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MORPHOMETRIC ANALYSIS OF FORAMEN MAGNUM IN HUMAN SKULL FOR SEX DETERMINATION

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Abstract

Introduction

The foramen magnum is a wide communication between posterior cranial fossa and the vertebral canal. The narrow anterior part of the foramen magnum has apical ligament of dens, upper fasciculus of the cruciate ligament and membrana tectoria, both are attached to the upper surface of basioccipital bone infront of the foramen magnum. Its wide posterior part contains the medulla oblongata and its meninges. In subarachnoid space spinal rami of the accessory nerve and vertebral arteries, with their sympathetic plexus, ascend into the cranium; the posterior spinal arteries descend posterolateral to the brain stem.

Materials and Methods

This is a prospective and observational study conducted in the Department of Anatomy, Index Medical College. Maximum anteroposterior diameter of the Foramen Magnum: Maximum distance between anterior and posterior margins measured along the midsagittal plane of the Foramen Magnum. Maximum transverse diameter of the Foramen Magnum: Maximum distance between the lateral margins measured along the transverse plane of the Foramen Magnum. Length of the occipital condyle: Maximum length of the Occipital Condyle taken along the articular surface and the parameter is recorded bilaterally. Maximum width of the occipital condyle: Maximum width of the Occipital Condyle taken along the articular surface perpendicular to the Occipital Condyle length and the parameter is recorded bilaterally

Results

100 subjects were studied (80 males and 20 females) with an overall mean age of 38.92 ± 10.95 years. The mean and standard deviation for all the five measurements were obtained to derive the FM dimensions in the study population, which showed that except LD all other parameters were noted higher in males, highlighting sexual dimorphism in FM dimensions. Gender accuracy formula: [(‾0.263 x LD) +0.156 x TD) + (0.437 x C) + (0.659 x A)] – 102.17 By applying the data to the derived equation, canonical variables were derived for all the parameters of FM dimensions. Also, an attempt was made to assess the efficiency of all

five parameters of FM in sex determination. The overall accuracy of 72.5% was got when 120 subjects were considered. The maximum accuracy was got for C and the least for LD.

Conclusion

The study recommends the use of SMV radiographs in elucidating FM morphometric variations for the identification of unknown individuals and may act as a guide to the anatomists, neurosurgeons, and in other medical fields as well. These findings would be interrogated as reliable indicators in sex determination of unknown skulls. Data should be only used as a corroborative finding in predicting sex in case of fragmented cranial bases and not recommended as sole indicators for sexing complete skulls.

Keywords: Foramen Magnum, Dry Human Skulls, Occipital Bone.

Introduction

The foramen magnum is a large opening in the base of skull, it is oval, wider behind with greatest diameter being antero-posterior. It contains the lower end of the medulla oblongata, the vertebral arteries and spinal accessory nerves [1]. The dimensions of the foramen magnum are clinically important because the above mentioned vital structures passing through it may endure compression such as in cases of foramen magnum herniation, foramen magnum meningiomas and foramen magnum achondroplasia [2]. The knowledge of foramen magnum diameters is needed to determine some malformations such as Arnold Chiari syndrome, which shows expansion of transverse diameter [3].

The dimensions of the foramen magnum are important prior to the cutting off of the foramen magnum lesions or posterior cranial fossa lesions, because more the antero-posterior diameter, greater is the contra lateral exposure [2]. The diameters and area of the foramen magnum are greater in males than in females, hence its dimensions can be used to determine sex in the medicolegal conditions, especially in the following circumstances, such as explosions, aircraft accidents and war fare injuries [3,4]. Foramen magnum is about 3cm wide by 3.5cm anteroposteriorly [5, 6]. It is located midway between and on a level with mastoid processes. The foramen magnum is surrounded by different parts of the occipital bone, squamous part lies behind and above, basilar part in front and a condylar part on either sides [7,8].

