Gender Determination Using Diagnostic Values of Foramen Magnum

Aghakhani K[1], Kazemzadeh N[1], Ghafurian F[1], Soltani B[2], Soltani S[1*]

[1] Department of Forensic Medicine, Iran University of Medical Sciences, Tehran, Iran
[2] Department of Pediatrics, Kashan University of Medical Sciences, Kashan, Iran

A R T I C L E I N F O

Article Type:
Original Article

Article History:
Received: 21 July 2015
Revised: 29 July 2015
Accepted: 13 Aug 2015

Keywords:
Foramen Magnum
Sexual Dimorphism
Morphometry

A B S T R A C T

Background: Foramen magnum is a big hole in the base of the skull. Its appearance can be useful in gender determination. So far, no study has been conducted in Iran that evaluates the value of foramen magnum in sex determination and calculates the cut-off points. This study aimed to evaluating of diagnostic value of the foramen magnum and to calculate the cut-off points for sex determination.

Methods: In this cross sectional study 50 male and 50 female patients referring to the radiology department of Rasol Akram Hospital in Tehran were evaluated. The required information about the sagittal diameter, transverse diameter, and diameter of foramen magnum were assessed by brain CT scan. Chi-square and independent t test was used for the comparison of different shapes and diameters between the sexes. ROC curve was used to determine the optimal cut-off point for each indicator.

Results: The best cut-off point to distinguish males from females along the anterior-posterior foramen magnum was calculated as 36.45 mm, at the transverse diameter of 30.4 mm. The proper cut-off points for the area of the foramen magnum were 877.477 mm^2 and 870.29 mm^2, based on the Teixeria formula and Routal formula respectively. Overall, the accuracy of these indicators was calculated as 85%.

Conclusion: Based on the results of this study using CT scans images, the diameter of the foramen magnum and its area had a high accuracy in sex determination.

►*Implication for health policy/practice/research/medical education:* Gender Determination Using Diagnostic Values of Foramen Magnum

► *Please cite this paper as:* Kazemzadeh N, Aghakhani K, Soltani S, Ghafurian F, Soltani B. *Gender Determination Using Diagnostic Values of Foramen Magnum. International Journal of Medical Toxicology and Forensic Medicine*. 2016; 6(1): 29-35.

1. Introduction:

It is obvious that identification is a subject of interest and is quite important. This could be explained by the following reasons; moral and humanitarian considerations, to announce the definite death of an individual, and to fulfill legal and official requirements for identity registration. Sex determination can be influenced by race and related differences in the bone structure and shape (1). After determining the general characteristics including race, sex, height,

Corresponding author: Soltani S, MD. Assistant Professor, Department of Forensic Medicine, Iran University of Medical Sciences, Tehran, Iran
E-mail: siamaksoltani92@yahoo.com

and age, it is needed to investigate and examine every bone from different aspects. From a statistical point of view, sex identification is important as it helps to achieve fast organization of the population in the process of identification (2).

When dealing with unidentified bodies, because of corruption of the corpse or when only skeletal parts of the body remain, it is not possible to recognize and identify the identity of the dead person, not even through DNA test. Various events have caused the loss of corpse and usually only a part of the body remains which makes it more difficult to identify the dead body (2, 3). One of the crucial features in determining the identity of a dead person is differences in the bone structure. On the other hand, areas such as air sinuses and foramen magnum in the skull are among the most resistant body elements which can resist hazards like fires, explosions, and other accidents. Therefore, skull is one of the most common bones to determine the sex of the dead bodies. In addition to pelvic, cranial bone can provide the most accurate information about sexuality (4, 5).

Foramen magnum is a big hole in the base of the skull through which the spinal cord merges with the brain. There are some differences in the characteristics of the skull bones and foramen magnum between men and women (6). It appears that foramen magnum can be helpful in determining the sex; however, the related features may vary in different ethnic groups (7-9). One of the advantages of foramen magnum is that after puberty, the diameter of the foramen magnum does not change and it is not affected by age (10).

Accuracy of sex determination depends on the type of bone and the community under study. Hence, in localizing the science of forensic medicine, conducting studies on these subjects can be very useful. Using local information in each community provide us with more accurate results. Yet, no study has been conducted in Iran that can evaluate the value of foramen magnum in sex determination and calculate the cut-off points. This study aimed at evaluating the diagnostic value of foramen magnum and calculates the cut-off points for sex determination.

