Print ISSN: 2321-6379
Online ISSN: 2321-595X

Original Article

Foramen Magnum: Morphometry, Possible Variation in the Shape and its Clinical Implication

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Abstract

Introduction: Foramen magnum is midline opening in the occipital bone in the floor of posterior cranial fossa. Morphometry of cranium also helps in establishing the origin of various neurological and skeletal pathologies and also designing various surgical procedures and approaches.

Methods: We conducted a study on 50 dry skull bones in the Department of Anatomy, Government Medical College and Hospital, Chandigarh. The foramen magnum was analyzed for its shape, anteroposterior (AP) diameter, width/transverse diameter (TD), area, perimeter, and FM index. All the measurements were taken with Vernier caliper and were statistically evaluated.

Results: The common shape observed was hexagonal in 45% of cases. The mean of AP and TD was found to be 34.44 mm and 30.46 mm. AP diameter was more than TD. FM index and perimeter were found to be 98.91 mm and 88.44. However, area of foramen magnum was observed to be 745.727 mm^2.

Key word: Foramen magnum, Morphometry, Arnold Chairi malformation

INTRODUCTION

Cranial osteometry has an important place in anthropology and basic medical sciences research.[1-5] It enables identification of species, sex from skeleton, or its remains. Morphometry of cranium also helps in establishing the origin of various neurological and skeletal pathologies and also designing various surgical procedures and approaches.

Foramen magnum is large opening at the lower part of occipital bones. It transmits important structures such as lower end of medulla oblongata, vertebral arteries, meninges, spinal accessory nerve, apical ligament of dens, and membrana tectoria.[6] The cranium base in posterior part of skull is formed of occipital bone and basilar part of sphenoid bone and laterally by mastoid and tympanic part of temporal bone.

Access this article online

www.ijss-sn.com

Month of Submission : 11-2018
Month of Peer Review : 11-2018
Month of Acceptance : 12-2018
Month of Publishing : 01-2019

Foramen magnum is midline opening in the occipital bone in the floor of posterior cranial fossa. This foramen is the largest opening in the occipital bone through which the cranial cavity communicates with the vertebral canal. The anterior part or margin of the foramen is formed by the basilar part of occipital bone while the lateral margins are formed by the condylar part of the occipital bone. The posterior margin is formed by the squamous part of the occipital bone. On the inferior surface just in front of its widest diameter, it is encroached on by its medial aspect of the occipital condyles. In most of the subject, it is ovoid in shape and wider in posterior part. Its narrow anterior part lies above the dens of the axis vertebra, its wider posterior part communicates below with the vertebral canal, and through it, the medulla oblongata becomes continuous with the spinal cord.[7] In comparing the different parts of skull, cranium base is thick and it is covered by many structures, protecting it from physical insults.[8]

MATERIALS AND METHODS

For this study on foramen magnum, 50 dry skulls were taken from the Department of Anatomy, Government

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Medical College, Chandigarh. The skull with broken base and deformed shape was not included. The sex and origin of the origin of the skull could not be ascertained as some skulls were part of the skeleton bought from market. The objective is to make a data of various parameters of the foramen magnum in human skull of the region. The various parameters measured were as follows:

1. Sagittal diameter (anteroposterior) from basion to opisthion
2. Transverse diameter (TD) (side to side) maximum diameter in transverse plane
3. Perimeter - length of the periphery of foramen magnum
4. Area of foramen magnum - $1/4 \times \pi \times Td \times APd$
5. Foramen magnum index - $(Td/AP\ d) \times 100$
6. Shape of foramen magnum – oval-, round-, and egg-shaped pentagonal, tetragonal, hexagonal, and irregular.

All the measurements were taken twice and average was recorded. The measurement was taken with the help of Vernier caliper which has minimum error of 0.01 mm. The perimeter was taken with the help of thread which was later measured with the calipers.

The data collected from dimensions of foramen magnum were statistically analyzed.

RESULTS

The results for the shape of foramen magnum [Figure 1] revealed that hexagonal shape is found in maximum skulls, i.e., 45% of cases followed by tetragonal and oval in 17% and 16% of cases. It was round and pentagonal in 4% of cases. The frequency distribution of shape of foramen magnum is depicted in Table 1.