On each side its antero-lateral margin is encroached by occipital condyles, hence the foramen magnum is narrow anteriorly. The anterior edge of the foramen magnum is slightly thickened and lies between the anterior ends of the condyles. The posterior half of the foramen magnum is thin and semicircular. Upper ends of anterior and posterior atlanto-occipital membranes are attached to the anterior and posterior margins of the foramen magnum respectively, and their lower ends are attached to the superior surface of anterior and posterior arches of the atlas respectively. [6]

The foramen magnum is a wide communication between posterior cranial fossa and the vertebral canal. The narrow anterior part of the foramen magnum has apical ligament of dens, upper fasciculus of the cruciate ligament and membrana tectoria, both are attached to the upper surface of basioccipital bone infront of the foramen magnum. Its wide posterior part contains the medulla oblongata and its meninges. In subarachnoid space spinal rami of the accessory nerve and vertebral arteries, with their sympathetic plexus, ascend into the cranium; the posterior spinal arteries descend posterolateral to the brain stem, where as anterior spinal artery descends anteromedian to the brain stem. The cerebellar tonsils may project into the foramen magnum [9].

The fitted nonachondroplastic foramen magnum growth curves demonstrate that the maximum growth occurs in the first 18 months and slows thereafter. Indeed, the sagittal dimension almost doubles within the first 2 years, while the transverse dimension enlarges by half the original dimension. Growth of this area is essentially complete by 5 years. The achondroplastic foramen magnum is small at birth, and during the first year it has a very severely impaired rate of growth essentially in the transverse dimension. This markedly diminished growth results not only from abnormal enchondral bone growth but also because of abnormal placement and fusion of the synchondroses [10].

Materials and Methods

This is a prospective and observational study conducted in the Department of Anatomy, Index Medical College.

- Hundred human adult dry skulls of either sex.

- Digital Vernier Calipers.

- Flexible wire.

STUDY METHODS: Dry skull Method

SPECIMEN COLLECTION: Hundred human adult dry skulls of either sex.

A. DRY SKULL METHOD:

Inclusion criteria:

1. Adult human dry skull of either sex of 18-60 years .

2. Third molar tooth erupted.

3. Well defined skull sutures.

Exclusion criteria:
1. Abnormal skulls.

2. Damaged skulls.

The measurements of parameters related to Foramen magnum and occipital condyle

Right Occipital Condyle length

Right Occipital Condyle maximum width

Right Occipital Condyle minimum width

Left Occipital Condyle length

Left Occipital Condyle maximum width

Left Occipital Condyle minimum width

Bicondylar distance

Anterior inter condylar distance

Posterior inter condylar distance

The following morphological parameters will be observed by gross examination.

1. Protrusion of Occipital Condyle into the Foramen Magnum

2. Presence of Posterior condylar canal

3. Presence of Septum of the Hypoglossal canal.

The following measurements will be made with the use of digital vernier calipers
1) Length of the occipital condyle: Maximum length of the Occipital Condyle taken along the articular surface and the parameter is recorded bilaterally

2) Maximum width of the occipital condyle: Maximum width of the Occipital Condyle taken along the articular surface perpendicular to the Occipital Condyle length and the parameter is recorded bilaterally

3) Minimum width of the occipital condyle: Minimum width of the OC taken along the articular surface perpendicular to the Occipital Condyle length and the parameter is recorded bilaterally

4) Bicondylar distance: Maximum distance between the lateral margin of right and left condylar articular facets perpendicular to the midsagittal plane

5) Anterior intercondylar distance: Distance between the anterior tips of the right and left Occipital Condyle perpendicular to the midsagittal plane

6) Posterior intercondylar distance: Distance between the posterior tips of the right and left Occipital Condyle perpendicular to the midsagittal plane

7) Distance between intracranial edge of Hypoglossal canal and anterior margin of Occipital Condyle: Distance between intracranial edge of HGC and anterior margin of the corresponding occipital condyle and the parameter is recorded bilaterally

8) Distance between intracranial edge of Hypoglossal canal and posterior margin of the Occipital Condyle: Distance between intracranial edge of HGC and posterior margin of the corresponding occipital condyle and the parameter is recorded bilaterally

Statistical analysis

Statistical analysis was performed using SPSS (Statistical Package for Social Sciences, version 25.0) computer software. Continuous variables were presented as mean ± SD (standard deviation). The two groups were compared with student-t test while paired t-test was used to compare paired groups.

