

Original Research Article

Sexual dimorphism of foramen magnum: a NCCT based study

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Received: 01 April 2019

Revised: 18 April 2019

Accepted: 19 April 2019

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ABSTRACT

Background: Radiological determination of gender relies predominantly on the skeletal radiology and assumes importance in mass natural disasters, bomb explosions, exhumations and warfare where skeletal fragmentation is common. Varied literature is present regarding the role of foramen magnum in establishing gender identification. The objective of the study was to establish normative values of cross-sectional area of foramen magnum in both genders using NCCT and try to ascertain any significant difference in cross-sectional area in the two genders which may help in gender identification.

Methods: NCCT head images of 378 subjects were analysed in individuals beyond the age of skeletal immaturity. Free ROI technique using electronic calliper tool was used. The cross-sectional area of foramen magnum was automatically obtained after tracing its whole inner circumference.

Results: Mean cross-sectional area of foramen magnum in females was $806.79 \pm 106.58 \text{ mm}^2$ and was $878.33 \pm 98.42 \text{ mm}^2$ in males. Although the cross-sectional area in males was greater than females no statistically significant difference was found. The correlation coefficient was found to be weaker ($R=0.0413$).

Conclusions: No statistically significant difference was found between the two genders. The correlation coefficient was also weak to draw any inference about the gender of the skull on CT imaging. Further studies are needed to include other parameters like the sagittal and transverse diameters of foramen magnum in a larger sample to show importance of foramen magnum, if any, in helping gender identification of skeletal remains.

Keywords: Sexual dimorphism, Cross-sectional area, Foramen magnum, Electronic calliper tool, Multi-planar reformation, Correlation coefficient

INTRODUCTION

Radiological determination of gender relies predominantly on the skeletal radiology. Differences in sizes, shapes, angles and other anatomical landmarks in bones like femur, pelvis and skull are most useful for gender determination. Gender identification is 100% accurate when whole skeleton is available.¹⁻³ Radiological gender determination using morphometric methods rather than morphological methods assumes importance in mass natural disasters, bomb explosions, exhumations and warfare where skeletal fragmentation is common.^{4,5} Bones especially skull and pelvis can resist hazards like

fires and explosions providing the most accurate information about sexuality.^{6,7} Extensive literature is available which discusses at length the importance of skeletal radiography in gender determination. Foramen magnum has its own set of advantages to be used for sexuality determination like constant cross-sectional area after puberty which does not change with advancing age.⁸ Various formulas can be applied in radiography to give accurate dimensions to determine gender.⁵ Multitude of landmarks have been used like head circumference, foramen magnum (FM), femoral neck-shaft angle and pelvic bones. Various dimensions of foramen magnum like maximum sagittal diameter, maximum transverse

diameter and cross-sectional area (CSA) have been used to determine gender in unidentifiable human remains.⁹⁻¹⁴ Sagittal and transverse diameters have been reported to be significantly higher in human males than females.^{15,16} However, many authors albeit noting some differences in these dimensions in males and females found total cross-sectional area not to be a good indicator for sexuality determination.¹⁷ Most of the studies have documented these morphometric dimensions of foramen magnum using exhumed skeletons. We undertook this study to establish the normative values of cross-sectional area of foramen magnum in both genders using non-contrast computed tomography (NCCT) and try to ascertain any significant difference in cross-sectional area in the two genders which may help in gender identification.

METHODS

This was a retrospective observational study where we analysed the NCCT (16 slice Siemens somatom sensation, Germany) head images of 378 subjects acquired in our accident and emergency CT section for various indications between July 2018 to December 2018. Institutional ethical committee clearance was obtained for the study. Individuals beyond the age range of skeletal immaturity (age more than 20 years) were included in the study. Individuals with age less than 20 years (skeletal immaturity), previous surgery involving occipital bone, trauma causing fractures around foramen magnum, basilar invagination, Chiari malformation, achondroplasia and other skeletal dysplasia's involving skull base were excluded from the study. On the CT workstation after retrieval of data from picture archiving and communication system (PACS) multi-planar coronal, sagittal and axial reconstructions were performed. Reconstruction parameters were slice thickness 1.5 mm, recon increment 1.0 mm, field of view (FOV) 223 × 223 mm, window: osteo and kernel as H70s sharp FR (Head 70 smooth sharp Fast Reconstruction). Analysis of CT images was done on a PACS workstation monitor by an experienced radiologist. 3D multi-planar reformation on CT console was done with reformation lines oriented along the lower most points of basion and opisthion (sagittal plane) and the mid-point of cervical spinal canal at C1/C2 level (coronal plane) to get the maximum cross-sectional area of foramen magnum (Figure 1). Reformatted axial image of the foramen magnum showing the greatest sagittal diameter was selected. Free ROI technique using electronic calliper tool was used to select the inner bony margin of the foramen magnum. The cross-sectional area of foramen magnum was automatically obtained after tracing the whole circumference of inner bony margin. The examining radiologist was unaware of the sex of the patient to remove any observer bias.

