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Evaluating Foramen Magnum Surface Area in Males and Females for Morphological Differences Using 3D Computed Tomography Among Maharashtrian Population

Ravi Christian[1], Gaurav Mishra[2]

[1]Ex- PG, M. Sc MRIT (Medical Radiology & Imaging Technology) – School of Allied Health Sciences, [2]Associate Professor & Guide (Dept. of Radio-diagnosis, A.V.B.R.H, Datta Meghe Institute of Medical Sciences – Deemed to be University, Sawangi (meghe) Wardha, Maharashtra

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ABSTRACT

Background: Bones play a vital part in the process of individual identification in medico-legal cases, as they resist decomposition for a long period. The foramen magnum, which is located at the cranial base, is also a good parameter for identifications with reasonable accuracy. The surface area of the foramen magnum can be calculated using 3D reconstructed computer tomography of the head to assess the morphological differences in males and females, which is useful in forensic sciences.

Objectives: To measure the antero-posterior length of the foramen magnum, the transverse diameter of the foramen magnum, the surface area of foramen magnum in males and females and to compare surface area of male and female foramen magnum to find morphological difference.

Method: CT scan was performed in 40 patients (20+20) in two groups consist male and female, using SIEMENCE SOMATOM 16 SLICE machine, in patients referred to Acharya Vinoba Bhave Rural Hospital for CT head scan with 3D skull. Scan will include the vertex to C3, received images then reconstructed into 3D images. From the 3D images the foramen magnum was measured; anterior-posterior, transverse and surface area in two groups of patients includes males and female. Teixeria's and Radinsky's formulae was used. Descriptive analysis to measure area of foramen magnum. Independent sample T test to determine any significant difference between male and female foramen magnum area and Discriminant analysis.

Result: 70% of original group cases were correctly classified using the derived data

Conclusion: foramen magnum can be used in forensic science as gender determination tool in the case where other identifying methods are inconclusive and modern imaging technology can be very useful.

Keywords: foramen magnum, 3D CT, antero-posterior, transverse, surface area.

INTRODUCTION

In medico-legal scenarios the individual Identification is one such required and important variable. Since bones resist decomposition for a considerable long time therefore, they provide a plethora of information for the pretension of identification of an individual. Skull among the list and also

Corresponding Author: Ravi Bharatsinh Christian (Asst. Prof. Dept. Radiation & Imaging Technology, School of Allied Health Sciences, JECRC University, Jaipur, Rajasthan), 2-316 Brookhill, Nr. Brookhill Primary School, kasumbad, Taluka-Borsad, Anand, Gujarat – 388 540

E-mail: ravichristian7@gmail.com ,, ravi.christian@jecrcu.edu.in

the suitable parameters for identifications with reasonable accuracy [1]

The human skull is considered as one of the most dependable bones for sex identification. The skull is fundamentally founded on contrasts in the size and robusticity and is additionally populace explicit being impacted by different components including hereditary and ecological.[2]

Numerous scientists have embraced a few examinations in various populaces to decide the sex with sensible precision utilizing various estimations of the skull including those of the foramen magnum.[2]

Williams and Roger in their study revealed 80% precision of sex assurance utilizing cranial morphological qualities in their investigation.[3]

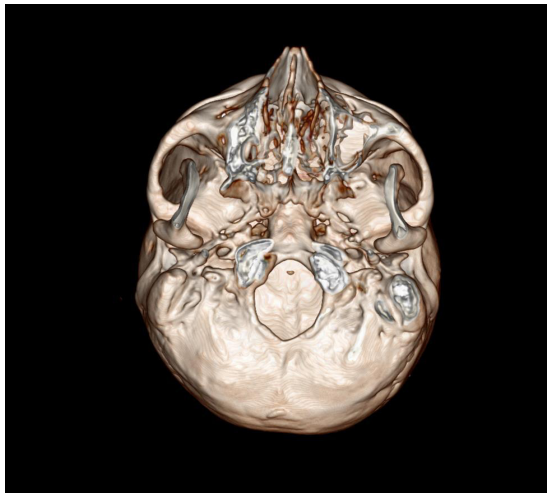
The current investigation is to find any sexual dimorphism of the foramen magnum by measuring FM using 3D CT.

