# MORPHOLOGICAL ANALYSIS OF FORAMEN MAGNUM FOR GENDER DETERMINATION BY USING COMPUTED TOMOGRAPHY

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## ABSTRACT

**Background:** *Radiographs and advance imaging of orofacial structures are routinely used for personal identification. Ante-mortem and post-mortem radiographs are essential in cases of human remains and computed tomography plays a significant role in such situations.*
**Aim:** *To determine the gender from foramen magnum using computed tomography scan.*
**Settings and Design**: *The retrospective study was conducted by assessing the radiographic records, available in the archives of department.*
**Method and Material:** *Two hundred and fifty computed tomography (CT) scans of head and neck region were considered for morphometric analysis of foramen magnum using Syngo CT 2009E software.*
**Statistical analysis**: *The analysis was performed by using ANOVA, chi-square, independent 't' test and discriminate function analysis.*
**Results:** *The CT scan images of participants ranged from 08-79 years of age with equal number of males and females. The mean dimensions of foramen magnum in different age group was statistically not significant (p>0.05).The total mean length of foramen magnum was 35.64 ± 3.39 mm and mean width was 29.17 ± 2.89 mm. The mean dimensions of foramen magnum were higher in males and was highly significant (p<0.001). The co-relation of gender with morphology of foramen magnum was significant (p<0.05). The accuracy for diagnosing male and female from dimension was 80% and 75.2% respectively. But the accuracy for gender identification from length and width was 74% and 70% respectively.*
**Conclusion:** *Personal identification is possible from the dimensions of foramen magnum and computed tomography plays a vital role.*

**Keywords:** *Computed tomography, Forensic radiology, Foramen magnum, Gender estimation, Personal identification.*

## INTRODUCTION

Identification of unknown individual has always been of paramount importance to the society and is important in calamities, forensic anthropology, anatomy and court of law.[1] Identification plays a significant role in forensic odontology by using different parts of orofacial structures either through radiographs or from clinical and pathological examination because of its uniqueness.[2] Gender determination is extremely important as it can positively rule out certain percentage of possibilities instantly.[3] Determining sex in unidentified skeletons is not all the time an easy and correct procedure. Radiography can help in giving accurate dimensions and have multiple useful identification markers.[4,5] Foramen magnum (FM) is one such important marker for sexual dimorphism (fig. 1).[6] Ante-mortem and post-mortem radiographs are essential in cases of human remains and computed tomography (CT) scan plays a significant role in such situations.[7] The craniometric points can be located and accurate measurements are achieved from CT scan images than on conventional radiographs.[8,9] CT scan has minimal superimposition of structures and allows better visualization of minute differences of density.[9,10]

The existing literature reveals numerous studies on dry skull using foramen magnum but very few have reported using CT scan. The present study was designed to determine gender from foramen magnum through computed tomography.

## SUBJECTS AND METHODS

The present hospital based retrospective study was conducted with the permission of Institutional Ethics Committee of Sumandeep Vidyapeeth University with protocol number SVIEC/ON/DENT/RP/1504, dated 07/07/2014. The CT scan images of head and neck (axial view) of total two hundred and fifty healthy participants, available in the archives of department were included for morphometric analysis of foramen magnum. Each image was subjected for measurements, in millimetre using Syngo CT 2009E software (fig. 2& 3). The collected data was subjected to statistical analysis using SPSS software version 16 and the test applied were ANOVA, chi-square, independent 't' test & discriminant function analysis.

## RESULTS

The age of participants in the present study ranged from 08-79 years with a mean of 35.96 ± 15.02 years and with equal number of males (n=125)

and females (n=125) (Graph 1). The minimum and maximum length of foramen magnum was 18.30 mm & 44.90 mm respectively; whereas the minimum and maximum width of foramen magnum was 18.60 mm and 37.80 mm respectively. The mean length and width of foramen magnum when core lasted with different age group, the values were statistically analysed by using ANOVA test and was found to be not significant ($p > 0.05$). The total mean length of foramen magnum was $35.64 \pm 3.39$ mm and total mean width was $29.17 \pm 2.89$ mm (Table 1).

