SCIENTIFIC ARCHIVES OF DENTAL SCIENCES (ISSN: 2642-1623)

Volume 4 Issue 11 November 2021

Research Article

Is there a She or a He in the Maxillary Sinus

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Received: September 13, 2021; **Published:** October 27, 2021

Abstract

Identification of remnants of skeletal and decomposing parts of humans is one of the most difficult skills in forensic medicine. Of the multiple parameters available, sex determination forms an important part in forensic identification. Because most bones used for sex identification are often fragmented and disfigured in mass disasters, it becomes crucial to use bones which are often recovered intact. Maxillary sinus is one of them and is used for sex determination of an individual. Hence, we compared the size and volume of the maxillary sinus between males and females by CT Scan images for sex determination. 120 individuals (71 males and 49 females) visiting the department of radiology at Sri Aurobindo Institute of Medical Sciences, Indore, India were selected and the maxillary sinuses were evaluated on MDCT imaging. The dimensions and volume of the maxillary sinuses of males were found to be larger than those of females and this difference was statistically significant ($p < 0.05$). The combined proportion of correctly identified sex was 74.2% using the right sinus and 76.7% using the left sinus. We can conclude that CT measurements of maxillary sinus dimensions and volume may be useful for identification of sex in forensic anthropology.

Keywords: *Maxillary Sinus; CT; Forensic; Imaging; Radiology*

Introduction

In the field of forensic medicine, sex estimation 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].

Sex estimation can be done with the help of various skeletal components of the body including the skull, 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 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 estimation 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 sex 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.

Aim of the Study

Thus, this study aimed to investigate whether the morphometric dimensions of the maxillary sinuses can be used for sex determination. This work has paramount significance in the identification of a person in forensic anthropology and also for various medico-legal forensic investigations.

Materials and Methods

Source of data and selection criteria

- This was an observational study done on 120 patients who had visited the department of radiology at Sri Aurobindo Institute of Medical Sciences, Indore, India for head and paranasal sinus CT scans. Collection of the cases was done in a five month period on patients who had complaints of headache and suspected sinus diseases but without any pathological radiographic findings or history of trauma and in whom the CT scans were considered within normal limits as per the consultant medical radiologists.
- Age group of 20 - 70 years was taken for the cases and out of the 120 taken, 71 were Males and 49 were females.

Exclusion criteria

Maxillary sinus pathology, trauma, gross facial asymmetry, defects in the ostio-meatal complex, previous sino-nasal surgeries, history of cleft lip and palate, and/or ectopic teeth in the sinuses noted in the CT images were excluded from the study.

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 reconstructed to sagittal and coronal slices and these native axial, reconstructed coronal and sagittal images were used for the radiographic evaluation of the dimensions of the maxillary sinuses
- The dimensional measurements were done using a PACS system based on MedSynapse.

Methodology

The following measurements were performed by the radiologists as done previously by Kanthem., *et al.* [4]:

- The right and left-sided height of the maxillary sinus (height- the maximal craniocaudal diameter) (Figure 1).
- The right and left-sided depth of the maxillary sinus (depth- the maximal anteroposterior diameter) (Figure 2).
- The right and left side width of the maxillary sinus (width- the maximal width) (Figure 3).
- 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.

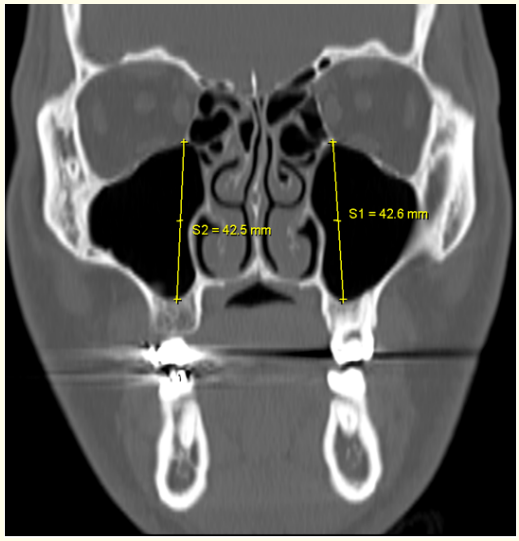

Figure 1: *The right and left-sided height of the maxillary sinus (height- the maximal craniocaudal diameter).*