2. Materials and Methods:

Study Design

This cross sectional study was conducted in the radiology department, Rasol Akram Hospital in Tehran.

Study Population

During the study, dimensions of the foramen magnum were evaluated using the brain CT images. The used images were collected from the ones which had been recommended by the physicians for different diagnostic purposes. The patient's names and other details remained confidential. During the study the data were assessed using coding system. Exclusion criteria were; trauma to the skull base, being a foreigner, and being under 18 years of age.

A total of 100 Images (50 were male and 50 were female) were selected through convenience sampling method from the latest CT scans of the skull. CT scans were obtained using a CT scan machine, type Helical CT (Siemens Somatom Emotion 16-slice with 4/8 mm thickness) (Germany), with the PACS system.

Tools and Measurements

At the next step, the required information about sex, sagittal diameter, transverse diameter and diameter of foramen magnum were assessed by Ruler Syngo software. Sagittal diameter was considered as the maximum distance between the anterior and posterior ends of the wall of the foramen magnum and transverse diameter was considered as the maximum width diameter of the inner wall of the foramen magnum (Figure 1).

Foramen Magnum Index = Sagittal diameter + Transverse diameter / 100

The following formulas were used to calculate the area of the foramen magnum:

Teixeira's Formula (12):

FM Area=π [(Sagittal diameter + Transverse diameter) / 4]^2

Ritual's Formula (13):

FM Area=Sagittal diameter × Transverse diameter × π/4

Two independent investigators were evaluated the CTs for equal interpretation

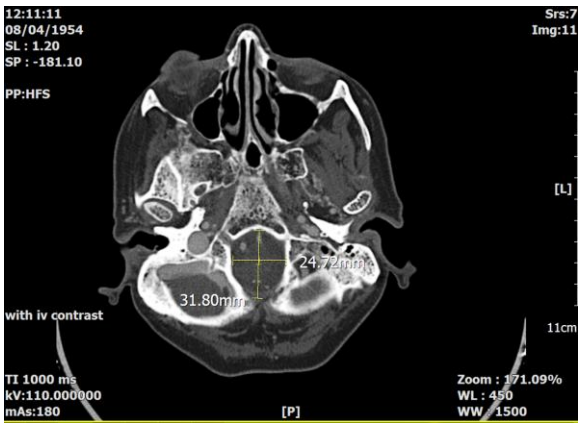

Fig. 1. CT scan of the foramen magnum. The lines indicate sagittal and transverse diameters.

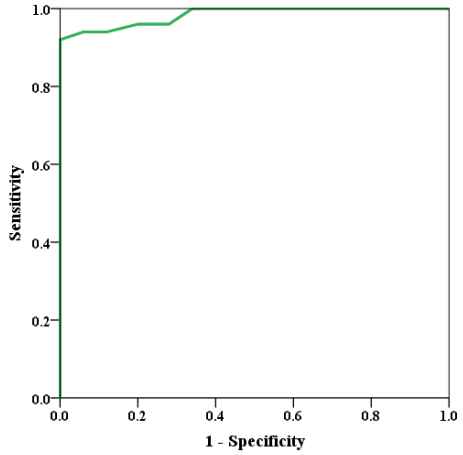

Fig. 2. ROC curve for male sex determination based on the indices of sagittal diameter, transverse diameter, and the area of foramen magnum, calculated by Routal and Teixeria formula; this chart shows that the mentioned indices had a proper diagnostic value, and the area under the curve was calculated as 0.984.

and we used the mean measurement of the 2 evaluations. To determine the shape of foramen magnum, we used the ideas of the research team members as well as Chethan *et al* (11).

Statistical Analysis

For data analysis, SPSS 19 software was used. The chi-square test was used to compare different forms of foramen magnum between both sexes, and independent t test was used for the comparison of different diameters between both sexes. ROC curve was used to determine the optimal cutoff point for each indicator. Then sensitivity and specificity at the cut-off point were calculated.

