

## Morphometric Analysis of Foramen Magnum for Gender Determination Using Helical CT Scans

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### ABSTRACT

**Aim:** The present research was undertaken to evaluate the accuracy and reliability of the foramen magnum (FM) in gender determination through the use of reconstructed helical CT images.

**Materials and Methods:** 250 patients (125 males and 125 females) with the age range of 18-75 years were selected for this study. FM sagittal diameter, transverse diameter, area and circumference were measured from the CT scan images and data were subjected to statistical analysis. Chi square test and unpaired t test was used for the comparison of the different shapes and diameters between the genders.

**Results:** Mean sagittal diameter in males was 35.68 and in females was 32.29 and the mean transverse diameter in the males was 27.92 and in females was 26.88. The mean dimensions of foramen magnum were higher in males ( $p < 0.05$ ). However, the different shapes of foramen magnum did not show any statistical significance.

**Conclusion:** It can be concluded that the reconstructed CT image can provide valuable measurements for the FM and could be used for sexing when other methods are inconclusive.

**Keywords:** Foramen Magnum, Forensic anthropology, Computed Tomography, Sex determination.

### INTRODUCTION

An important aspect of medico-legal investigations is to establish the identity of a deceased individual and to determine the biological sex of unknown skeletal remains.<sup>1</sup> Assigning sex to remains that are incomplete, fragmented or damaged as a result of incidents such as mass disasters, airplane crashes, fire, explosions or physical violence is a difficult task for the anthropologists.<sup>2</sup> The identification of sex is highly reliable if the complete skeleton is available for analysis. A 100% accuracy of sex determination was reported in 750 intact skeletons by Krogman.<sup>3</sup> Sex determination from human pelvis alone had an

accuracy rate of 90-100% making it the most preferred bone for sex determination.<sup>4</sup> Giles and Elliot have stated that "next to the pelvis, the skull is the most easily sexed portion of the skeleton".<sup>5</sup> The development of reliable sexing criteria from isolated bony elements of compromised remains is of paramount importance and therefore affects the accuracy of sex estimation.<sup>6</sup>

Owing to the robusticity of the occipital bone and the relatively protected anatomical position of the foramen magnum beneath a depth of soft tissue makes it less vulnerable to fragmentation and taphonomic processes in comparison to other cranial and facial bones. Foramen magnum is thus

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considered as an important marker of sex determination.<sup>7</sup> Radiography provides accurate dimensions and is considered a valuable aid in determining the important measurements. Computed tomography plays a significant role in determining the sex as the exact craniometric points can be located and accurate measurements can be obtained from the CT scan images.<sup>8</sup> The transverse width, sagittal width, foramen magnum circumference and foramen magnum area have been used to determine the gender in unidentifiable human remains. Many studies have been conducted on different populations for sexual dimorphism. Foramen magnum measurements have a high level of accuracy in sexual dimorphism. The present study was conducted to evaluate the accuracy of Foramen Magnum dimensions in gender determination using helical CT scans.

## MATERIALS AND METHODS

### Study Design:

The present hospital based retrospective study was conducted with the prior permission of institutional ethics committee of Raichur Institute of Medical Sciences, Raichur, Karnataka.

### Study Population:

The study comprised of CT scan images of head and neck (axial view) of two hundred and fifty healthy participants recommended by the physician for different diagnostic purpose available in the archives of the department for the morphometric analysis of foramen magnum. The study included 125 males and 125 females within age range of 18-75 years. Patients with a history of trauma to cranium, upper cervical vertebrae, surgery and pathological condition involving foramen magnum were excluded from the study. FM measurements (sagittal, transverse, circumference and area) were obtained from reformatted axial sections using helical CT scan (Phillips) with 5mm thickness, 130 kVp, 200-230 mAs, 1800 AU window levels and 35-45 s scan time. All sections selected were parallel to the plane of the FM in order to select the best image of the foramen (Figure 1).

The FM sagittal diameter (FMSD) was recorded as the greatest anteroposterior dimension of the FM i.e from the anterior border (basion)

through the center of the foramen magnum to the end of posterior border. The FM transverse diameter (FMTD) was recorded as the greatest width of the FM. The area of the foramen magnum (FMA) was initially calculated by tracing the bony rim of the feature. By positioning markers around the circumference of the foramen magnum (FMC), the enclosed area was calculated automatically as a function of the imaging software on the CT image using a 3D program on the CT workstation with a resolution of 1280×1042 full screen format and picture size of 360×288 mm.

To place the statistical findings of the study into context, a visual examination was conducted of the morphology of the foramen magnum. For the 250 individuals in the sample, the morphology of the foramen magnum was classified according to the following seven shape types as selected from previous studies; egg, oval, round, tetragonal, pentagonal, hexagonal and irregular A.<sup>9</sup>

An intra- and interexaminer calibration was done in order to determine the reliability and the reproducibility of the FM and other craniometric measurements. This calibration was carried out by 2 radiologists, who compared the greatest measurements of 10 randomly selected radiographs. Examination of the radiographic images was carried out on a poorly lit computer monitor. The data was analysed using unpaired 't' test and chi square test and was subjected to statistical analysis using the SPSS software version 20.