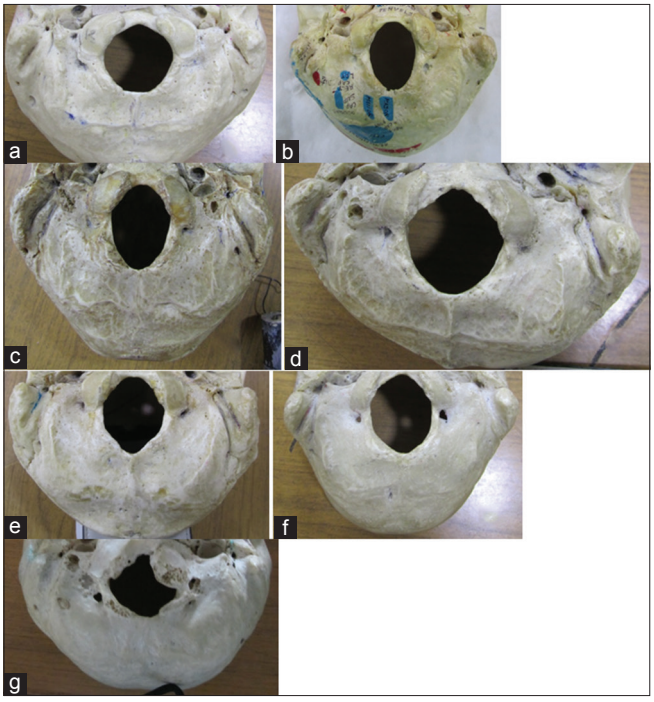

Figure 1: (a) Round, (b) oval, (c) egg shaped, (d) tetragonal, (e) pentagonal, (f) hexagonal, (g) irregular

The mean of anteroposterior (AP) diameter in all shapes was found to be 34.44 mm. The mean TD or width was found to be 30.46 mm. The mean perimeter was 98.91 mm. FM index which was calculated by TD divided by AP diameter was found to be 88.4 mm. The mean area of foramen magnum was 745.727 mm^2.

The mean of all dimensions is shown in Table 2. This gives a good perspective about the mean dimension of the foramen magnum in our region's population.

The measurement of the different shapes separately is also tabulated one by one in the following Tables 4-7.

AP diameter ranged from 29.59 to 34.51 mm. AP diameter was found smallest in oval shape while egg shape had largest AP diameter of foramen magnum [Table 3].

Table 1: Showing frequency distribution of Shape of Foramen magnum (%)

Shape	Frequency	Percentage (%)
Oval	8	15.7
Round	2	3.9
Egg	3	5.9
Pentagonal	2	3.9
Tetragonal	9	17.6
Hexagonal	23	45.1
Irregular	3	5.9

Table 2: Mean of parameters of Foramen magnum

Parameters	Mean
AP	34.44mm
Width	30.46mm
Perimeter	98.91mm
FM index	88.44
Area	745.72mm^2

Table 3: Anteroposterior diameter of foramen magnum

Shape	Number	Mean (mm)	Std.Dev	Median (mm)
Oval	8	29.59	12.22	32.82
Round	2	33.11	3.804	33.11
Egg	3	34.41	2.18	33.56
Pentagonal	2	31.30	1.032	31.30
Tetragonal	9	34.51	2.4653	34.22
Hexagonal	23	33.59	2.88	33.36
Irregular	3	32.01	5.13	31.55

The width of the foramen magnum of different shapes ranged from 23.50 to 29.27 mm. It was found to be maximum in tetragonal shape and minimum in oval shape as shown in Table 4.

The mean of perimeter ranged from 86.49 to 103.05 mm. The standard deviation of perimeter ranged from 3.81 to 36.45 mm. It was found maximum in egg shape and least in oval shape (least AP diameter and width) as shown in Table 5.

FM index ranged from 69.98 to 104.15. It was seen maximum in round shape and least in oval shape as shown in Table 6.

The area of foramen magnum ranged from 63.21 mm to 80.41 mm. It was seen maximum in tetragonal shape and least in oval shape as shown in Table 7.

Table 4: Width of foramen magnum

Shape	Number	Mean (mm)	Std.Dev	Median (mm)
Oval	8	23.50	9.64	26.48
Round	2	27.37	3.27	27.37
Egg	3	27.33	1.22	27.47
Pentagonal	2	27.79	1.407	27.79
Tetragonal	9	29.27	1.59	29.24
Hexagonal	23	28.36	2.141	28.58
Irregular	3	29.01	0.474	28.90

Table 5: Perimeter of foramen magnum

Shape	Number	Mean (mm)	Std.Dev	Median (mm)
Oval	8	86.49	36.45	100.22
Round	2	90.27	10.97	90.27
Egg	3	103.05	3.84	105.13
Pentagonal	2	90.51	3.81	90.51
Tetragonal	9	100.83	6.32	99.34
Hexagonal	23	93.63	20.10	96.45
Irregular	3	98.09	12.79	99.01

