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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. Therefore, thorough knowledge of morphometric and morphological variation of foramen magnum is important for authentic radiological diagnosis and surgeries in the area of cranio-cervical junction.

Materials and Methods: This study was done on 70 dried human skulls taken from the Department of Anatomy, TS Misra Medical College & Hospital, Era's Lucknow Medical College & Hospital, and KGMU, Lucknow. The shape of foramen magnum was observed and transverse and antero-posterior (AP) diameters of foramen magnum (FM) were measured with the help of vernier caliper. Foramen magnum index (FMI) and foramen magnum area (FMA) were also calculated.

Results: The study showed six types of shapes of foramen magnum. The oval shaped foramen magnum was found in 47% (in 33 skulls), round 30% (in 30 skulls), tetragonal 10 % (in 10 skulls), triangular & irregular 10% (in 5-5 skulls), pentagonal 2% (in 2 skulls), and hexagonal 1% (in single skull). The mean anteroposterior and transverse diameter were 34.3±2.90mm and 28.9±2.80 mm respectively. The mean foramen magnum index and Foramen magnum area were 77.80±27.80 and 845.90±87.50 mm^2 respectively.

Conclusions: The data obtained from the present study will be useful to the neurosurgeons prior to the surgeries in the area of cranio-cervical junction and posterior cranial fossa. The morphometric and morphological knowledge of the foramen Magnum has important clinical implications in the prognosis and treatment of various neurological pathologies 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 located at the anteromedian position in the occipital bone of the skull [1]. It provides a 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]. Knowledge of anatomical variations of the foramen magnum is important in terms of its morphology as well as morphometry because in cases of congenital abnormalities and pathologies at the cranio-cervical junction, the morphometry and morphology of the foramen magnum are greatly affected.

Therefore, neurosurgeons should be aware of the anatomical variations of the foramen magnum and its related structures prior to surgery. Additionally, knowledge of anatomical variation of the foramen magnum also helps physical anthropologists and forensic experts in the identification of mutilated bodies in conditions of warfare, nuclear explosions, or natural disasters.

Very little work has been done on the basic morphometric and morphological variations of the foramen magnum [2]. To the best of our knowledge, to date, there is only one research study done by Philipp Guber et al., where they attempted to explore any changes in biological characters of the foramen magnum that occur from generation to generation [2].

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

MATERIAL 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. Approval from the Institutional Ethics Committee was obtained prior to the study. Fully cleaned, undamaged skulls were selected, whereas deformed and damaged skulls were excluded. The shape of the foramen magnum was observed. The anteroposterior and transverse diameters were measured with the help of a digital vernier caliper. The precision of the caliper's measurement was 0.01mm. The FMI (foramen magnum index) and FMA (Foramen magnum Area) were also calculated and registered in tabulated form.

The anteroposterior diameter (AP) was measured from basion (the midpoint of the anterior margin of the foramen magnum) to opisthion (the midpoint of the posterior margin of the foramen magnum). The transverse diameter (TD) was measured between the

maximum concavity of the right and left lateral margins of the foramen magnum (Fig.1).

The Foramen magnum Index (FMI) and Foramen magnum area (FMA) were calculated by the following formulae:

FMI = (Transverse diameter × 100) / Anteroposterior 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 were done by using the SPSS software version16.0.

Fig. 1. Land marks 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 from the North Indian population. The most common shape was an oval-shaped foramen magnum found in the maximum number of skulls (33 skulls), accounting for 47.1% of the total.

The second most common shape was a round-shaped foramen magnum, found in 16 skulls, representing 22.8%. Tetragonal-shaped foramen magnum was found in 10 skulls, accounting for 14.2%, irregular-shaped foramen magnum in 5 skulls (7.1%), and hexagonal-shaped foramen magnum in a single skull (1.7%).

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

A new variant, "trigonal" shaped foramen magnum, was found in 5 skulls (7.1%). Table 1 and Figure 2 illustrate the different shapes of the foramen magnum observed in the current study. Table 2 shows all the morphometric and morphological parameters of the foramen magnum according to the different shapes found in this study.

