Original Article

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Assessment of Gender Determination: By Morphometric Dimensions of the Maxillary Sinuses and Computed Tomography

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Abstract

Background: Gender determination is considered to be an important step inidentification.For gender determination, anthropometric assessment is one of the main forensic assessments. **Objective:** The aim of this study was to investigate whether the morphometric dimensions of the maxillary sinuses can be used for gender determination. **Subjects and Methods:** A total of 147 patients from the age group of 20-70 were included in the study.Out of which 85(57.8%) were males and 62(42.2%) were females, and who came for head and paranasal sinusComputed Tomography (CT) scan in the duration of one year from June 2018 to April 2019 and who had complaints of head ache and suspected sinus diseases but without any pathological radiographic findings or history of trauma and in whom the CT Scans were considered normal as per the consultant radiologists.To obtain the Multiple detector computed tomography (MDCT)images, an MDCT Siemens Somatom Definition AS 64 SLICE machine with a high-resolution bone algorithm, 233 mm field of view, 120 kV, 395 mA, scanning time of 6.5 seconds and slice thickness of 1.0 mm was used to obtain the axial images. **Results:** The proportion of correctly identified females with right and left sinus was 74.2 % and 77.4% while using right and left sinus 76.5% and78.8% of males were correctly identified respectively. The combined proportion of correctly identified gender was 75.5% using the right sinus and 78.2% using the left sinus. **Conclusion:** All the parameters were equally and statistically significant in gender determination in our study making imaging of maxillary sinus on CT scan as an important anatomical structure as an aid in forensic anthropology for criminal investigations. Based on the multiple regression analysis a formula is also derived to easily and conveniently calculate the gender based on the values of maxillary sinus obtained on CT scan.

Keywords: Morphometric Dimensions, Gender Determination, CT Scan.

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Introduction

In the field of forensic medicine, sex determination is one of the most important parameters of identification. The foremost step for identification in medico-legal examination consists of gender determination in the damaged, mutilated dead and damaged bodies or from skeletal remains.[1] Gender determination can be done with the help of various skeletal components of the body including the skull, the pelvis, the long bones with an epiphysis and a metaphysis, the mastoid process, the foramen magnum and the paranasal air sinuses. In large explosions, warzones and other mass disasters like aircraft crashes or bombings, most of the bones of the body are badly disfigured; however, the Maxillary Sinuses in the skull have been reported to remain intact.[2]

The paranasal sinuses consist of paired frontal, ethmoid, maxillary and sphenoid sinuses. The maxillary sinus is the largest of the sinuses and is situated in the body of the maxillary bone and can have dimensional variability. The sinus has thin walls. The anterior wall is the facial surface of the maxillary bone, its posterior wall is the infratemporal surface, and its medial wall is that of the nasal cavity. The roof of the sinus encompasses the floor of the orbit.[3]

With advances in technology, Computed Tomography (CT) scans can be used for the morphometric measurements of the maxillary sinuses which can help in age and sex determination when other methods remain inconclusive. Measurements of the Maxillary Sinus are valuable tools in studying sexual dimorphism. The sinuses tend to complete their development after the second decade of life and radiographic imaging provides precise and accurate measurements that cannot be done otherwise.

Hence, morphometric analysis of the maxillary sinuses can be a worthy tool in gender determination studies. It has been reported that CT is a suitable imaging modality in the identification of unknown human skeletal remains and as compared with other conventional radiographic modalities presents a lot of advantages. Thus, the aim of this study was to investigate whether the morphometric dimensions of the maxillary sinuses can be used for gender determination. This work has paramount significance in the identification of a person in forensic anthropology and also for various medico-legal investigations.

Subjects and Methods

Source of Data and Selection Criteria

This was an observational study done on 147 patients who had visited the department of radio-diagnosis at D.Y. Patil Medical College, Kolhapur for head and paranasal sinus CT scan. Collection of the cases was done in a one-year period from June 2018 to April 2019on patients who had complaints of head ache and suspected sinus diseases but without any pathological radiographic findings or history of trauma and in whom the CT Scans were considered normal as per the consultant radiologists. Age group of 20-70 years was taken for the cases and out of the 147 taken, 85(57.8%) were males and 62(42.2%) were females.