In our study, it was distinctly observed that the mean length and width of foramen magnum in males (L$= 37.54 \pm 2.57$ mm, W$= 30.57 \pm 2.42$ mm) was more when compared with females (L$= 33.75 \pm 3.04$ mm, W$= 27.78 \pm 2.65$mm). These values were statistically analysed by using independent 't' test and was found to be highly significant ($p < 0.001$) (Table 2).

The dimensions of foramen magnum when correlated with gender, the statistical analysis was highly significant ($p < 0.001$). The stepwise discriminant function analysis was performed to differentiate male and female using dimensions of foramen magnum (Table 3).

The accuracy for gender determination was obtained by using Canonical Discriminant Function for Coefficient and constant value from the dimensions of foramen magnum. The formula used was $Y = A + (B \times X)$. ['Y' signifies estimated gender, 'A' signifies canonical discriminant function coefficient value of constant, 'B' signifies canonical discriminant function coefficient value and 'X' signifies length or width of foramen magnum].

**For length**: Estimated gender $= -12.657 + (0.355 \times$ foramen magnum length)

If they obtained discriminant function value is near to 0.672, then the person is probably discriminate by male and if they obtained discriminant function value is near to - 0.672, then the person is probably discriminate by female.

**For width**: Estimated gender $= -11.502 + (0.394 \times$ foramen magnum width)

If they obtained discriminant function value is near to 0.550, then the person is probably discriminate by male and if they obtained discriminant function value is near to - 0.550, then the person is probably discriminate by female.

We could correctly diagnose 75.2 % of males and 72.8 % of females from length of foramen magnum with an overall accuracy of 74 % in diagnosing gender. Also from width, 68 % of males

and 72 % of females were correctly diagnosed; with an overall accuracy of 70 % in diagnosing gender (Table 4).
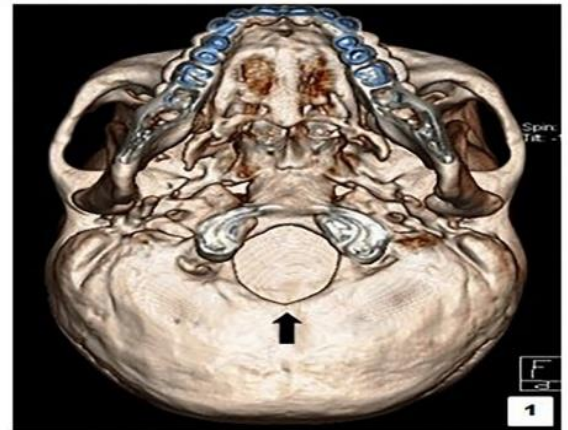


**Fig. 1: 3D reconstructed computed tomography scan - axial view shows foramen magnum (black arrow).**
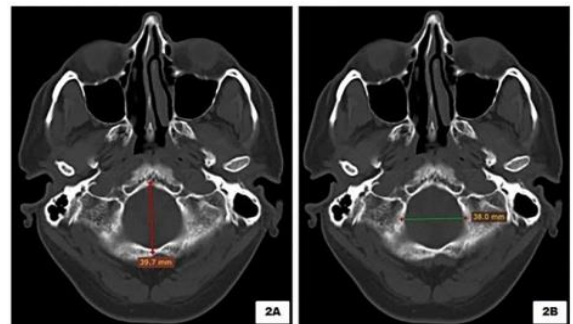


**Fig. 2: Computed tomography scan - axial view shows length (fig. 2A) and width (fig. 2B) of foramen magnum.**
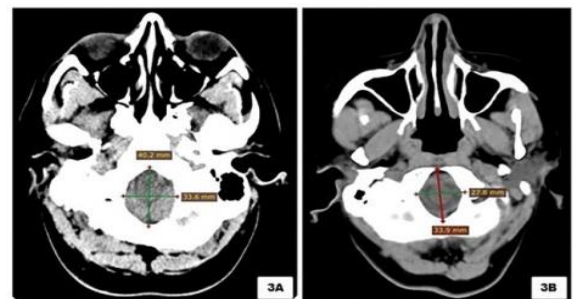