The mean anteroposterior (AP) and transverse diameters (TD) of oval-shaped foramen magnum were 35.0±3.1 mm and 28.7±2.2 mm, respectively, with mean FMA and FMI values of 826.7±84.0 mm^2 and 78.8±28.0, respectively. For round-shaped foramen magnum, the mean AP and TD were 33.5±2.9 mm and 30.9±3.1 mm, with mean FMA and FMI values of 951.6±39.0 mm^2 and 81.2±28.4, respectively.

Trigonal-shaped foramen magnum had mean AP, TD, FMA, and FMI values of 34.6±1.6 mm, 27.6±1.9 mm, 764.7±25.0 mm^2, and 74.9±27.3, respectively. Tetragonal-shaped foramen magnum had mean AP, TD, FMA, and FMI values of 32.4±2.5 mm, 29.0±3.2 mm, 868.2±77.0 mm^2, and 73.8±27.1, respectively.

Hexagonal-shaped foramen magnum was observed in one skull (1.7%), with AP and TD diameters of 35.0±0.0 mm and 26.0±1.0 mm, respectively. The foramen magnum index for hexagonal-shaped foramen magnum was 70.6±26.5, and the foramen magnum area was 778.7±43.0 mm^2. Irregular-shaped foramen magnum had mean AP, TD, FMA, and FMI values of 34.6±1.8 mm, 26.0±1.0 mm, 778.7±43.0 mm^2, and 70.6±26.5, respectively. Table 3 shows the morphometric parameters of the total studied skulls (70 skulls). The mean AP and TD dimensions of the foramen magnum of all 70 skulls were 34.3±2.90 mm and 28.9±2.80 mm, respectively, with mean FMI and FMA values of 77.80±27.80 and 845.90±87.50 mm^2.

The minimum mean values of AP and TD of the foramen magnum for all skulls were 32.44 mm and 24.00 mm, respectively, while the minimum FMI and FMA values were 73.80 and 611.72 mm^2. The maximum mean values of AP and TD of the foramen magnum for all studied skulls were 35.09 mm and 30.90 mm, respectively, with the maximum mean values of FMI and FMA being 88.05 and 851.93 mm^2.