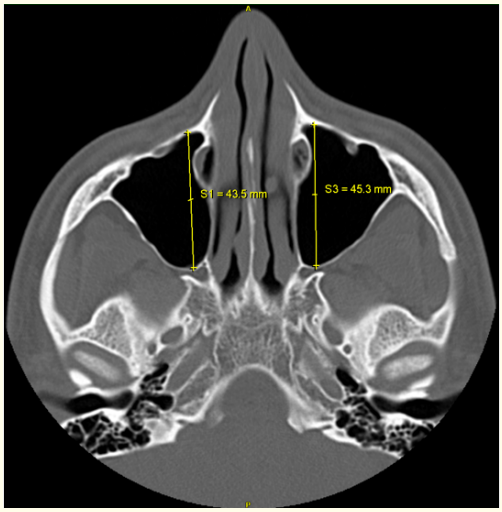

Figure 2: *The right and left-sided depth of the maxillary sinus (depth- the maximal anteroposterior diameter).*

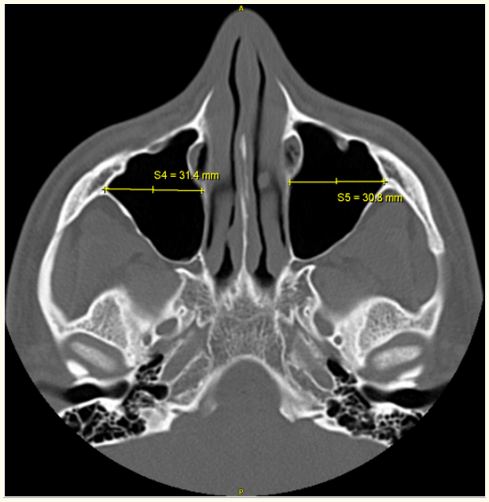

Figure 3: *The right and left side width of the maxillary sinus (width- the maximal width).*

The Volume of each maxillary sinus was also calculated from the above determined parameters using the following equation: Volume = (height x depth x width x 0.5).

Statistical analysis

- The data was entered Microsoft Excel software and then transferred into Statistical Software MiniTab Version 17.0.
- The Student's unpaired 't' test was used for calculating the mean differences between the male and female sex for 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 sex using width, depth, and height of sinus. A P value of < 0.05 was considered significant.

Results and Discussion

The comparison of the various dimensions of the sinus bilaterally was done between the two sex - Male and Female which included 49 females and 71 males.

The proportion of correctly identified females with the right sinus was 73.5% while 77.6% using the left sinus while using right and left sinus 74.6% and76.1% of males were correctly identified respectively. The combined proportion of correctly identified sex was 74.2% using the right sinus and 76.7% using the left sinus.

The formula was generated for sex estimation using the right and left sinus:

- Right Sinus - Sex = -0.375 + 0.3177 Width R + 0.108 Depth R + 0.212 Height R.
- Left Sinus - Sex = -0.437 + 0.1461 Width L + 0.209 Depth L + 0.269 Height L.
- Combined Right and Left Sinus - Sex = -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.

If the sex value falls between < 1 to 1.5, the sex identified will be a 'Female' and if the sex value falls been > 1.5 to 2.50 the sex identified will be a 'Male.

Sex	Width	Depth	Height	Volume
Female (49)	2.25 ± 0.36	3.29 ± 0.37	3.10 ± 0.48	11.87 ± 4.16
Male (71)	2.92 ± 0.50	3.79 ± 0.47	3.73 ± 0.41	21.23 ± 6.83
't' Value	-8.02	-6.17	-7.69	-8.56
P value	0.000	0.000	0.000	0.000
Sign.	Sig.	Sig.	Sig.	Sig.