Statistical analysis

The data was analysed using statistical softwares SPSS v 20 and STATA v 11. Categorical variables were

described in terms of frequency and range and the continuous variables in terms of descriptive statistics like mean and standard deviation. The P value of <0.05 indicated a significant statistical difference using two-sample independent student *t* test. Pearson correlation coefficient (R value) was calculated using an algorithm supplied by meta numerics statistical library.

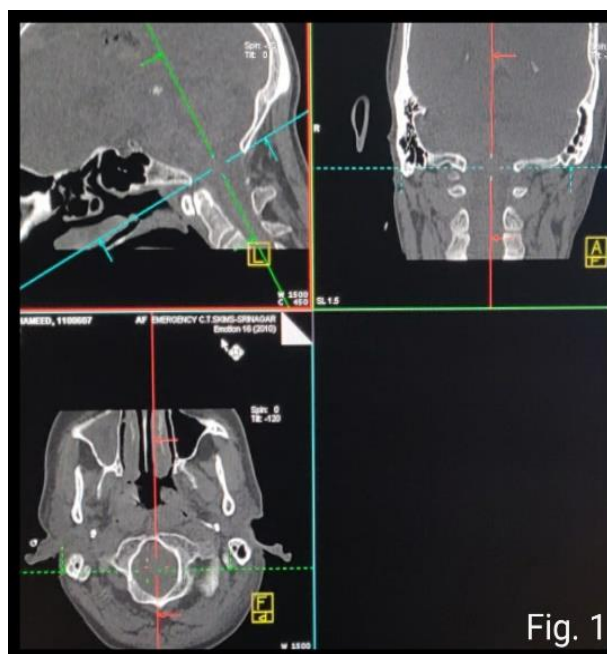


Figure 1: Image showing 3D multi-planar reformation on CT console with reformation lines oriented along the lower most points of basion and opisthion (sagittal plane) and the mid-point of cervical spinal canal at C1/C2 level (coronal plane) to get the maximum cross-sectional area of foramen magnum.

RESULTS

A total of 378 NCCT head images were analysed with equal number of males (n=189) and females (n=189). Mean age of females was 44.50±13.89 years with age range 24–70 years. Mean age of males was 40.48±13.61 with age range of 23–72 years. No statistically significant difference (p-value 0.7804) was seen in mean age and range of the two gender groups. The mean cross-sectional area of foramen magnum in females was 806.79±106.58 mm² (Figure 2). The smallest and largest cross-sectional area of foramen magnum in females in our study was 624 mm² and 1052 mm² respectively. The mean cross-sectional area of foramen magnum in males was 878.33±98.42 mm². The smallest and the largest cross-sectional area of foramen magnum in our study in males was 729 mm² and 1192 mm² respectively. Although the cross-sectional area in males was larger than females no statistically significant difference was found (p value 0.2757). The correlation coefficient (R value) was found to be weaker (R=0.0413). Because of this very low correlation coefficient, discriminant analysis was not performed. These findings are summarized in Table 1.

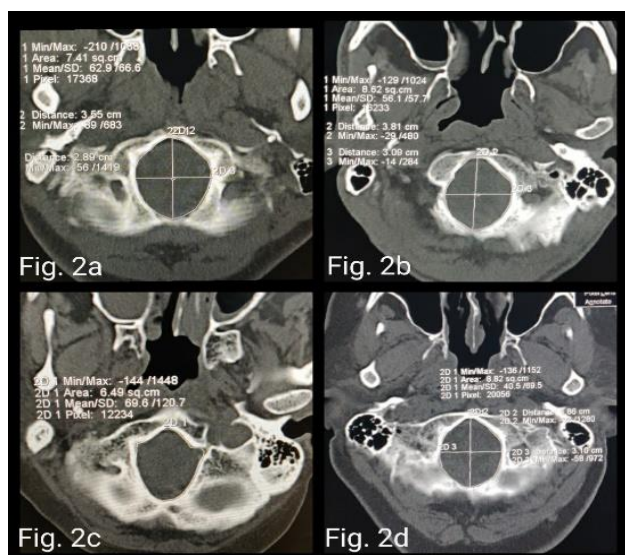


Figure 2: Axial NCCT reformatted images showing CSA of foramen magnum (a) 741 mm² (b) 862 mm² (c) 649 mm² and (d) 882 mm².