3. Results:

For all the population, the mean sagittal diameter (anterior-posterior diameter) of foramen magnum was 35.047 mm (±2.059). Transverse diameter (width diameter) was 30.012 mm (±2.151). The area calculated by Teixeira formula was 860.317 mm^2 (± 109). The area calculated by Routal formula was

Table 1: Comparison of the frequency of different shapes of Foramen Magnum in male and female cases

Shapes of Foramen Magnum	**Male** **Frequency (%)**	**Female** **Frequency (%)**	**Total**
Round shape	4 (8%)	4 (8%)	8 (8%)
Tetragonal shape	4 (8%)	2 (4%)	6 (6%)
Oval shape	19 (38%)	16 (32%)	35 (35%)
Irregular shape	5 (10%)	10 (20%)	15 (15%)
Hexagonal shape	13 (26%)	10 (20%)	23 (23%)
Pentagonal shape	5 (10%)	8 (16%)	13 (13%)

There is no statistically significant difference between males and females in terms of the shapes of Foramen Magnum using Chi square test (P=0.597).

Table 2: Comparison of mean and standard deviation of studied indices in two sexes

Index	Sex	Mean	Standard Deviation	P-Value
Sagittal Diameter	Female	34.376	1.468	< 0.001
	Male	37.718	1.007	
Transverse Diameter	Female	28.342	1.432	< 0.001
	Male	31.682	1.267	
Teixeria_Formula	Female	773.969	70.393	< 0.001
	Male	946.665	61.941	
Routal_Formula	Female	766.817	70.305	< 0.001
	Male	939.476	62.489	
FM_Index	Female	82.419	0.736	< 0.001
	Male	83.972	1.324	

Table 3: Calculation of cut off point, area under the curve, sensitivity, and specificity of studied indices to discriminate males from females

Index	Cut-Off point	Area Under Curve	Sensitivity	Specificity	Accuracy	P-Value
Sagittal Diameter	36.45	0.984	92%	100	96%	< 0.001
Transverse Diameter	30.4	0.984	92%	100	96%	< 0.001
Teixeria Formula	877.477	0.984	92%	100	96%	< 0.001
Routal Formula	870.29	0.984	92%	100	96%	< 0.001
FM Index	83.1	0.970	96%	86%	85%	< 0.001

For example, the table shows that Foramen magnum with a sagittal diameter equal to or larger than 36.45 should belong to a man (specificity 100%), however, the sensitivity of this cut off point is not equal to 100%, i.e. the sagittal diameter of foramen magnum may be less than the mentioned value in 8% of men.

853.147 mm^2 (±109.12), and FM Index was 83.196 (±1.321). The shape of the foramen magnum in 35 subjects (35%) was oval shaped, and it was Hexagonal shape in 23 patients (23%) (Table 1).

As shown in the Table 2, mean sagittal diameter in men and women was 37.718 mm (±1.007) and 34.376 mm (±1.468), respectively. The difference was statistically significant (P<0.001). In addition, the transverse diameter and the area of the foramen magnum was larger in men than in women (P<0.001).

The proper cut-off point to distinguish males from females along the anterior-posterior foramen magnum was calculated as 36.45

mm, at the transverse diameter of 30.4 mm. The proper cut-off point for the area of the foramen magnum was calculated as 877.477 mm^2 based on the Teixeira formula and as 870.29 mm^2, based on the Routal formula. In all of these indicators, specificity and sensitivity were equal to 100% and 92%, respectively. Based on these indicators, all individuals with an equal size or more of the listed values were men. However, 8% of the men population may mistakenly be determined as women. Overall, the accuracy of the indicators was calculated as 96% (Figure 2).

In the case of FM index, the obtained sensitivity was higher than other indices. However, its specificity was lower (i.e. for values of 83.1 or higher). Only 4% of men were not correctly determined; however, 14% of women were mistakenly determined as men with the same values. Overall, the accuracy of these indicators was calculated as 85% (Table 3).

4. Discussion:

Based on the results of this study, the most common forms of foramen magnum are Oval and Hexagonal shapes. The parameters associated with the foramen magnum such as the sagittal diameter, transverse diameter, and its area had a high sensitivity and specificity for the determination of sex, their accuracy was about 96%; however, the FM index had less specificity and accuracy.

Sex determination in missing or damaged skeletal remains is a major problem in forensic medicine. Therefore anthropo-morphic measurements can help us in solving this problem. Since the foramen magnum has a regular structure and is located in an area that is less prone to injury, it can be used as a helpful tool for sex determination. Nevertheless, to utilize these indicators, it is required to have local data in each country. It is also necessary to use the cut off points specific to every population in each country. As a result, performing such studies is of great value.