Exclusion Criteria

Maxillary Sinus pathology as evident on the radiograph or trauma, facial asymmetry or any septal deviation or any defects in the osteo-meatal complex or patients who had undergone previous sinus surgeries, history of cleft palate, or ectopic and supernumerary teeth were excluded from the study.

The Machine Specifications

To obtain the MDCT images, an MDCT Siemens Somatom Definition AS 64 SLICE machine with a high resolution bone algorithm, 233 mm field of view, 120 kV, 395 mA, scanning time of 6.5 seconds and slice thickness of 1.0 mm was used to obtain the axial images. The axial images were then reconstructed to sagittal and coronal cross-sectional images and this reconstructed coronal and the axial cross-sections were used for the radiographic evaluation of the dimensions of the Maxillary Sinus. The dimensional measurements were done using Picture Archiving and Communication System (PACS) based on Med Synapse Technology (MST).

Method for measurement for maxillary sinus

The following measurements were performed by the single center. Height depth and width from both right and left side of maxillay sinus were measured as shown in figure 1, 2 and 3 respectively. The measurement of the height of the maxillary sinus was performed on the coronal cross-sectional images, whereas the depth and width measurements of the sinus were performed on the axial cross-sectional images. Also, the volume of each maxillary sinus was also calculated from the above determined parameters using the following equation.[4]

Volume= (height x depth x width x 0.5)

Statistical Analysis

The data was entered into Microsoft excel software and then transferred into Statistical Software. Student's unpaired 't' test was used for calculating the mean differences between the male and female genders with respect to parameters width, depth, height and volume of both right and left sinuses. Multiple logistic regression analysis was used to generate the formula for finding out the gender using width, depth and height of sinus. A *p*-value of < 0.05 was considered as significant

Results & Discussion

The comparison of width, depth, height and volume of right side of sinus was done between the two genders male and female which included 62(42.2%) females and 85(57.8%) males. When width, depth, height and volume of right& left sinus were compared, the*p*-value obtained was < 0.05, which was statistically significant.

Thus, the parameters width, depth, height and volume differ significantly between the two genders. The proportion of correctly identified females with right sinus was 73.5% while 77.6% using the left sinus while using right & left sinus 74.6% &76.1% of males were correctly identified respectively. The combined proportion of correctly identified gender was 74.2% using the right sinus & 76.7% using the left sinus.

Multiple regression analysis was used using width, depth and height to identify the gender using the right sinus.The formula generated wasGender = -0.375+0.3177 Width R+0.108 Depth R+0.212 Height R. Similarly, a formula was generated for left side of sinusGender =-0.437+ 0.1461 Width L+0.209 Depth L+0.269 Height L. If the gender value falls between < 1 to 1.5, the gender identified will be a "Female" and if the gender value falls been > 1.5 to 2.50 the gender identified will be a "Male".For the combined Right and Left Sinus, the formula generated wasGender = -0.375+0.733 Width R-0.411 Width L -0.443 Depth R +0.560 Depth L+0.200 Height R +0.016 Height L.

Table 1: Comparison of width, depth, height and volume of right side of sinus between the two genders.

Gender	Width(cm)	Depth(cm)	Height(mm)	Volume(cm^3)
Female (*n*=62)	2.26 ± 0.26	3.39 ± 0.37	3.11 ± 0.38	11.77 ± 3.36
Male (*n*=85)	2.93 ± 0.42	3.76 ± 0.41	3.83 ± 0.44	22.13 ± 4.71
p-value	0.000	0.000	0.000	0.000