Table 1: Age and cross-sectional area of foramen magnum in males and females.

Parameter	Males	Females	P-value
Age (in years)			
Mean	40.48	44.50	0.7804
Standard deviation	13.61	13.89	
Range			
Min.	23	24	
Max.	72	70	
C. S. A (in mm²)			
Mean	878.33	806.79	0.2757
Standard deviation	98.42	106.58	
Range			
Min.	729	624	
Max.	1192	1052	

DISCUSSION

Skull morphometry forms an important and comprehensive domain in gender determination in forensic medicine. Gender determination can be accomplished using either morphological or morphometric analysis of the various skeletal parts. The skull, pelvis and femoral bones are most suitable for radiological determination of gender. Sexual dimorphism has been reported to be shown by various skeletal parts. Various studies have reported that foramen magnum shows sexual dimorphism. Gender discrimination is 100% precise when whole skeleton is available. In contrast in cases of explosions, warfare and mass disasters, gender discrimination is difficult as only fragments of skeleton are available. In the aforementioned scenario, radiological imaging can assist in giving precise dimensions after applying specific formulas to determine the gender.¹⁹ Majority of the morphometric values of foramen magnum have been established on exhumed dry skeletons. We measured the

cross-sectional area of foramen magnum on NCCT in the axial plane showing largest sagittal dimension. Mean age of females was 44.50 ± 13.89 years with age range 24–70 years while as mean age of males was 40.48 ± 13.61 with age range of 23–72 years in our study. No statistically significant difference (p-value 0.7804) was seen in mean age and range of the two gender groups. The mean age of males and females in our study was comparable to most of the studies comparing differences in foramen magnum CSA between males and females. The mean cross-sectional area of foramen magnum in females was 806.79 ± 106.58 mm² in our study. The smallest and largest cross-sectional area of foramen magnum in females in our study was 624 mm² and 1052 mm² respectively. The mean cross-sectional area of foramen magnum in males was 878.33 ± 98.42 mm². The smallest and the largest cross-sectional area of foramen magnum in our study in males were 729 mm² and 1192 mm² respectively. Although the cross-sectional area in males was larger than in the females in our study, no statistically significant difference was found (p-value 0.2757). The correlation coefficient (R value) was found to be weaker (R=0.0413). Catalina-Herrera, Uthman et al, Uysal et al, Radhakrishna et al, Jain et al, and Patel and Mehta studied morphometry of foramen magnum using skull base, radiographs, or CT scans and found that the FM shows sexual dimorphism.²⁰⁻²⁵ Kanchan et al and Shepur et al have stated that the FM does not show sexual dimorphism.^{26,27} Age does not affect the size of the foramen magnum after puberty. Therefore, differences in the results of various studies could not be due to the age of the samples. In fact, age may not be considered at all beyond puberty while determining sex based on the dimensions of the foramen magnum.²⁸ In addition, some authors are of the opinion that this could be an advantage in using the foramen magnum. Most of the studies document larger dimensions of foramen magnum in males as compared to females, however its discriminative value in gender differentiation is a controversial topic. In nutshell we conclude that although we found the CSA of foramen magnum consistently higher in males as compared to females, no statistically significant difference was found between the two genders in our study. The correlation coefficient was also weak (R=0.0413) to draw any inference about the gender of the skull on CT imaging. Further studies are needed to include other parameters like the sagittal and transverse diameters of foramen magnum in a larger sample to show importance of foramen magnum, if any, in helping gender identification of skeletal remains.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. Krogman WM, Isçan MY. The human skeleton in forensic medicine, Charles C. Thomas, Springfield,