## RESULTS

Based on the measurements of the CT scan images, the mean sagittal diameter of foramen magnum was 35.68mm and 32.29mm and the transverse diameter was 27.92mm and 26.88mm in males and females respectively. (Table.1)

Regarding FMC, the mean values were greater in males than in females. (Males- 97.37 & Females- 92.75mm) . The foramen magnum measurements were considerably higher in males when compared to females.(Males-852.72mm<sup>2</sup> and Females- 721.22mm<sup>2</sup>) Based on the results of this study, the most common forms of foramen magnum are Round (42.24 % - Males & 32% - Females) and Oval shapes(Males- 36% and Females - 34.4%).(Table.2)

In our study, the distribution of different shapes of foramen magnum showed no significant statistical differences in two sexes.



Fig 1: Axial CT image showing transverse and sagittal diameters.



Fig 2: Axial CT image showing the Foramen magnum area (FMA).

## DISCUSSION

Sex determination of unidentified human remains is very important in forensic medicine, medicolegal cases and forensic anthropology. The accuracy the determination of sex is largely affected

when the remains are incomplete, compromised by damage and fragmentation and thus this necessitates the development of reliable techniques using individual bony markers.<sup>2,6</sup> Foramen magnum is present at the basal central region of occipital bone and is a fundamental component in the complex interaction of bony, ligamentous, and muscular structures composing the craniovertebral junction.<sup>10</sup> Usually the dimensions of FM will remain constant after second decade of life and will differ in male and female. The thickness of the cranial base and the anatomical position of FM, prevents any damage due to physical insult and inhumation. The morphometric analysis provides an objective approach and allows comparisons with the results of the other studies for assessing the sexual dimorphism.<sup>11</sup>

Past researches evaluating the foramen magnum measurements as an aid in determining the sex have reported variable but high levels of accuracy. In a study of Indian crania by Routal et al. an accuracy of 100% in sex estimation using measurements of the foramen magnum was attained.<sup>12</sup> An accuracy of 71–90% was achieved in predicting sex from the foramen magnum region using regression analysis in skulls from the Hamann-Todd collection by Holland.<sup>13</sup> Other researchers have obtained similarly high levels of accuracy from using CT techniques to study sexual dimorphism of the foramen magnum region. Uysal et al. reported 81% accuracy in sex prediction having used 3DCT to study the foramen magnum in Turkish individuals.<sup>14</sup> Uthman achieved a similar accuracy of 81.8% in the classification of sex in a Turkish sample using CT data.<sup>8</sup> These high levels of accuracy indicate the foramen magnum may be a useful feature for sex determination.

Based on the results of the present study, the parameters associated with the foramen magnum such as the sagittal diameter, transverse diameter, and its area and circumference had a high sensitivity and specificity for the determination of sex, their accuracy was about 96%. The length and width in males was considerably higher as compared to females. Mean sagittal diameter in males was 35.68 & in females was 32.29 while the mean transverse diameter in the males was 27.92 and in females was 26.88. Murshed et al. studied FM dimensions using spiral CT and recorded the

Table 1: Mean of Foramen magnum measurements on CT scan images.

| Parameter           | Male   | Female |
|---------------------|--------|--------|
| Sagittal diameter   | 35.68  | 32.29  |
| Transverse diameter | 27.92  | 26.88  |
| FMA                 | 852.72 | 721.22 |
| FMC                 | 97.37  | 92.75  |

Table 2: Variable shapes of foramen magnum.

| Gender          | SHAPE |           |             |       |            |       |            |              | Total  |
|-----------------|-------|-----------|-------------|-------|------------|-------|------------|--------------|--------|
|                 | Egg   | Hexagonal | Irregular A | Oval  | Pentagonal | Round | Tetragonal | Unclassified |        |
| Count           | 2     | 11        | 2           | 45    | 7          | 53    | 3          | 2            | 125    |
| % within Males  | 1.6%  | 8.8%      | 1.6%        | 36.0% | 5.6%       | 42.4% | 2.4%       | 1.6%         | 100.0% |
| Count           | 4     | 11        | 6           | 43    | 10         | 40    | 6          | 5            | 125    |
| % within Female | 3.2%  | 8.8%      | 4.8%        | 34.4% | 8.0%       | 32.0% | 4.8%       | 4.0%         | 100.0% |
| Count           | 6     | 22        | 8           | 88    | 17         | 93    | 9          | 7            | 250    |
| % within Total  | 2.4%  | 8.8%      | 3.2%        | 35.2% | 6.8%       | 37.2% | 3.6%       | 2.8%         | 100.0% |

mean value of the FMSD (37.2 mm+/-3.43 mm in males and 34.6 mm +/-3.16 mm in females) and of the FMTD (31.6 mm+-2.99 mm in males and 29.3 mm+-2.19 mm in females).<sup>15</sup> These results were higher than those recorded in the present study.

The findings of the present study were consistent with the study done by Catalina-Herrera et al. A significant difference between sagittal and transverse diameters of the foramen magnum was noted with these parameters being larger in male than in female skulls.<sup>16</sup> 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.

## CONCLUSION

Based on the results of this study using CT scan images, the diameter of foramen magnum and its area have shown a high precision in gender determination. Therefore, CT images can be accurately used in further investigations to provide basis for anthropometric and forensic issues.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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