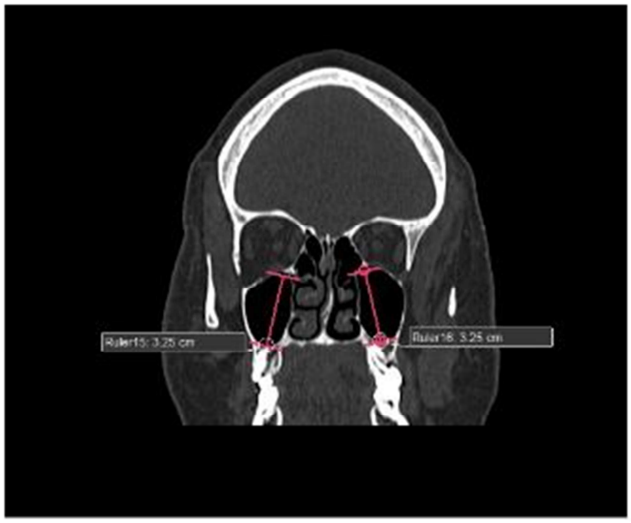

Figure 1: Coronal Section of CT Head Showing Height measurement of Maxillary Sinus

Table 2: Comparison of width, depth, height and volume of left side of sinus between the two genders.

Gender	Width(cm)	Depth(cm)	Height(mm)	Volume(cm^3)
Female (*n*=62)	2.24 ± 0.42	3.24 ± 0.33	3.06 ± 0.51	11.47 ± 3.11
Male (*n*=85)	2.99 ± 0.45	3.87 ± 0.51	3.73 ± 0.37	21.14 ± 6.12
p-value	0.000	0.000	0.000	0.000