In our study, the distribution of different shapes of foramen magnum showed no significant statistical differences in two sexes and it seems that the shape does not make any problem for sex determination (12). Various studies suggest different shapes of foramen magnum, however the most common shapes are oval, hexagonal, and round shapes and the differences can be attributed to ethnicity (11, 13).

In our study, the mean sagittal diameter was 37.718 mm in men and 34.376 mm in women. The index shows some varieties in different studies. Sagittal diameter varies from 35.70 mm to 37.90 mm in men and from 31.72 mm to 35.10 mm in women. According to some reports, the diameter is larger in men than women (4, 8, 11-19).

The transverse diameter was 28.342 mm in women and 31.682 mm in men. In other studies, the mean transverse diameter was reported differently from 29.5 mm to 31.6 mm in men and from 27.1 to 29.4 in women; the reported diameters are larger in men than in women (4, 8, 9, 11-19). Foramen magnum area has been calculated 931.7 to 862.41 mm^2 in men and 765.29 to 819.01 mm^2 in women (13, 14, 16-20). In our study, various diameters were relatively larger than those found in other studies and it is likely that the foramen magnum in Iranian community would be larger than other ethnic groups. It seems that different ethnic groups have differences in the dimensions of the foramen magnum. Hence, it is not possible to set a specific cut-off point for all human beings. Another reason for these differences could be due to the method of measurement (via CT scan or direct measurement of the skull). After puberty, age does not affect the size of the foramen magnum. Therefore, differences in the results of various studies could not be due to the age of the samples and there is no need to consider age while determining sex based on the dimensions of the foramen magnum (21). In addition, this could be an advantage in using the foramen magnum.

The accuracy of foramen magnum diameters to determine sex shows inconsistent results in other studies and diagnostic value has not been discussed in most of the studies (8, 13, 22). In our study, all dimensions and parameters had a proper level of accuracy in sex determination. In a study by Jain et al. (15), the accuracy of sagittal diameter,

transverse diameter, and foramen magnum area varied between 57% to 70%. In Galdames *et al*'s study (23), the accuracy of sex determination was reported to be 66.5%. According to another study, the accuracy of the foramen magnum was also calculated to be around 70% (8). In Gapert *et al*'s study (14), sex of 76% of men and 70% of women (overall 68%) were correctly determined using the foramen magnum diameters. In another study, all diameters were larger in men than in women. However, results of the measurements of sagittal diameter, transverse diameter, and foramen magnum area showed the approximate sex of 86.5%, 65.4%, and 82.2% of the cases respectively (19).

However, some other studies have showed that these dimensions can be helpful in determining sex. In a study in India, the best cut off points for sex determination in sagittal diameter, transverse diameter, and foramen magnum area were 34.01 mm, 30.62 mm and 820 mm^2, respectively. In their study, sagittal diameter was successfully used to determine 95.9% of the men and 82.1% of the women correctly. However, using the transverse diameter, the correct percentage of men and women were determined as 88.4% and 89.3%, respectively. The area of the foramen magnum had an accuracy of above 90% for both sexes (24). In Holland *et al*'s study (25), the accuracy of sex determination using the foramen magnum diameters was estimated between 70% and 85%. Moreover, in Uthman *et al*'s study (7), using the diameters and the area of the foramen magnum, 73.3% of the women and 90.7% of the men were classified correctly, and the overall accuracy was calculated as 81%. Yet, usage of no solitary diameters showed a high diagnostic value. Overall, the related studies were not consistent and conducting further studies with larger sample sizes among different ethnicities is recommended. One of the limitations of our study was the small sample size. Despite that, this study was a perfect base for further studies to be conducted on the Iranian population. Therefore, morphometric characteristics of the skull base and comparing the results with the morphometric characteristics of the foramen magnum is recommended.

5. Conclusion:

Based on the results of this study using CT scan images, the diameter of the foramen magnum and its area showed a high precision in sex determination. Therefore, it could be used as a valuable tool in calculating the study sample size.