Many factors that can affect the precision of identification from remains of the adult skeletal. Multiple anatomical gaps between the skeleton element of males and females are not significantly specified. If consider skeletal dimensions than males and females differ only by approximately 8%.[4] The validity and accuracy of traditional approaches for identification highly depends on a preservation method and skeletal completeness, especially with different morphologic element of the body such examples are skull and pelvis.[4]

In most Medico-Legal procedures, identification from the morphology of the skull is one of essential. Especially in Forensic studies were the remaining of skeletons are sometimes incomplete and this will make the sex identification very difficult.

Clearly distinguishing proof is a subject of intrigue and is very significant. This could be clarified by the accompanying reasons; good and helpful contemplations, to declare the positive demise of an individual, and to satisfy lawful and official necessities for personality enrolment.[5]

The reason why base of skull attracting the researcher because the basal area of the occipital bone is probably going to endure the physical abuses than different pieces of the skull as a result of the bountiful soft-tissue spread, skull thickness in the district, furthermore, anatomical position which is moderately all around ensured, in this manner protecting it for scientific assessment [6]



Territories, for example, air sinuses and foramen magnum in the skull are among the safest body components which can oppose risks like flames, blasts, and different mishaps. In this manner, the skull is one of the most well-known participants that remains to be worked out for sexing of the dead bodies. Notwithstanding pelvic, cranial bone can give the most precise data about sexuality [5] that are already proven for the same purpose.

Foramen Magnum among the primary capitals of ossification during the process of growth and development, situated at cranial base. Therefore, Foramen Magnum might be important in the identification process specifically in forensic studies. [6]

Anatomically, the Foramen magnum is a major gap in the base of the skull through which the spinal line converges with the mind. There are a few contrasts in the qualities of the skull bones and foramen magnum among people. Apparently, foramen magnum can be useful in deciding the sex; notwithstanding, the related highlights may fluctuate in various ethnic groups. One of the upsides of foramen

magnum is that after pubescence, the width of the foramen magnum doesn't change and it isn't influenced by age [5]

The FM is a significant structure of the skull base and is of significant enthusiasm for human studies, life structures, legal medication, and other clinical fields. It is a three-dimensional (3D) roundabout or on the other hand oval opening inside the occipital bone halfway. FM passage for the medulla oblongata and its layers.[7]

Primarily, it can be measured with traditional methods, but it can only be possible on dead bodies. By Using imaging modalities such as CT scans on living persons and by measuring the dimensions of Foramen Magnum, previous researchers able to provide data on similar topic and able to differentiate between male female FM [1] From the mentioned study, and other researchers and authors also claims the efficacy of Foramen Magnum in gender determination.[8]

Imaging modalities play a crucial role in such studies and many researchers uses imaging modalities as a tool, D.P Mohite [9] uses orthopantomography (OPG) in his research for mandible assessment, Prajakta Kale [10] use CBCT to study morphology of Atlas vertebrae in different skeletal pattern, Prasheelkumar Premnarayan Gupta [11] use computed tomography craniovertebral junction.

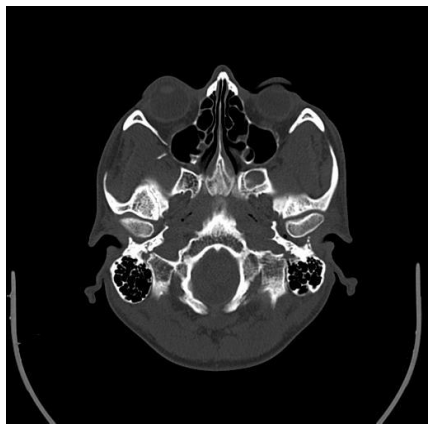
AIM

To evaluate foramen magnum area in males and females for morphological differences using 3D computed tomography among Maharashtrian population.