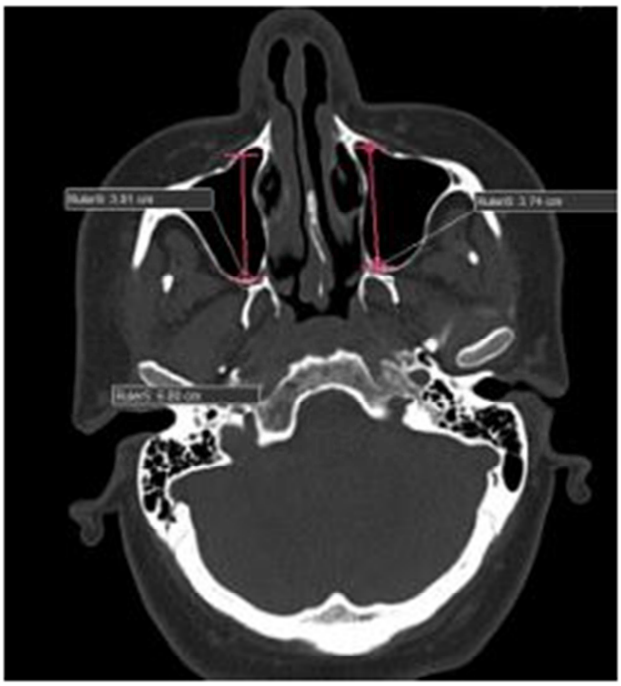

Figure 2: Axial section of CT head showing depth measurement of Maxillary sinus

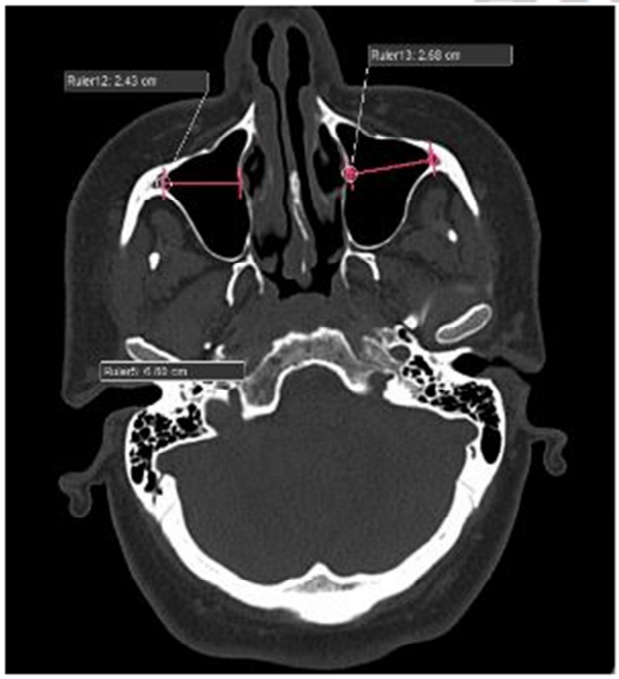

Figure 3: Axial section of CT head showing width measurement of Maxillary sinus

Determination and identification of skeletal remnants of humans forms the basis of forensic investigation. Gender determination is an important partin identification and may sometimes form a benchmark in the investigative procedure. It has been cited form the literature that the accuracy rate of gender determination is 100% from a skeleton, 98% from both the pelvis and the skull, 95% from the pelvis only or the pelvis and the long bones, 90–95% from both the skull and the long bones and 80–90% from the long bones only.[1]

In our study the comparison of width, depth, height and volume of right side of sinus was done between the two genders. There were 62 females and 85 males registered, the CT scans recorded for various pathologies involving head & neck.When the width, depth, height and volume of right sinus& left sinus were compared, the *p*-value obtained was < 0.05, which was statistically significant suggesting that the parameters width, depth, height and volume differ significantly between the two genders.

Maxillary Sinus Width

The mean width of the maxillary sinus recorded was 2.26±0.26cm and2.24±0.42cm on right and left side respectively in females as compared to 2.93±0.42 cm and 2.99±0.45cm on right and left side respectively in males. The P value thus obtained was significant. The results obtained by Suresh et alwere 24.63±4.6 mm for males and 23.6±3.8 mm for females[2] which were less for males and comparable to females as compared to our study. In accordance with the other studies, the average sinus width reportedwas 2.40±0.471 cm for male and 2.39±0.43 cm for female by Jehan et al.[5] The results in females were consistent with our studies with lower values obtained for males comparatively. The average sinus width estimatedby Baweja et al was 21.8±3.4 mm for male and21.6±3.7 mm for female[6] which was lesser comparatively than our results.Uthman et al & Teke et al also found lower values in females compared to males making it a significant variant in gender determination.[7,8]

Maxillary Sinus Depth

The mean sinus depth on right and left side in females were found to3.39±0.37cm and 3.24±0.33 cm respectively and 3.76±0.41 cm and 3.87±0.51cm for males respectively, which were consistent with the results obtained by Jehan et al who studied 191 subjects (106 males and 85 females)[5] and estimated the average sinus depth as 3.643±0.426 cm formale and 3.493±0.414 cm for female. However, the average sinus depth estimated by Baweja et alwas 34.1± 5.1 mm for male and33±5.6mmfor female[6] which are close to our results.The mean value for maximum length of maxillary sinus by Uthman et al for male group was 39.3±3.8 mm for the rightside and 39.4±3.7mmfor the left side[7] which was greater thanthat recorded for female group 36.9±3.8mmfor right side and37.0±4.0 mm for left side and with statistically significant difference($p<0.05$). The depth recorded by Suresh et alwas 34.96±3.4 mm for males and 33.39± 2.9 mm for females.[2] On statistical analysis non-significant side difference was seen for both the genders.

Teke et al also estimated the mean value for the maximumdepth of maxillary sinus for male group was 42.58±7.9 mmfor the right side and 43.7±7.78 mm for the left side whichwas significantly greater than that recorded for femalegroup which was 37.8±5.69 mm for right side and37.6±6 mm for left side and with statistically significantdifference ($p < 0.05$)[8]. These values are somewhat higher than our results.

Maxillary Sinus Height

The mean height of maxillary sinus obtained in our study was 31.1 ± 0.38mm and 30.6 ± 0.51 mm on right and left side for females as compared to 38.3±0.44 mm and 37.3±0.37 mm for males, which are on a lower side as compared to studies who reported the height of the sinus to be in 37.3±8.0 mm, 43.4±4.8 (right side); 45.1±4.1 mm (left side), 47.6±6.4(right side) ; 47.2± 6.5mm (left side) in males respectively and 36.9±7.4mm, 39.9±5.2(right side); 40±4.8 mm (left side), 45.1±4.6 mm (right side); 43.6±4.4 (left side) in females respectively [6,7,8].However, in a study by Suresh et [2] al the mean sinus height for male was 36.07±6.12 mm and 36.72±5.65 mm for the right and left siderespectively and average 36.4±5.88 mm which was notsignificantly ($p>0.05$) greater than that of female with34.51±4.032 mm for right side and 34.63±4.41 mm for leftside and average 34.57± 4.22 mm. This was in contrast with our results in which we found significant variations between the 2 groups.