Results

100 subjects were studied (80 males and 20 females) with an overall mean age of 38.92 ± 10.95 years [Table 1]. The mean and standard deviation for all the five measurements were obtained to derive the FM dimensions in the study population, which showed that except LD all other parameters (TD, circumference, area, FI) were noted higher in males, highlighting sexual dimorphism in FM dimensions. To substantiate this, *P* - value was calculated using Student's t-test and it was seen that *P* - value was <0.05 for TD, circumference, area, and FI suggesting statistically significant differences between the two genders [Table 2].

Table 1: Distribution of subjects among both genders

			Age	
Gender	***n***	**%**	**Mean**	**SD**
Male	80	80%	39.24	12.15
Female	20	20%	38.61	9.75
Total	100	100%	38.92	10.95

n: no of subjects, SD: standard deviation

Table 2: Descriptive statistics and t-value for the measured variables of the occipital bone

	Males				Females				
Variable	**N**	**Mean**	**S.D**	**CV**	**N**	**Mean**	**S.D**	**CV**	**t-value**
LFM	80	36.67	3.20	9.63	80	36.13	3.84	10.67	1.999
WFM	80	30.27	2.80	8.75	80	30.12	3.65	11.72	0.842
BCB	80	50.24	3.26	6.89	80	48.92	2.93	5.70	3.387*
MnD	80	18.64	2.67	16.52	80	18.16	2.98	18.40	0.874
MxID	80	30.34	3.72	13.96	80	28.17	9.77	18.91	1.349
EHC	80	36.46	4.90	15.78	80	34.57	1.99	5.91	1.689
FMA - Routal	80	821.18	9.86	14.93	80	764.46	13.97	19.76	1.353
FMA - Teixeria	80	799.32	9.96	13.82	80	740.71	13.96	19.91	1.378

Discussion

The FM measurements in our study showed statistically significant ($p < 0.05$) differences between the gender with all values significantly greater in males than females except LD which was noted slightly higher among females (36.9 ± 3.51 mm). Babu *et al.* [11] found the mean LD values to be 40.86 mm in males and 39.75 mm in females, whereas Kanchan *et al.* [12] reported values of 41.15 mm in males and 40.3 mm in females. This difference of result can be because of different populations studied, different study method.

In the present study, the area of FM among both genders (male = 944.12 ± 164.64 mm2 and female = 902.16 ± 90.21 mm2) was found comparable to Kanchan *et al.* and Babu *et al.* [12] studies with statistically significant gender difference. The FM area was calculated by using Radinsky's formula as in a review of literature also, researchers had used two formulae to calculate the FM area, Texeira formula, and Radinsky's formula. Among the studies conducted in the Indian population, the value for area obtained by Radinsky's formula is a better evaluator of sex.

A significant statistical difference regarding FM circumference (male = 99.62 ± 6.44 mm and female = 96.51 ± 12.94 mm) was found in the present study, the results are following Raikar *et al..,* [13] studies where the mean C values were male = 127.51 mm; female = 119.59 mm and male = 119.6; female = 110.3 mm respectively. The FI was calculated (if FI ≥ 1.3) which helps us in determining the shape of FM when values of circumference and area cannot be assessed.

In the present study, the most common morphological FM shape was found to be Egg shape (27%) in both genders, whereas the least common shape was round (no case) in females and hexagon and round (4%) in males. Raikar *et al.* [13], observed similar findings. But according to Holland *et al.* the incidence rate of round shape was most common followed by egg and tetragonal. This difference among the results of studies might result from racial differences or visualization techniques.

The strong interobserver correlation in our study implies that FM dimensions are minimally affected by subjective variations and hence are highly reproducible in determining sexual dimorphism. It was seen that FM dimensions tested using digital SMV were 69.73% accurate in differentiating sex and 82.29% and 85.45% in male and female determination, respectively. The results were following the Gapert *et al.* [15] (82.1%), Texeira *et al.* (80%), and Suazo *et al.* [16] (78.2%). However, the accuracy achieved by Uysal *et al.* [17] in their studies on a sexual determination by FM using CT was found to be 85%.

