hexagonal shaped foramen magnum was 70.6±26.5 and foramen magnum area was 778.7±43.0 mm^2.

The mean AP, TD, FMA, and FMI of irregular shaped foramen magnum were 34.6±1.8 mm (AP diameter), 26.0±1.0 mm (transverse diameter), 70.6±26.5 (FMI) and 778.7±43.0 mm^2 (FMA).

Table 3 shows the details of morphometric parameters of total studied skulls (70 skulls). The mean AP and TD dimensions of foramen magnum of overall studied 70 skulls were 34.3±2.90 mm, and 28.9±2.80 mm and mean FMI and FMA were 77.80±27.80 and 845.90±87.50 mm^2. The minimum mean values of AP and TD of foramen magnum all the skulls were 32.44 mm and 24.00 mm. while the minimum FMI and FMA of foramen magnum were 73.80 and 611.72 mm^2. The maximum mean value of AP and TD of foramen magnum of all studied skulls were 35.09 mm and 30.90 mm. The maximum mean value of FMI and FMA of all skulls were 88.05 and 851.93 mm^2.

DISCUSSION

The knowledge of various morphometric parameters of the foramen magnum helps to determine some congenital malformations such as Achondroplasia and the Arnold-Chiari malformation in which the shape and size of foramen magnum is variable in humans [4]. The patients with achondroplasia have extremely small foramen magnum, whereas in cases of Arnold-Chiari malformation, there is unusually large foramen magnum [4].

Total number (N) – 70	Antero-posterior (AP) diameter (mm)	Transverse Diameter (mm)	Foramen magnum Index (FMI)	Foramen magnum Area (FMA) (mm^2)
Mean ± SD	34.3±2.90	28.9±2.80	77.80±27.80	845.90±87.50
Minimum value	32.44	24.00	73.98	611.72
Maximum value	35.09	30.90	88.05	851.93

Table 3. Dimensions of foramen magnum of total sample (n = 70)

The “oval shaped” foramen magnum was most common shape found in current study. This shape of foramen magnum was also the dominant shape observed in the studies done by Kulesh et.al (2017) [5], Bharati et.al (2021) [6], Bharath et.al (2022) [7] and Gupta AK et.al (2022).[8] However, Faazila et al. (2015) [9] found that the most dominant shape of the foramen magnum in their study was egg-shaped (36%). Rohini devi et.al, (2016) [10] and Sarthak et.al (2017) [11] found round shaped of foramen magnum as most common shape.

In the present study, the second most common shape of the foramen magnum was round, observed in 22.8% of the skulls. These findings were similar to the findings of Bharati et.al (2021) [6], Gupta AK et.al (2022) [8], and Kulesh et.al (2017). [5] The result of the current study was different from the findings of Faazila Fathima et.al (201) [9] and Bharath et.al (2022) [7] where the most common shape of foramen magnum was “egg shape’ while in our study it was round shape.

In the current study, a new uncommon shape “trigonal” shaped foramen magnum, was also observed in 5 skulls. Similarly, the uncommon shape of foramen magnum was also reported by Archana et.al, (2019) [12] and Giridhar et.al (2020). [13] Archana et.al, (2019) [12] found “pear shaped” foramen magnum in 8 skulls and Giridhar et.al (2020) [13] found “leaf shaped” foramen magnum in 6% skull.

In the current study, the mean antero-posterior diameter was 34.3±2.90 mm and mean transverse diameter was 28.9±2.80 mm. These findings were consistent with the findings of Archana et al (2019), [12] Giridhar et.al, (2020), [13] Bharat. J. Sarvaiya et.al, (2018) [14] and M. Rohinidevi et.al, (2016) [10] (Table 5). Gruber P et al. (2009) and Shikha Sharma et al. (2015) reported higher anteroposterior and transverse diameters compared to those found in our study (Table 5).

In the current study, the FMI was 77.80±27.80 which is lower as compared to the findings of Bharat. J. Sarvaiya et.al (2018) [11] and M. Rohini Devi et.al (2016). [12] The present study recorded significantly higher values of FMI (77.80±27.80) as compared to Giridhar et.al. (2020), [13] (1.21±0.12).