RADIOGRAPHIC APPEARANCE

The foramen magnum is located in the posterior cranial fossa's most inferior region. [25] The medulla oblongata and other essential structures pass through it. The basion is the anterior margin and the opisthion is the posterior margin in the midline. [23-25]

With the help of advanced modalities such as computed tomography (CT) and Magnetic Resonance Imaging (MRI) it is possible to get thin section, 3D volume rendering of the area of interest.



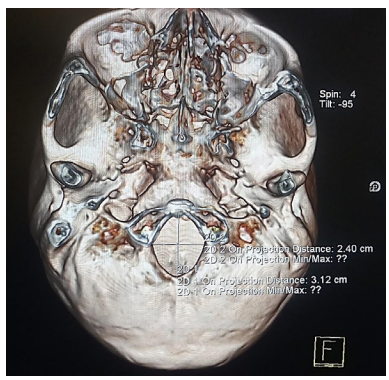
METHODOLOGY AND STUDY DESIGN

CT scan was performed in total 40 patients in which 20 male and 20 females, using SIEMENS SOMATOM 16 SLICE machine in patients referred to Acharya Vinoba Bhave Rural Hospital for CT head scan with 3D skull, patient was positioned for the head scan. Scan include the vertex to C3 area of the head, received images then reconstructed into 3D images. From the 3D images the foramen magnum was measured in two separate groups of males and females, both groups with 20 participants and a total 40 patients.

The measurement parameters are,

a. anterior-posterior
b. transverse diameter and
c. surface area calculated by below formula

Teixeira's and Radinsky's formula was used.



1. Teixeira's [12] formula: A = π x {(APL+TD)/4} ²

   Were,

   A = Area

   π = 3.14

   APL = Antero-posterior length

   TD = Transverse distance

2. Radinsky's [13] formula: A = ¼ x π x TD x APL

   Were,

   A = Area
   π = 3.14
   TD = Transverse distance
   APL = Antero-posterior length

Inclusion criteria

- Patients referred to radio-diagnosis department for CT HEAD scan
- Patients aged between 21-80 years

Exclusion criteria

- Patient with history of head Trauma affecting region of interest
- Patients with history of any mass/space occupying lesion involving the mastoid air cells.

OBSERVATIONS

The age of the participants in the present study ranged from 21-80 years with a mean age of 46.82 ± 14.27 years (Table-1)and with equal numbers of males (n=20) and females (n=20) (Table 1).

The mean of the antero-posterior (AP) length of the foramen magnum was measured 3.30 cm (33 mm approx.) whereas the mean of the transverse (TR) width was measured 2.76 (27.6 mm approx.).

The gender wise comparison shows that the mean value of antero-posterior (AP) length in males was measured 3.36 cm (33.6 mm approx.) in males and 3.25 cm (32.5 mm approx.) in females whereas the mean value of transverse width in males was measured 2.89 cm (28.9 mm approx.) in males and 2.63 cm (26.3 mm approx.) in females.

Using the derived values, the area of the foramen magnum was calculated with two different methods Teixeira and Radinsky.

Mean area calculated by Teixeira in males was 7.74 cm and in females it was 6.83 cm. whereas mean area calculated by Radinsky in males was 7.68 cm and in females it was 6.74 cm. Correlation was performed using Pearson's Correlation and p value of 0.0001 achieved (Table-2)

RESULTS

70% of original group cases were correctly classified using the derived data.

DISCUSSION

Identification in forensic science or gender determination is not always easy and most complicated especially when the skeleton is not in full form or the skeletal fragmentation or from the decomposing human skeleton remains.