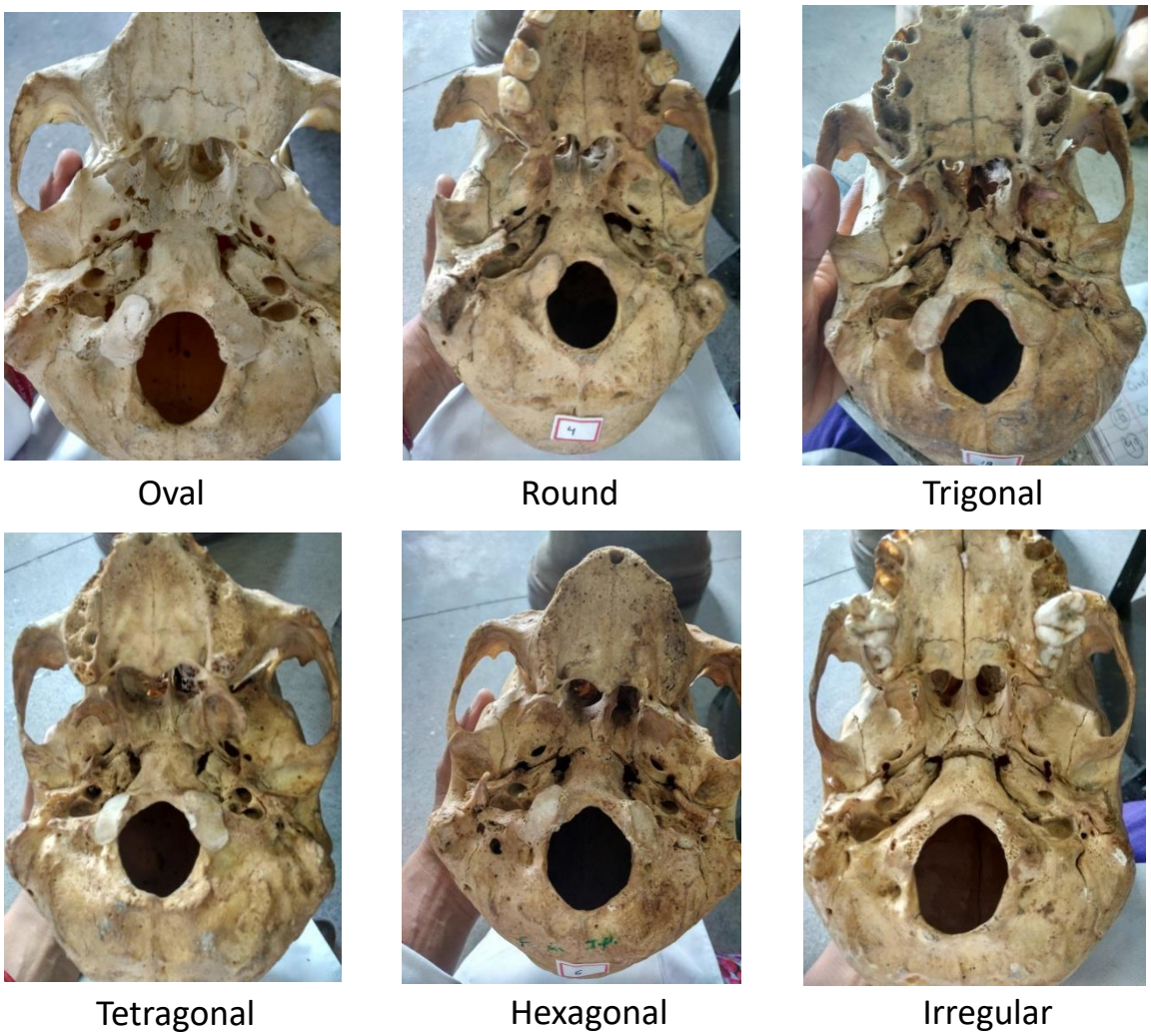

Fig. 2. Different shapes of foramen magnum

DISCUSSION

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

The "oval-shaped" foramen magnum was the most common shape in the current study. This shape was also the dominant shape observed in studies conducted 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 the egg-shaped (36%) foramen magnum to be the most dominant shape in their study. Rohini devi et al. (2016) [10] and Sarthak et al. (2017) [11] found the round shape to be the most common shape.

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

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

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)

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 2. Comparison of shape of foramen magnum with the result of other studies

In the current study, the mean anteroposterior diameter was 34.3±2.90 mm, and the 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] (refer to Table-5). Gruber P et al. (2009) [2] and Shikha Sharma et al. (2015) [3] measured higher anteroposterior and transverse diameters compared to our study (Table 5).

In the current study, the foramen magnum index was 77.80±27.80, which is lower 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) compared to Giridhar et al. (2020) [13] (1.21±0.12).

The mean foramen magnum area calculated in the present study was 845.90±87.50 mm^2. This value was similar to the values obtained by M. Rohinidevi et al. (2016) [10], whereas it was higher 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 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 the craniovertebral junction are of interest not only to anatomists and physical anthropologists but also to surgeons, as they produce clinical symptoms that drastically affect human health.

S. No.	Authors	No.	Mean Anatero-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 3. Comparison of dimensions of foramen magnum with different studies

Abnormalities of the foramen magnum can be classified as congenital, developmental, acquired, traumatic, and pathological. These abnormalities can occur either alone or in combination. The data analysis and values of the current study may help anatomists, radiologists, and neurosurgeons with transcondylar surgical approaches, which are increasingly utilized for brainstem lesions and surgeries at the craniovertebral junction. Thorough knowledge of the anatomical variation of the foramen magnum helps radiologists differentiate deformities such as Arnold-Chiari malformation, in which the transverse diameter of the foramen magnum is increased.

These findings can also be useful to neurosurgeons for better approaches to treating foramen magnum meningiomas and other posterior cranial fossa lesions. The morphology and morphometry of the foramen magnum also have evolutionary importance. Further studies are needed, as there could be variations in the shapes and dimensions of the foramen magnum in different regions of India.

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