1. IL. 1986;413-57. Longia GS. Anthropometrical features laryngeal cartilages. *Adli Tip Dergisi*. 1990;6:141-8.
2. Teixeira WRG. Sex identification utilizing the size of the foramen magnum. *Am J Forensic Med Pathol*. 1982;3:203-6.
3. Holland TD. Use of the cranial base in the identification of fire victims. *J Forensic Sci*. 1984;29:1087-93.
4. Di Vella G, Campobasso CP, Dragone M, Introna F Jr. Skeletal sex determination by scapular measurements. *Boll Soc Ital Biol Sper*. 1994;70:299-305.
5. Shanthi CH, Lokanadham S. Morphometric Study on Foramen Magnum of Human Skulls. *Med Sci*. 2013;2(4):792-8.
6. Hayashizaki Y, Usui A, Hosokai Y, Sakai J, Funayama M. Sex determination of the pelvis using Fourier analysis of postmortem CT images. *Forensic Sci Int*. 2015;246:122.
7. Gruber P, Henneberg M, Boni T, Ruhli FJ. Variability of human foramen magnum size. *Anat Rec (Hoboken)*. 2009;292(11):1713-9.
8. Quatrehomme G, Fronty P, Sapanet M, Grevin G, Bailet P, Olier A. Identification by frontal sinus pattern in forensic anthropology. *Forensic Sci Int*. 1996;83:147-53.
9. Gu'nay Y, Altinko'k MC, Agdir S, Kirangil B. Gender determination with skull measurements (in Turkish). *J Forensic Med*. 1997;13:13-9.
10. Gu'nay Y, Altinko'kM, C, agdir S, Sari H. Is foremen magnum size useful for gender determination (in Turkish). *Bull Legal Med*. 1998;3:41-5.
11. Cameriere R, Ferrante L, Mirtella D, Rollo UF, Cingolani M. Frontal sinuses for identification: quality of classifications, possible error and potential corrections. *J Forensic Sci*. 2005;50:770-3.
12. Rogers LT. Determining the sex of human remains through cranial morphology. *J Forensic Sci*. 2005;50:493-500.
13. Gruber P, Henneberg M, Bo'ni T, Ru'hli F. Varaibility of human foramen magnum size. *Anat Rec*. 2009;292:1713-9.
14. Catalina-Herrera CJ. Study of the anatomic metric values of the foramen magnum and its relation to sex. *Acta Anat*. 1987;130:344-7.
15. Zaidi SH, Dayal SS. Variations in the shape of foramen magnum in Indian skulls. *Anat Anz Jena*. 1988;167:338-40.
16. 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;26:104-8.
17. Krogman WM, Iscan MY. *The human skeleton in forensic medicine*. 2nd edn. Springfield, Illinois: Charles C Thomas Publishing; 1986.
18. Di Vella G, Campobasso CP, Dragone M, Introna F Jr. Skeletal sex determination by scapular measurements. *Boll Soc Ital Biol Sper*. 1994;70:299-305.
19. Catalina-Herrera CJ. Study of the anatomic metric values of the foramen magnum and its relation to sex. *Acta Anat (Basel)*. 1987;130:344-7.
20. Uthman AT, Al-Rawi NH, Al-Timimi JF. Evaluation of foramen magnum in gender determination using helical CT scanning. *Dentomaxillofac Radiol*. 2012;41:197-202.
21. Uysal S, Gokharman D, Kacar M, Tuncbilek I, Kosa U. Estimation of sex by 3D CT measurements of the foramen magnum. *J Forensic Sci*. 2005;50:1310-4.
22. Radhakrishna SK, Shivarama CH, Ramakrishna A, Bhagya B. Morphometric analysis of foramen magnum for sex determination in South Indian population. *Nitte Univ J Health Sci*. 2012;2:20-2.
23. Jain SK, Choudhary AK, Mishra P. Morphometric evaluation of foramen magnum for sex determination in a documented North Indian sample. *J Evol Med Dent Sci*. 2013;2:80938.
24. Patel R, Mehta CD. Morphometric study of foramen magnum at the base of human skull in South Gujarat. *IOSR J Dent Med Sci*. 2014;13:235.
25. Kanchan T, Gupta A, Krishan K. Craniometric analysis of foramen magnum for estimation of sex. *Int J Med Health Biomed Pharm Eng*. 2013;7:1113.
26. Shepur MP, Magi M, Nanjundappa B, Havaladar PP, Gogi P, Saheb SH. Morphometric analysis of foramen magnum. *Int J Anat Res*. 2014;2:24955.
27. Gapert R, Black S, Last J. Test of age-related variation in the craniometry of the adult human foramen magnum region: implications for sex determination methods. *Forensic Sci Med Pathol*. 2013;9(4):478-88.

Cite this article as: Wani HA, Feroz I, Dar SM, Parry AH, Gojwari TA, et al. Sexual dimorphism of foramen magnum: a NCCT based study. *Int J Clin Trials* 2019;6(2):52-5.