Table – 1

Age Group(yrs)	No of patients	Percentage
21-30 yrs	8	20
31-40 yrs	6	15
41-50 yrs	10	25
51-60 yrs	12	30
>60 yrs	4	10
Total	40	100
Mean±SD	46.82 ± 14.27 (22-78 years)	

Table – 2

Method	Mean	Std. Deviation	N	Correlation 'r'	p-value
Teixeira	7.28	1.09	40	0.999	0.0001,S
Radinsky	7.21	1.08	40		

This type of study helps to evaluate the accuracy and reliability of the foramen magnum (FM) in gender estimation or identification. [14]

Based on Uthaman et al [14] study results, they find that, 1.8% or higher accuracy rate of FM in females, while in males was lower than the present study by 12.2%.[14] Uysal et al[8] also in their study finds the mean values of FM diameters statistically different in each sex (p , 0.001), with a sex determination accuracy rate of 81%.[8]

FM measurement helps in forensic studies to find morphological differences in individual identification and CT reconstruction technique is perfect tool to measure FM dimensions in living individuals and to find any morphological differences.[15]

In this study FM was evaluated based on some previous studies that suggest, there is significant morphological difference of FM dimensions in male and female, which may prove useful and efficient for prediction of sex in forensic identification from skeletal remains.[15]

Comparable studies have also been performed in India, one by by RP Singh[16] and one by S. Sukumar[6] using mastoid triangle formed by asterion, porion and mastoidale for sex determination and other by mastoid process.

Uysal stated in his research that using imaging modalities such as CT scans on living persons and by measuring the dimensions of Foramen Magnum, able to prove that it is larger in males compare to the females.[8]

Mayuri Jaitley[17] and Heba I.Lashin[20] also used computed tomography as a tool in their respective studies.

The results from the present study have also suggested the morphological difference in foramen magnum between males and females with 70 percent accuracy.

CONCLUSION

Based on the derived results it can be concluded that foramen magnum can be used in forensic science as a gender determination tool in the case where other identifying methods are inconclusive and the technological advancement in the medical imaging field such as multidetector computed tomography can be used as an accurate method.

CONFLICT OF INTEREST: Nil

SOURCE OF FUNDING: Self

ETHICAL CLEARANCE

Ethical clearance taken from Institutional Ethical Committee of Datta Meghe Institute of Medical Sciences (Deemed to be University), Sawangi, Wardha, Maharashtra-442004.

REFERENCES

1. Sukumar S, Yadav S, Vipinkumar G. Sex Determination by Mastoid Process in South Indian Population by 3d Computer Tomography Imaging. International Journal of Pharmacy and Biological Sciences. 2012;2(4):193-5.
2. Singh PK, Tamrakar D, Karki S, Menezes RG. Determinaton of sex from the foramen magnum using 3DCT a nepalese study. Kathmandu University Medical Journal. 2017;15(57):61-5.
3. Williams BA, Rogers TL. Evaluating the accuracy and precision of cranial morphological traits for sex determination. Journal of forensic sciences. 2006 Jul;51(4):729-35.
4. Allam FA, Allam MF. Sex discrimination of mastoid process by anthropometric measurements using multidetector computed tomography in Egyptian adult population. Egyptian Journal of Forensic Sciences. 2016 Dec 1;6(4):361-9.
5. Aghakhani K, Kazemzadeh N, Ghafurian F, Soltani B, Soltani S. Gender determination using diagnostic values of foramen magnum. Int J Med Toxicol Forensic Med. 2016 Jan 1;6(1):29-35.
6. Sukumar S, Yadav S, Manju HB. 3D Reconstruction Computer Tomography of foramen magnum and fronto nasal junction for sex determination in south Indian population. Int J Pharm Bio Sci. 2012 Oct 1;3(4):615-9.
7. Gargi V, Prakash SR, Malik S, Nagaraju K, Goel S, Gupta S. Sexual dimorphism of foramen magnum between two different groups of Indian population: A cross-sectional cone-beam computed tomography study. Journal of Forensic Science and Medicine. 2018 Jul 1;4(3):150
8. Uysal SE, Gokharman D, Kacar M, Tuncbilek I, Kosar U. Estimation of sex by 3D CT measurements

of the foramen magnum. Journal of Forensic Science. 2005 Sep 7;50(6):JFS2005058-5.