Table 1: *Comparison of width, depth, height and volume or right sinus between male and females (N = 120).*

Sex	Width	Depth	Height	Volume
Female (49)	2.31 ± 0.42	3.19 ± 0.36	2.95 ± 0.42	11.32 ± 4.06
Male (71)	2.95 ± 0.57	3.75 ± 0.48	3.61 ± 0.45	20.56 ± 7.08
't' Value	-6.64	-6.79	-7.94	-8.24
P value	0.000	0.000	0.000	0.000
Sign.	Sig.	Sig.	Sig.	Sig.

Table 2: *Comparison of width, depth, height and volume of left sinus between male and females (N = 120).*

Determination and identification of skeletal remnants of humans forms the basis of forensic investigation. Sex estimation plays an important part in identification and may sometimes form a benchmark in the investigative procedure. It has been cited form the literature that the accuracy rate of sex 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 the right side of the sinus was done between the two sexes. There were 49 females and 71 males registered in our thesis from the CT scans recorded for various pathologies involving head and neck.

When the width, depth, height and volume of right sinus and left sinus were compared, the P- value obtained was < 0.05, which is statistically significant suggesting that the parameters width, depth, height and volume differ significantly between the two sexes.

Results of maxillary sinus width

The mean width of the maxillary sinus recorded was 2.25 ± 0.36 cm and2.31 ± 0.42 cm on right and left side respectively in females as compared to 2.92 ± 0.50 cm and2.95 ± 0.57 cm on right and left side respectively in males. The P value thus obtained was significant. The results obtained by Suresh., *et al.* [5] were 24.63 ± 4.6 mm for males and 23.6 ± 3.8 mm for females which were less for males and comparable to females as compared to our study. Following the other studies, the average sinus width reported was 2.404 ± 0.471 cm for male and 2.39 ± 0.438 cm for female by Jehan., *et al* [6]. The results in females were consistent with our studies with lower values obtained for males comparatively.

The average sinus width estimated by Baweja., *et al.* [7] was 21.8 ± 3.4 mm for male and 21.6 ± 3.7 mm for female which was lesser comparatively than our results.

Uthman., *et al.* [8] and Teke., *et al.* [1] also found lower values in females compared to males making it a significant variant in sex estimation.

Results of maxillary sinus depth

The mean sinus depth on right and left side in females were found to3.29 ± 0.37 cm and 3.19 ± 0.36 cm respectively and 3.79 ± 0.47 cm and 3.75 ± 0.48 cm for males respectively, which were consistent with the results obtained by Jehan., *et al.* [6] who studied 191 subjects (106 males and 85 females) and estimated the average sinus depth as 3.643 ± 0.426 cm for males and 3.493 ± 0.414 cm for females. However, the average sinus depth estimated by Baweja., *et al.* [7] was 34.1 ± 5.1 mm for males and 33 ± 5.6 mm for females which are close to our results.

The mean value for the maximum length of maxillary sinus by Uthman., *et al.* [8] for male group was 39.3 ± 3.8 mm for the right side and 39.4 ± 3.7 mm for the left side which was greater than that recorded for female group 36.9 ± 3.8 mm for right side and 37 ± 4 mm for left side and with statistically significant difference ($p < 0.05$). The depth recorded by Suresh., *et al.* [5] was 34.96 ± 3.4 mm for males and 33.39 ± 2.9 mm for females. On statistical analysis non- significant side difference was seen for both.

Teke., *et al.* [1] also estimated the mean value for the maximum depth of maxillary sinus for male group was 42.58 ± 7.9 mm for the right side and 43.7 ± 7.78 mm for the left side which was significantly greater than that recorded for female group which was 37.8 ± 5.69 mm for right side and 37.6 ± 6 mm for left side and with statistically significant difference ($p < 0.05$). These values are somewhat higher than our results.

