

Sex identification from foramen magnum using computed tomography scanning in a sample of Peshawar population

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Submitted

June 23, 2022

Accepted

December 07, 2022

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Citation: Ullah I, Khurshid H, Aziz I, Bangash NN. Sex identification from foramen magnum using computed tomography scanning in a sample of Peshawar population. J Rehman Med Inst. 2023 Jan-Mar;9(1):8-10.

ABSTRACT

Introduction: Forensic identification of dead bodies is hampered by mutilated remains due to fires, crash accidents, explosions, decay inducing conditions, and other reasons that do not permit proper or complete examination. Among many other modalities undertaken to overcome this issue, one that can be used is the radiographic examination of the foramen magnum at the base of the skull to determine the biological sex of victims.

Objective: To identify the biologic sex of an individual from foramen magnum (FM) on computed tomography (CT).

Materials & Methods: This retrospective study was conducted at Combined Military Hospital (CMH) Peshawar from July 1, 2021, to October 30, 2021, on 150 Computerized Tomography (CT) scans of patients. The inclusion criteria were age ranging from 18 to 70 years, both sexes, Pakistani nationals, and CT images of high quality. CT scans that were of low quality, having artefacts due to metallic objects, and pathological lesion in skull base region were excluded. Length and width was measured from these scans. The area of foramen magnum was calculated by using the standardized formula of Routal et al. The Student's T test was used to compare the dimension of FM between males and females; a $p \leq 0.05$ denoted significance.

Results: The mean age was 40.24 ± 14.89 years. The males were more ($n=78, 52\%$) than females ($n=72, 48\%$). The mean length of FM in males was 37.52 ± 3.89 mm and in females was 33.71 ± 3.94 mm ($p < 0.001$). The mean width of FM in males was 32.23 ± 4.81 mm and 30.87 ± 4.80 mm in females ($p = 0.084$). Similarly the mean area of FM in males (948.52 ± 165.99 mm²) was significantly higher than the mean area (815.76 ± 151.52 mm²) of females ($p < 0.001$).

Conclusion: Sexual dimorphism exists in dimension of FM. The mean length, width and area of FM are higher in males than females. We established mean values for dimension of FM for both sexes which can be helpful in sex identification.

Keywords: Sex determination, foramen magnum, sex identification, forensic medicine

The authors declared no conflict of interest. All authors contributed substantially to the planning of research, data collection, data analysis, and write-up of the article, and agreed to be accountable for all aspects of the work.

INTRODUCTION

In the discipline of forensic medicine it is of paramount important to make a positive identity for a person.¹ The identification of an individual is much complicated in case of mutilated dead body affected by fires, high speed crashes, bomb explosions or decayed skeletal remains. The determination of sex in anonymous dead body is not easy job and cannot be properly performed.² The identification of sex can play an important role in the recognition of human remains and it in turn help in detailed identification of a person by 50%.³

Sex can be recognized by using whole skeleton with 100% accuracy.⁴ But in most forensic cases the whole skeleton cannot be available so the next diagnostic tool for sex determination is the use of skull and pelvic bone.⁵ Pelvic bone is helpful in sex recognition in up to 95% cases while skull in up to 90% individuals.⁶ When the skull and pelvic bone is used in combination it can give sex determination with 98% accuracy.⁷

At the base of human skull the foramen magnum (FM) is a good landmark from forensic point of view.⁸ The measurement of various dimension of FM (length, width, and area) can be helpful in sex determination. The traditional way to measure its dimensions are calipers and paper strips.⁹ Radiography especially three dimensional can give perfect results for dimensions of FM.¹⁰

Many studies were reported on FM to determine sex. An Egyptian study reported that FM is valid indicator for sex determination.¹¹ Another study conducted in Iraq also reported that FM can be reliably used for sex identification.¹² A study conducted on Indian population found that statistically significant differences existed in size of foramen magnum between males and females.⁸

Sex identification is one of the important investigations in forensic medicine. Although many studies have been conducted at international levels but there is lack of research on local population. The results can variable in different populations due to genetic and ethnic reasons. This can provide statistics about the reliability of foramen magnum in sex determination in our population.

The objective of this study was to determine the role of foramen magnum in sex determination in sample of Peshawar population.

MATERIALS & METHODS

This study was conducted at Combined Military Hospital, Peshawar from 1st July 2021 to 30th October 2021 on CT scans of 150 participants available at department of radiology by non-probability consecutive sampling technique. Ethical approval was obtained from hospital ethical review committee.

The inclusion criteria were age ranging from 18 to 70 years, both sexes, Pakistani nationals on basis of NIC, and CT images of high quality. CT scans that were of low quality, having artifact due to metallic objects, and pathological lesion in skull base region were excluded.

Participant’s age and sex was recorded from record saved in software. All CT scans were acquired by Toshiba 160 (MDCT Japan inc.) with variable field of view having slice thickness of 0.5 to 10mm, 30 ms x-ray pulse time, 120 KVp, 187 mA and 10 seconds exposure time. The CT images of good quality with 512 x 512 pixels were used in this study. CT scans present in DICOM format were transferred to diagonal HD Bright Viewer (Germany inc.) for measurement. Maximum Length and width of foramen magnum were measured in axial view as below.