It is evident from the results that males displayed larger mean values than females for all measured variables of the foramen magnum. Of all the variables only one variable i.e., Maximum Bicondylar Breadth (BCB) exhibited statistically significant difference between the sexes. Although length and width of foramen magnum was found to be slightly larger in males than females in the present sample, these dimensions did not yield statistically significant differences.

However, in French sample the length of foramen magnum did not reveal significant differences but width showed the significant results. In African – American group (Wescott & Morre Jansen, 2000) [18] found length of foramen magnum as one of the most reliable measurements for sex determination. Our findings are in contrast with the results reported on British sample (Gapert *et al*., 2009), [15] UNIFESP sample (Suazo *et al*., 2009) [19] as well as on Indian populations which show statistically significant differences between males and females for length and breadth. In our study the mean of foramen magnum area in females was found to be smaller than in males. This result is in consensus with the findings reported by Suazo *et al*., 2009 [19]. Morphometric analysis of foramen magnum for sex determination: Singh & Talwar (2013) al., (2009) [20] and Macaluso Jr. (2011). [21] Our study did not reveal significant differences for mean of foramen magnum area. This finding is in contrast with those reported by Singh & Talwar (2013) al., (2009). [20]

Maximum Bicondylar Breadth (BCB) exhibited significant differences between skull of males and females in the present sample. Similar findings have been reported from other studies where intercondylar dimension i.e., Maximum Bicondylar Breadth (BCB) displayed significant difference in diverse populations including the historic British samples from St. Bride's church. In the present study, the values of maximum bicondylar breadth (BCB) as observed in both sexes (males 52.37mm; females 50.92mm) were comparatively smaller than French skulls (males 61.23mm; females 59.37mm) British samples (males 61.92mm; females 57.76mm) and African– American group (Black males 49.6mm; females 55.6mm; white males 61.3mm; females 59.4mm). Besides BCB, Gapert *et al.* (2009) [15] in the British sample, found MxID and EHC to be significantly dimorphic, which was not the case in the present study. In our study maximum bicondylar breadth was found to be the most reliable variable for sex estimation.

There are sexual differences in foramen magnum of varying magnitude across different Populations. To ascertain these differences the results of the present study were have been compared with the existing studies as shown in Table 4.

It is widely recognized however, that size related levels of sexual dimorphism are generally population specific, due to a combination of genetic, environmental and socio-cultural factors and thus metric standards developed for sexing cranial remains may not be accurately applied to other skeletal samples (Kajanoja 1966). [22] It can be concluded from the present study that of, all the variables considered in the present study, maximum bicondylar breadth was found to be the most reliable variable for sex estimation. In stepwise, analysis it was found to be more discriminating variable providing an accuracy of 72%. The accuracy of sex prediction base on discriminant function analysis ranged from 72% to 75%. Looking at the overall accuracy rates in the present study it can be inferred that morphometric analysis of foramen magnum dimensions cannot be regarded as a very reliable method for determining sex in the present collection on complete skulls.

However, in case of highly fragmentary remains, where no other skeletal remains are preserved, metric analysis of the basal region of the occipital bone may provide a statistically useful indication as to the sex of an unknown skull. (Gapert *et al*.,2009). [15] Similar findings have been reported by present study. Since the present study was based on a limited sample, it is suggested that further research based on larger samples of documented Indian skulls should be undertaken to check the reliability of morphometric measurements of foramen magnum in sex determination.

Conclusion

The present study indicates significant sexual dimorphism exist in these parameters. These parameters should be taken into consideration during craniovertebral and cervical spine surgical procedures. Morphometric analysis of foramen magnum can be used as supportive findings in estimation of sex of fragmented, incomplete or damaged dry human skulls. The

knowledge of morphology and morphometry of foramen magnum is important for neurosurgeons, radiologists as well as anthropologists.