**Fig. 3: Computed tomography scan - axial view shows measurements of foramen magnum in male (fig. 3A) and female (fig. 3B) participant.**

**Table 1: Co-relation of morphological of foramen magnum with different age group**

| Parameters | Age (in Years) | n | Mean (mm) | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum (mm) | Maximum (mm) | p-value (p<0.05) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | | |
| Length | 0-9 | 2 | 36.00 | 6.93 | 4.90 | -26.2604 | 98.2604 | 31.10 | 40.90 | 0.827 Not significant |
| | 10-19 | 20 | 35.70 | 3.38 | 0.75 | 34.1231 | 37.2869 | 30.10 | 41.50 | |
| | 20-29 | 71 | 36.11 | 2.83 | 0.34 | 35.4394 | 36.7804 | 29.40 | 42.90 | |
| | 30-39 | 65 | 35.30 | 4.06 | 0.50 | 34.2973 | 36.3089 | 18.30 | 44.10 | |
| | 40-49 | 34 | 35.19 | 3.65 | 0.63 | 33.9157 | 36.4667 | 28.10 | 44.90 | |
| | 50-59 | 34 | 35.34 | 3.51 | 0.60 | 34.1122 | 36.5643 | 27.90 | 42.80 | |
| | 60-69 | 17 | 36.00 | 1.70 | 0.41 | 35.1252 | 36.8748 | 32.70 | 38.00 | |
| | >=70 | 7 | 36.57 | 2.75 | 1.04 | 34.0292 | 39.1136 | 33.30 | 40.00 | |
| | Total | 250 | 35.64 | 3.39 | 0.21 | 35.2200 | 36.0648 | 18.30 | 44.90 | |
| Width | 0-9 | 2 | 27.85 | 0.64 | 0.45 | 22.1322 | 33.5678 | 27.40 | 28.30 | 0.241 Not significant |
| | 10-19 | 20 | 29.45 | 2.86 | 0.64 | 28.1105 | 30.7895 | 24.50 | 35.10 | |
| | 20-29 | 71 | 29.93 | 2.60 | 0.31 | 29.3163 | 30.5456 | 24.30 | 35.20 | |
| | 30-39 | 65 | 28.92 | 3.37 | 0.42 | 28.0846 | 29.7554 | 18.60 | 37.80 | |
| | 40-49 | 34 | 28.71 | 3.17 | 0.54 | 27.6039 | 29.8137 | 23.70 | 35.90 | |
| | 50-59 | 34 | 28.69 | 2.50 | 0.43 | 27.8197 | 29.5685 | 23.60 | 33.70 | |
| | 60-69 | 17 | 28.45 | 2.13 | 0.52 | 27.3511 | 29.5430 | 25.10 | 31.90 | |
| | >=70 | 7 | 29.77 | 2.52 | 0.95 | 27.4362 | 32.1067 | 27.00 | 33.20 | |
| | Total | 250 | 29.17 | 2.89 | 0.18 | 28.8131 | 29.5333 | 18.60 | 37.80 | |

(n = number, mm = millimeter, Std= Standard, p= Probability value)

**Table 2:Co-relation of dimensions of foramen magnum with gender**

| Parameters | Gender | n | Mean (mm) ± Std Deviation | Std. Error mean | t | p-value (p<0.05) | Significance |
|---|---|---|---|---|---|---|---|
| Lenght | Male | 125 | 37.54± 2.57 | 0.23 | 10.632 | <0.001 | Highly Significant |
|  | Female | 125 | 33.75±3.04 | 0.27 | 10.632 | <0.001 | Highly Significant |
| Width | Male | 125 | 30.57±2.42 | 0.22 | <0.001 |  | Highly Significant |
|  | Female | 125 | 27.78±2.65 | 0.24 | <0.001 |  | Highly Significant |