Sinus Volume

The mean volume obtained was 11.77± 3.36cm^3 on right side and 11.47±3.11 cm^3 on left side for females which were significantly lower as compared to males which was 22.13±4.71 cm^3 on right side and21.14±6.12 cm^3 on left side. The results obtained were however lower in comparison to study by Suresh et al who reported the mean volume in male sinus as15.84± 5.86 cm^3 for right side and 16.45±6.143 cm^3 for leftside and average was 16.147±5.99 cm3.[2] The mean volume in female sinus was 13.65±3.93 cm^3 of right side and 14.18±4.672 cm^3 of left side and average was 13.92±4.299 cm^3. The volume of the maxillary sinuses of both sides was significantly greater in males compared to females. The range of maxillary sinus volume as calculated by Ariji et al[9] is 4.56 cm^3 - 35.21 cm^3 which is comparable with our study. The total average (Male + Female) mean volume by Chang-Hee et al[10] was 21.9 cm^3 which was in accordance with our study.

Analysis between the true gender and expected gender of Right & Left side of sinus

46 females were correctly identified and 65 males were correctly identified using the right sinus making the proportion of correctly identified females as 74.2% and males as 76.5% and combined proportion of correctly identified gender was 75.5% on right side.

However, 48 females were correctly identified and 67 males were correctly identified using the left sinus and the proportion of correctly identified females was 77.4% and males was 78.8% and combined proportion of correctly identified gender was 78.2% using the left sinus.

Thus, all the 4 parameters viz, depth, height, width and volume of maxillary sinus on right and left side were found to be statistically significant in males and females with a higher value in males making it an important determinant in sexual dimorphism. However, our results vary from studies done by other authors who found one or more parameter significant as compared to others in gender determination.

Uthman et al found that maxillary sinus heightwas the best discriminant parameter that could be used tostudy sexual dimorphism with an overall accuracy of 71.6%,74.4% of male sinuses and 73.3% of female sinuses were sexed correctly[7]. Similarly, Fernandes et al[11]examined CT scans of 53 dried skulls of Zulu and Europeans and reported no sexual significant differencefor the maxillary sinus width while all other parameters were significant. This was also true for the study done by Suresh et al.[2] who along with the width found volume also to be an important determinant. Amin[12] also found cephalocaudal distance & size of left maxillary sinus as important variables in gender determination in Egyptian population. Jasim[13] reported that if both genders are considered together, the correlations with the depth, width and height in dentate were (r=0.52,0.86,0.64) respectively, while in edentulous group were (r=0.56, 0.88, 0.86) respectively. From these results it can be derived that the strongest correlation was with the width (r=0.88, 0.86) and height (r=0.86) in edentulous group with the weakest correlation with the depth in the dentate subjects (r=0.52).

The variations, however noted in some of the results between various studies of maxillary air sinus dimensions and volume are probably dueto multi-factorial causes like different racial & ethnic groups with difference in body physique, stature, skeletal size and height of an individual; sample size being recorded, environmental and genetic factors; anatomical variations of sinus; differences in osteoblastic and osteoclastic activity and pneumatization process of sinus in different age and sex groups or any history of past infections.

Conclusion

All the parameters were equally and statistically significant in gender determination in our study making imaging of maxillary sinus on CT scan as an important anatomical structure as an aid in forensic anthropology and for criminal investigations. The results are comparable with other studies done in this regard. Based on the multiple regression analysis a formula is also derived which is a tip of the iceberg to easily & conveniently calculate the gender based on the values of maxillary sinus obtained on CT scan. However, studies are required to validate the practicality of gender determination using the stated equation.

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