References

1. Chethan P, Prakash KG, Murlimanju BV, Prashant KU, Prabhu LV, Saralaya VV et al. Morphological analysis and Morphometry of the Foramen Magnum: An Anatomical Investigation. Turkish Neurosurgery. 2012;22(4):416-419.
2. Tubbs RS, Griessenauer CJ, Loukas M, Shoja MM, Cohen-Gadol AA. Morphometric analysis of the foramen magnum: an anatomic study. Neurosurgery 2010; 66:385-388.
3. Madadin M, Menezes RG, Al Saif HS, Abu Alola H, Al Muhanna A, Gullenpet AH, et al. Morphometric evaluation of the foramen magnum for sex determination: A study from Saudi Arabia. J Forensic Leg Med. 2017 Feb;46:66–71.
4. Naderi S, Korman E, Çıtak G, Güvençer M, Arman C, Şenoğlu M, et al. Morphometric analysis of human occipital condyle. Clinical Neurology and Neurosurgery. 2005 Apr 1;107(3):191–9.
5. Saluja S, Das SS, Vasudeva N. Morphometric Analysis of the Occipital Condyle and Its Surgical Importance. J Clin Diagn Res. 2016 Nov;10(11):AC01–4.
6. Kanodia G, Parihar V, Yadav YR, Bhatele PR, Sharma D. Morphometric analysis of posterior fossa and foramen magnum. J Neurosci Rural Pract. 2012;3(3):261–6.
7. Zdilla MJ, Russell ML, Bliss KN, Mangus KR, Koons AW. The size and shape of the foramen magnum in man. Journal of Craniovertebral Junction & Spine. 2017 Sep;8(3):205.
8. Sumana R, Kirubhanand C, Iddalgave S. Morphometric study of the foramen magnum in adult Human skulls in South Indian Population. Int J Anat Sci. 2014; 5(2):43-45.
9. Radhika PM, Shetty S, Prathap KJ, Sheshgiri C, Jyothi KC. Morphometric study of the foramen magnum in adult human skulls in Indian Population. Asian J Med Clin Sci. 2014; 3(1):68-72.
10. Rathva A, Shah K, Panchal B, Malukar O. Morphometry and sexual dimorphism of human skull foramen magnum. Int J of Recent Trends in Science and Technology. 2015; 15(2):379-386.
11. Babu R, Manjunath S, Rastogi P, Mohan KTS, Bhat VJ, Yoganarasimha K. Determination of sex by foramen magnum morphometry in South Indian population. J Med Singapore 2013; 54: 458‑62.
12. Kanchan T, Gupta A, Krishan K. Craniometric analysis of foramen magnum for estimation of sex. Int J Med Health Biomed Pharm Eng 2013; 7: 111‑3.
13. Raikar NA, Meundi MA, David CM, Rao MD, Jogigowda SC. Sexual dimorphism in foramen magnum dimensions in the South Indian population. A digital submentovertex radiographic study. J Forensic Dent Sci 2016; 8: 180‑1.
14. Holland TD. Sex determination of fragmentary crania by analysis of crania base. Am J Phys. Anthropol. 1986; 70: 203-208.

15. Gapert R, Black S, Last J. 2009. Sex determination from the occipital condyle; discriminant function analysis is an eighteenth and nineteenth century British sample. *Am J Physical Anthropology*. **138**: 384-94.
16. Teixeria WR. Sex identification utilizing the size of foramen magnum. Am J Forensic Med Pathol 1982; 3: 203‑6.
17. Uysal S, Gokjharman S, Kacar M, Tuncbilek I, Kosa U. Estimation of sex by 3D CT measurements of the foramen magnum. J Forensic Sci 2005; 50: 1310‑4.
18. Westcott, D. and Moore-Jansen P. (2001): Metric variation in the human occipital bone: forensic anthropological applications. J. Forensic Sci., 46: 1159–1163.
19. Suazo GIC, Russo PP, Zavando MD, Smith RL. Sexual dimorphism in the foramen magnum dimensions. Int J Morphol 2009; 27: 21‑3.
20. Singh, G. and Talwar, I. (2013): Morphometric analysis of foramen magnum in human skull for sex determination. Human Biology Review, 2(1): 29-41.
21. Macaluso Jr PJ. 2011. Metric sex determination from basal region of the occipital bone in a documented French sample. *Bull Mem.Soc.Anthropol.Paris.* **23**: 19-26.
22. Kajanoja P (1969) Sex determination of Finnish crania by discriminant function analysis. American Journal of Physical Anthropology 24: 29-34.