Along the principal axis of the FM the maximum length of the foramen magnum was calibrated in sagittal direction. Perpendicular to the maximum length of FM the width of FM was measured at point where widest transverse diameter exists. These two values (maximum length and width were put in following formula by Routal et al.¹³ to calculate area of FM.

$$\text{Area} = 1/4 \times \pi \times \text{length} \times \text{width}$$

The data analysis was conducted in Stata 14. Continuous data were computed as Mean and SD while Percentages were calculated for categorical data. Dimensions of foramen magnum (length, width, area) were compared between males and females using Independent Samples T Test. A $p \leq 0.05$ was considered significant.

RESULTS

The mean age was 40.24 ± 14.89 years (range 18 to 65 years). The males were more (n=78, 52%) than females (n=72, 48%). Most common age group was 46 to 70 years (n=59, 39.33%) followed by 18 to 30 years (n=48, 32%) and least number of cases were in age group 31-45 years (n=43, 28.66%). (Figure 1).

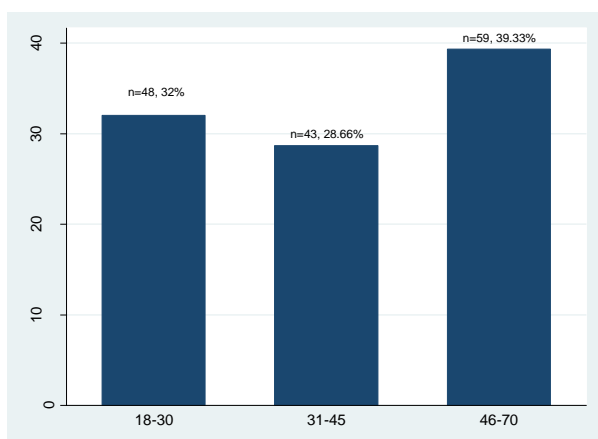


Fig 1: Age distribution of subjects in the study (n=150).

The mean maximum length of foramen magnum in overall sample was 35.69 ± 4.35 mm, maximum width of FM was 31.58 ± 4.84 mm, and area was 885.22 ± 172.15 mm². The details are given in Table 1.

Table 1: Mean length, width, and area of foramen magnum of subjects (n=150).

Variables	Mean ± SD	Range
Length (mm)	35.69 ± 4.35	26.9 - 43.1
Width (mm)	31.58 ± 4.84	23.3 - 40.7
Area (mm ²)	885.22 ± 172.15	492.25 - 1377.68

The mean length of FM in males was 37.53 ± 3.89 mm and in females was 33.71 ± 3.94 mm ($p < 0.001$). The mean width of FM in males was 32.24 ± 4.81 mm and 30.87 ± 4.80 mm in females ($p = 0.084$). Similarly, the mean area of FM in males was 948.52 ± 165.99 mm² and 815.76 ± 151.52 mm² in females ($p < 0.001$). The details are shown in Table 2.

Table 2: Comparison of the length, width, and area of foramen magnum between males and females (n=150).

Gender	Length (mm)	Width (mm)	Area (mm ²)
Males			
Mean ± SD	37.53 ± 3.89	32.24 ± 4.81	948.52 ± 165.99
95% C I	36.65 - 38.40	31.15 - 33.32	911.09 - 985.95
Females			
Mean ± SD	33.71 ± 3.94	30.87 ± 4.80	815.76 ± 151.52
95% C I	32.79 - 34.64	29.74 - 32.00	780.16 - 851.37
p value	<0.001	0.084	<0.001

DISCUSSION

This study was conducted to determine sex identification from the measurements of foramen magnum. Our results showed that statistically significant differences in the dimensions of FM exist between the sexes. The mean length, width and area were statistically larger in males than females. This shows that foramen magnum can be used to determine sex of the participants.

We used CT scans to measure the dimensions of foramen magnum. CT is three dimensional radiograph containing three views (sagittal, coronal and axial) and can show real measurements without magnification issue.¹⁴ This diagnostic radiography has in built measuring gauges which can give dimensions like length, area and volume. Previous studies also used CBCT and CT to determine the dimension of foramen magnum.^{6, 8} CT is also three dimensional and can give accurate picture of anatomical.¹⁵

Our findings showed that the mean area of FM was 948.52 ± 165.99 mm² in males and 815.76 ± 151.52 mm² in females. Catalina-Herrera¹⁶ found that the mean area of FM in males was 888.4 mm² and in female was 801 mm². Though the mean values of area of FM are different from our study but one thing is common that area of FM in males is larger. Another study conducted in India⁸ reported that mean area of FM in males was 877.88 ± 108.78 mm² and in females was 791.24 ± 106.135 mm². These results are closer to our study.

Our findings showed that the dimensions of FM were higher in males than females. Previous literature showed different results.

An Iranian study by Aghakhani et al.¹⁷ showed that statistically significant difference exist in dimension of foramen magnum being larger in males. Madadin et al.¹⁸ in Saudi Arabian study also found larger dimension of FM in males than females. These results are similar to our study. On the other hand, two Indian studies by Kazi et al.¹⁹ and Samara et al.²⁰ reported that dimension of foramen magnum was higher in females than males. These differences showed that the size of foramen magnum can varies due to genetic and ethnic reasons.

Our findings showed that differences for dimensions of length and area of Foramen Magnum are statistically different among sexes. Hence FM can be applied for sex identification. Previous studies found similar results.^{20, 21}

LIMITATION

The study was based on a small sample size and from a single center, hence the results are not generally applicable.

RECOMMENDATION

Further multicenter studies with large sample sizes are needed to better explore this area.

CONCLUSION

The dimensions of length and area of the foramen magnum can be used to determine the biologic sex of a person as the values are significantly higher in males compared to females.

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