Sr. No.	Shapes of FM	Faazila Fathima et. al, 2015[9]	Kulesh S Chandekar et. al, 2017[5]	Archana et.al, (2019)[12]	Giridhar et.al (2020)[13]	Bharati et al 2021[6]	Gupta AK et. al, 2022[8]	Bharath et al. 2022[7]	Present study (2023)
1	Oval	26.42%	38.75%	33.3%	30%	35%	46.9%	36%	47.1%
2	Round	13%	32.5%	13.3%	12%	32.5%	18.8%	18%	22.8%
4	Trigonal	0	0	0	0	0	0	0	7.1%
5	Tetragonal	0	0	16.6%	0	25%	15.6%	8%	14.2%
6	Hexagonal	20.75%	0	16.6%	3%	7.5%	12.5%	6%	1.7%
7	Irregular	0	28.75%	0	27%	0	6.3%	0	7.1%
10	Egg	35.85%	0	0	17%	0	0	24%	0
11	Pentagonal	3.77%	0	13.3%	5%	0	0	8%	0
12	Leaf shaped	0	0	0	6%	0	0	0	0
13	Pear shaped	0	0	6.6%	0	0	0	0	0
Total		53	80			40	32	50	70

Table 4. Comparison of shape of foramen magnum with the result of other studies

S. No.	Authors	No.	Mean Antero-Posterior diameter (mm)	Mean transverse diameter (mm)	Foramen magnum index	Foramen magnum area (mm^2)
1	Gruber P et al 2009[2]	110 skulls	36.6±2.8	31.1±2.7	-	-
2	Shikha Sharma et al 2015[3]	50 skulls	38.76	33.44	87.68	970.57
3	M. Rohinidevi et al 2016[10]	35 skulls	34.80	28.5	82.54	820.53
4	Bharat.J.Sarvaiya et al 2018[14]	326 skulls	34.18±2.74	28.49±2.13	83.60±6.21	766.86±104.76
5	Archana et al 2019[12]	120 skulls	33.79±2.60	28.25±1.83	83.91±6.43	-
6	Giridhar et al 2020[13]	64 skulls	34.10±2.63	28.07±1.87	1.21±0.12	752.07±111.97
7	Bharati et al 2021[6]	40 skulls	Male- 30±2.35 Female- 29.43±2.69	Male- 26.1±2.13 Female- 25.03±1.84	Male- 87.33±8.20 Female- 85.54±7.88	Male- 616.39±82.20 Female- 580.48±80.23
8	Present study	70 skulls	34.3±2.90	28.9±2.80	77.80±27.80	845.90±87.50

Table 4. Comparison of shape of foramen magnum with the result of other studies

The mean foramen magnum area calculated in the present study was 845.90±87.50 mm2. This value was similar to the values obtained by M. Rohinidevi et.al. (2016), [10] whereas this value was high in comparison to the values by Giridhar et.al. (2020), [13] Bharati et.al. (2021) [6] and Bharat. J. Sarvaiya et.al. (2018). [14] Our recorded mean FMA was lower as compared to Shikha Sharma et al (2015) [3].

Limitations: The sample size of the present study was small and study done on dry human skulls of unknown age and gender.

CONCLUSION

Bony abnormalities of cranio-vertebral junction are of interest not only to an anatomist and physical anthropologist but also to the surgeons as they produce clinical symptoms which affect human health drastically. Abnormalities of foramen magnum can be classified as congenital, developmental, acquired, traumatic and pathological. These abnormalities can occur either individually or in combination. The data analysis and values of current study may help the anatomist, radiologist and neuro-surgeons for transcondylar surgical approaches which are in increasing trend in recent time for brain stem lesion and surgeries at cranio-cervical junction. The thorough knowledge of anatomical variation of foramen magnum helps radiologists to differentiate deformities such as Arnold Chiari malformation in which the transverse diameter of foramen magnum is increased. These findings can also be useful to neurosurgeons for better approach to treat foramen magnum meningiomas and other posterior cranial fossa lesions. The morphology and morphometry of foramen magnum also has some evolutionary importance. More studies are required, as there may be variations in the shapes and dimensions of the foramen magnum across different regions in India.

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