Results of maxillary sinus height

The mean height of maxillary sinus obtained in our study was 3.10 ± 0.48 cm and 2.95 ± 0.42 cm on right and left side for females as compared to 3.73 ± 0.41 cm and 3.61 ± 0.45 cm for males, which are on a lower side as compared to studies done by Baweja [7], Uthman [8] and Teke., *et al*. [1] 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 ± 6.5 mm (left side) in males respectively and 36.9 ± 7.4 mm, 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.

However, in a study by Suresh., *et al.* [5] the mean sinus height for males was 36.07 ± 6.12 mm and 36.72 ± 5.65 mm for the right and left side respectively and average 36.4 ± 5.887 mm which was not significantly ($p > 0.05$) greater than that of females with 34.51 ± 4.032 mm for right side and 34.63 ± 4.414 mm for left side and average 34.57 ± 4.223 mm. This was in contrast with our results in which we found significant variations between the 2 groups.

Results of sinus volume

The mean volume obtained was 11.87 ± 4.16 cm^3 on right side and 11.32 ± 4.06 cm^3 on left side for females which were significantly lower as compared to males which was 21.23 ± 6.83 cm^3 on right side and 20.56 ± 7.08 cm^3 on left side. The results obtained were however lower in comparison to study by Suresh., *et al.* [5]

who reported the mean volume in male sinus as 15.84 ± 5.86 cm^3 for right side and 16.45 ± 6.143 cm^3 for left side and average was 16.147 ± 5.99 cm^3. 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 (M + F) mean volume by Chang-Hee., *et al.* [10] was 21.9 cm^3 which was in accordance with our study.

Analysis between the true sex and expected sex of right and left side of sinus

36 females were correctly identified, and 53 males were correctly identified using the right sinus making the proportion of correctly identified females as 73.5% and males as 74.6% and combined proportion of correctly identified sex was 74.2% on right side.

However, 38 females were correctly identified, and 54 males were correctly identified using the left sinus and the proportion of correctly identified females was 77.6% and males was 76.1% and combined proportion of correctly identified sex was 76.7% 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 sex estimation.

Uthman., *et al.* [8] found that maxillary sinus height was the best discriminant parameter that could be used to study sexual dimorphism with an overall accuracy of 71.6%, 74.4% of male sinuses and 73.3% of female sinuses were determined correctly. Similarly, Fernandes., *et al.* [11] examined CT scans of 53 dried skulls of Zulu and Europeans and reported no sexual significant difference for the maxillary sinus width while all other parameters were significant. This was also true for the study done by Suresh., *et al.* [5] who along with the width found volume also to be an important determinant. Amin and Hassan [12] also found cephalocaudal distance and size of the left maxillary sinus as important variables in sex estimation in the Egyptian population.

Jasim [13] reported that if both the sexes are considered together, the correlations with the depth (AP), 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 sinus dimensions and volume are probably due to multi-factorial causes like different racial and 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.

Mathematical formula for sex determination

Multiple regression analysis was used using width, depth and height to identify the sex. The formula generated using the right sinus is:

Sex = -0.375 + 0.3177 Width R + 0.108 Depth R + 0.212 Height R .....(a)

Similarly, a formula using the left side of sinus is:

Sex = -0.437 + 0.1461 Width L + 0.209 Depth L + 0.269 Height L .....(b)

For the combined right and left Sinuses, the formula generated is:

Sex = -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 .....(c)

If the value falls between < 1 to 1.5, the sex identified will be a 'Female' and if the value falls been > 1.5 to 2.50 the sex identified will be a 'Male.

So, by putting the values of width, depth and, height of both the left and the right side sinus, the sex can be quite accurately identified using the above-mentioned formula.

Conclusion

All the parameters were equally and statistically significant in sex estimation 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 and conveniently determine the sex based on the values of maxillary sinus obtained on CT scan. However, studies are required to validate the practicality of sex estimation using the stated equation.

Conflict of Interest

None.

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