9. Mohite, D. P., M. S. Chaudhary, P. M. Mohite, and S. P. Patil. "Age Assessment from Mandible: Comparison of Radiographic and Histologic Methods." ROMANIAN JOURNAL OF MORPHOLOGY AND EMBRYOLOGY 52, no. 2 (2011): 659–68.
10. Kale, Prajakta, Sunita Shrivastav, Ranjit H. Kamble, and Narendra Sharma. "Variation in the morphology of atlas vertebrae in different skeletal patterns: a three - dimensional computed tomography evaluation." journal of evolution of medical and dental sciences-JEMDS 4, no. 17 (February 26, 2015): 2948-55.
11. Gupta PP, Dhok AM, Shaikh ST, Patil AS, Gupta D, Jagdhane NN. Computed tomography evaluation of craniovertebral junction in asymptomatic central rural Indian population. Journal of Neurosciences in Rural Practice. 2020 Jul;11(3):442.
12. Teixeira WR. Sex identification utilizing the size of the foramen magnum. The American journal of forensic medicine and pathology. 1982 Sep;3(3):203-6.
13. Radinsky L. Relative brain size: a new measure. Science. 1967 Feb 17;155(3764):836-8.
14. Uthman AT, Al-Rawi NH, Al-Timimi JF. Evaluation of foramen magnum in gender determination using helical CT scanning. Dentomaxillofacial Radiology. 2012 Mar;41(3):197-202
15. Saleh SM, Allam WA, Mahmoud H. sex determination by measuring length and breadth of foramen magnum at computed tomographic images of skull. The Egyptian Journal of Forensic Sciences and Applied Toxicology. 2019 Sep 1;19(3):93-101.
16. Singh RP, Verma SK, Tyagi AK. Determination of sex by measurement of area of Mastoid triangle in human skull. Indian Internet Journal of Forensic Medicine & Toxicology. 2008;6(2):29-43.
17. Jaitley M, Phulambrikar T, Kode M, Gupta A, Singh SK. Foramen magnum as a tool for sexual dimorphism: A cone beam computed tomography study. Indian Journal of Dental Research. 2016 Sep 1;27(5):458.
18. Lashin HI, Eldeeb BS, Ghonem MM. Sex identification from foramen magnum using computed tomography scanning in a sample of Egyptian population. Journal of Forensic Radiology and Imaging. 2019 Dec 1;19:100341.
19. Manoel C, Prado FB, Caria PH, Groppo FC. Morphometric analysis of the foramen magnum in human skulls of Brazilian individuals: its relation to gender. Journal of Morphological Sciences. 2017 Jan 16;26(2):0-.60
20. More C, Saha N, 20Vijayvargiya R. Morphological analysis of foramen magnum for gender determination by using computed tomography.
21. Principles of Anatomy and Physiology 13th ed - G. Tortora, B. Derrickson (Wiley, 2012) BBS
22. Essentials of Anatomy and Physiology 5th ed – V. Scanlon, T. Scanders (2007 by F. A. Davis.)
23. AVCI, Emel, et al. Anatomical variations of the foramen magnum, occipital condyle and jugular tubercle. *Turkish neurosurgery*, 2011, 21.2: 181-190.
24. BOULTON, Melfort R.; CUSIMANO, Michael D. Foramen magnum meningiomas: concepts, classifications, and nuances. *Neurosurgical focus*, 2003, 14.6: 1-8.
25. Drake. Gray's Basic Anatomy: with STUDENT CONSULT Online Access, 1e (Grays Anatomy for Students). Churchill Livingstone. ISBN:1455710784.