(n = number, mm = millimeter, Std= Standard, p= Probability value)

**Table 3:  Stepwise discriminant function analysis using length and width of foramen magnum**

| Parameter | Wilks' Lambda | Eigen Value | Chi-square | Df | Obtained p-value | Significance (<0.05) |
|---|---|---|---|---|---|---|
| Length | 0.687 | 0.456 | 92.955 | 1 | <0.001 | Highly Significant |
| Width | 0.767 | 0.305 | 65.791 | 1 | <0.001 | Highly Significant |

(df = Degree of Freedom, p= Probability value)

**Table 4: Canonical discriminant function using length and width of foramen magnum**

| Parameter | Constant | Coefficients Value | Accuracy |
|---|---|---|---|
| Length | -12.657 | 0.355 | 74 % |
| Width | -11.502 | 0.394 | 70 % |

(% = percentage)

**Graph 1: Distribution of participants according to age group and gender**
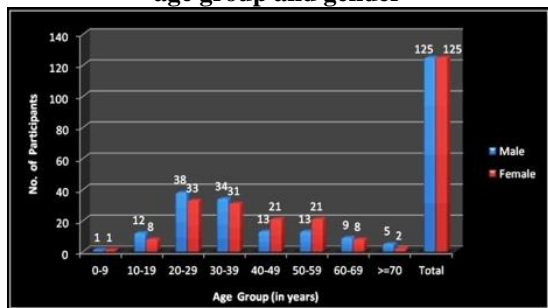


## DISCUSSION

Foramen magnum is present at the base of the skull and is of interest for anthropology, anatomy, forensic medicine, and other medical fields.[11] It is the primary centre of ossification during growth and development. The ossification is completed by the age of 3 - 4 years and the fusion by 7 years. Usually the dimensions of FM will remain constant after second decade of life and will differ in male and female. It is a three dimensional, oval or circular apertures within the basal central region of the occipital bone.[12-14] The location of FM plays a vital role in understanding of human evolution.[15,16] The thickness of the cranial base and the anatomical position of FM, prevents any damage due to physical insult and inhumation. The skull and especially the skull base, has been analyzed with differing results and the levels of achievement in forensic related work.[17-19]

The morphometric analysis of foramen magnum revealed minimum (L=18.30 mm, W= 18.60 mm) and maximum (L=44.90 mm, W=37.80 mm) length and width which was statistically not significant (p>0.05). The total mean length (35.64 $\pm$ 3.39 mm) was higher than mean width (29.17 $\pm$ 2.89 mm) of foramen magnum. Also, the co-relation of dimensions of foramen magnum with age could not be ascertained.

Our study revealed that there is significant correlation between dimension of foramen magnum and gender. The length and width in males was considerably higher as compared to females (fig. 3). This observation matched with the findings of Uthman et al.[8] Further we noted that even by discriminate function analysis test, the correlation was statistically highly significant (p<0.001). Our study had derived an equation Y = A+ (B×X) for determining the accuracy for gender and we could correctly diagnose 75.2 % of males and 72.8 % of females from length of foramen magnum with an overall accuracy of 74 % in diagnosing gender. Also from width, 68 % of males and 72 % of females were correctly diagnosed; with an overall accuracy of 70 % in diagnosing gender. Thus, from overall dimension of foramen magnum, the accuracy for diagnosing

male and female was 80% and 75.2% respectively. Our finding was contradictory with the findings of Uthman et al[8] wherein 90.7% of males and 73.3% of females were correctly diagnosed.

The results of our study indicate that foramen magnum is important in gender determination, although other oro facial structures are also helpful.

The results may vary geographically and depending on skeletal structure, arising due to genetic, environmental and nutritional factors.

## CONCLUSION

The role of foramen magnum in diagnosing unknown person is notable and should be used in day-to-day practice of forensic radiology. The findings of the present study would enhance the knowledge and would help in identifying human remains when other identifying methods are inconclusive.

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