Table 6: FM index of foramen magnum

Shape	Number	Mean	Std.Dev	Median
Oval	8	69.98	29.76	76.79
Round	2	104.15	24.35	104.15
Egg	3	79.53	3.70	77.59
Pentagonal	2	88.77	1.56	88.77
Tetragonal	9	85.23	7.69	90.23
Hexagonal	23	85.98	10.65	82.66
Irregular	3	92.01	13.19	91.60

Table 7: Area of foramen magnum (mm^2)

Shape	Number	Mean (mm)	Std.Dev	Median (mm)
Oval	8	712.54	66.32	70.71
Round	2	716.40	166.84	72.64
Egg	3	739.20	74.80	71.67
Pentagonal	2	683.50	57.09	69.30
Tetragonal	9	792.76	66.94	82.76
Hexagonal	23	748.23	88.99	75.87
Irregular	3	730.37	129.21	72.57

DISCUSSION

The occipital bone consists of basilar, lateral, and squamous parts. The basilar, lateral condylar, and lower squamous parts of the occipital are laid down in cartilage, but the upper part of the squama is laid down in membrane. The ossification centers for all these parts appear early in the 3rd month, i.e., for the lower squamous, lateral part, and upper squamous (in that order) in the first few days of the 3rd month followed by that for the basilar part appearing a week later. The supraoccipital has one center. Each lateral occipital has a single center, appearing near the margin of the foramen magnum. The interparietal apparently begins with paired centers, which rapidly merge with each other and with the supraoccipital ossification, but, like most ossification in membrane, the number of centers appears to vary in individuals. There have been described two interparietals and two pre-interparietals, but these seem to be only assumptions based on abnormalities and in any case would probably only have the value of individual variations. The basilar part has a single center, which does not appear to have been seen at any time in an early paired state. The basal ossification extends somewhat backward and outward, and is separated at birth at first by a layer of cartilage from the lateral occipital: It joins this around 6 years. Basioccipital is separated from the basisphenoid by cartilage; result of this is that at birth the bone is in four separate pieces. The tabular and lateral parts unite in the 3rd year and the basal portion joins a few years later. Lateral occipitals form the greatest part of the margin of the foramen, the other elements of the bone only contributing small piece each in front and behind.[9]

The present study is an attempt to see pattern in the various dimensions of foramen magnum in dry adult skulls in North Indians. The knowledge of the anatomy of foramen magnum with all its parameters will be quite helpful in patients with craniocervical/craniovertebral anomalies. The shape and morphology of foramen magnum guide in knowing the cause and devising the treatment of neurological conditions in live born as in Arnold Chiari malformation. The irregularity in the shape of the foramen may be due to developmental anomalies related to bone development and soft tissues at base of cranium.[10]

According to Zaidi *et al.*,[11] foramen magnum shape was oval (64%), hexagonal (24.5%), pentagonal (7.5%), irregular (3.5%), and round (0.5%) cases. In a study conducted by Murshad *et al.*,[12] it was found that foramen magnum was oval shaped in 8.1% of cases. It was round, pentagonal, hexagonal, and irregular in 0.3%, 10.9%, 13.6%, and 13.6%, respectively.

The mean APD and TD in our study were 34.44 mm and 30.46 mm, respectively. Sharma *et al.*[13] found it 47.70 mm and 40.80 mm. Tubs *et al.*[14] observed APD to be 31 mm

and TD to be 27 mm. Murshed *et al.*[12] found it to be 35.9 mm and 30.45 mm. Muthukumar *et al.*[5] found APD and TD to be 33.3 mm and 27.9 mm. Our study findings were similar to the findings of Murshed*et al.*[11]

In the present study, we calculated perimeter, area, and FM index of foramen magnum. The perimeter, area, and FM index were found to be 98.91 mm, 745.72 mm^2, and 88.4, respectively. FM index of the present study was found similar to a study conducted by Sharma *et al.*[13] which was 87.68, respectively. Burdan *et al.*[15] found area and FM index of foramen magnum to be 877.4 mm^2 and 89.34.

CONCLUSION

Knowledge of variation at the craniovertebral junction is important in designing the surgeries at this site. This will help the surgeon in avoiding the damage and unnecessary hemorrhage during the operation. For this variation in morphometry of the foramen magnum giving passage to the spinal medulla becomes even more important. The present study will provide important reference and measurements data might be helpful for anatomists, neurosurgeons, and in other medical fields.

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How to cite this article: Sharma A, Kaur R, Sharma MK. Foramen Magnum: Morphometry, Possible Variation in the Shape and its Clinical Implication. Int J Sci Stud 2019;6(10):13-16.

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