6. Acknowledgements:

This article is extracted from the thesis of Dr. Farzad Ghafurian, assistant in the Legal Medicine Organization. The thesis was approved by Tehran University of Medical Sciences. We thank all participants and personnel who helped us to conduct this study.

7. References:

1. Robling AG, Ubelaker DH. Sex estimation from the metatarsals. J Forensic Sci. 1997;42(6):1062-9.
2. Luo L, Wang M, Tian Y, Duan F, Wu Z, Zhou M, et al. Automatic sex determination of skulls based on a statistical shape model. Computational and mathematical methods in medicine. 2013:251628.
3. Kranioti E, Paine R. Forensic anthropology in Europe: an assessment of current status and application. J Anthropol Sci. 2011;89:71-92.
4. Shanthi CH, Lokanadham S. Morphometric Study on Foramen Magnum of Human Skulls. Medicine Science. 2013;2(4):792-8.
5. 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 e1-9.
6. Zaidi SH, Dayal SS. Variations in the shape of foramen magnum in Indian skulls. Anat Anz. 1988;167(4):338-40.
7. Uthman AT, Al-Rawi NH, Al-Timimi JF. Evaluation of foramen magnum in gender determination using helical CT scanning. Dentomaxillofac Radiol. 2012;41(3):197-202.
8. 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(2):104-8.
9. Tubbs RS, Griessenauer CJ, Loukas M, Shoja MM, Cohen-Gadol AA. Morphometric analysis

of the foramen magnum: an anatomic study. Neurosurgery. 2010;66(2):385-8; discussion 8.
10.Gruber P, Henneberg M, Boni T, Ruhli FJ. Variability of human foramen magnum size. Anat Rec (Hoboken). 2009;292(11):1713-9.
11.Chethan P, Prakash KG, Murlimanju BV, Prashanth KU, Prabhu LV, Saralaya VV, et al. Morphological analysis and morphometry of the foramen magnum: an anatomical investigation. Turk Neurosurg. 2012;22(4):416-9.
12.Burdan F, Szumilo J, Walocha J, Klepacz L, Madej B, Dworzanski W, et al. Morphology of the foramen magnum in young Eastern European adults. Folia Morphol (Warsz). 2012;71(4):205-16.
13.Murshed KA, Çiçekçibasi AE, Tuncer I. Morphometric Evaluation of the Foramen Magnum and Variations in its Shape: A Study on Computerized Tomographic Images of Normal Adults. Turkish Journal of Medical Sciences. 2003;33(1):301-6.
14.Gapert R, Black S, Last J. Sex determination from the foramen magnum: discriminant function analysis in an eighteenth and nineteenth century British sample. Int J Legal Med. 2009;123(1):25-33.
15.Jain D, Jasuja OP. Evaluation of foramen magnum in sex determination from human cranial by using discriminate function analysis. El Mednifico Journal. 2014;2(2):89-92.
16.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(6):1310-4.
17.Sendemir E, Savci G, Cimen A. Evaluation of the foramen magnum dimensions. Kaibogaku Zasshi. 1994;69(1):50-2.
18.Burdan F, Umlawska W, Dworzanski W, Klepacz R, Szumilo J, Staroslawska E, et al. Anatomical variances and dimensions of the superior orbital fissure and foramen ovale in adults. Folia Morphol (Warsz). 2011;70(4):263-71.
19.Raghavendra Babu YP, Kanchan T, Attiku Y, Dixit PN, Kotian MS. Sex estimation from foramen magnum dimensions in an Indian population. J Forensic Leg Med. 2012;19(3):162-7.
20.Gunay Y, Altinkok M. The value of the size of foramen magnum in sex determination. J Clin Forensic Med. 2000;7(3):147-9.
21.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.
22.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.
23.Galdames ICS, Russo PP, Matamala DAZ, Smith RL. Sexual Dimorphism in the Foramen Magnum Dimensions. Int J Morphol. 2009;27(1):21-3.
24.Raghavendra Babu YP, Manjunath S, Prateek R, Kumar Mohan TS, Janardhan BV, Yoganarasimha K, et al. Determination of Sex by Foramen Magnum Morphometry in South Indian Population. Indian Journal of Forensic Medicine and Pathology. 2011;4(1):29-33.
25.Holland TD. Sex determination of fragmentary crania by analysis of the cranial base. Am J Phys Anthropol. 1986;70(2):203-8.