ORIGINAL ARTICLE

Diagnostic Accuracy of Computed Tomography Based Anthropometric Measurements of Maxillary Sinuses in Sex Determination in Pakistani Population

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ABSTRACT

Objective: The aim of this study is to determine the diagnostic accuracy and reliability of CT based anthropometric measurements of maxillary sinuses in sex determination of human beings

Methodology: This prospective cross-sectional study was conducted in Dow University of Health Sciences' Institute of Radiology from October 2019 till June 2020. Cases of CT para nasal sinuses with morphologically intact maxillary sinuses without any disease were included. The anthropometric measurements of the maxillary sinuses were determined by a radiologist. Using those values, sex was predicted by a formula and compared with actual sex to determine diagnostic accuracy and reliability of CT scan.

Results: We reviewed CT scan PNS of 97 patients (194 sinuses); 45 females and 52 males. Most of the patients were between 20-40 years of age (75.6%). All the dimensions and volumes were larger in males than females and statistically significant. When using the dimensions of both maxillary sinuses (n=194 sinuses) on CT scans, the over all diagnostic accuracy to determine sex was found to be 90% with accuracy of 78% in females and 100% in males. However, the reliability (predictive value) for females and males was 100% and 84.5%, respectively.

Conclusion: CT measurements of maxillary sinuses are useful to determine sex in forensic identification. If the CT scan suggests that the skull belongs to a female or a male, the probability that it would turn out to be so is 100% and 84.5%, respectively.

INTRODUCTION

Identification of human beings is essential for personal, social and legal reasons[1]. Establishment of the identity of a person, living or dead, is a legal necessity and is consistent with social requirements. Forensic science is of considerable help in establishing the identity of an individual, both living and dead. In forensic medicine, post mortem identification of bony remnants and putrefactive human remains is one of the most arduous tasks[1]. When established methods of identification, such as visual recognition and comparison of dental data, cannot be used as in cases of advance decomposition or insufficient record, alternative methods should be considered.

Sex determination is one of the vital parameters in forensic identification as sex assessment constitutes an integral step in building a post mortem profile[2]. The skull and the pelvis, along with assessment of epiphysis and metaphysis of the long bones, are considered the most useful for radiological determination of sex[1,3]. In addition to these conventional methods, one of the methods suggested by many studies is; sex determination through the size and volume of maxillary sinus specially in cases of mass disasters and incineration[1,3,4]. Furthermore, it has been reported that the anatomical shape and structure of maxillary sinus remains intact even though the skull and other bones may be severely disfigured[1,4].

Maxillary sinuses are two air filled spaces, situated in the maxillary bone and can be in diverse sizes and shapes. After maturity, their size and shape may alter due to loss of teeth. The sizes of maxillary sinuses can

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also be altered by genetic diseases, by infections and other environmental factors[5].

Computed Tomography (CT) scanning is considered the gold standard for examining maxillary sinuses[2]. An over all accuracy of 83.3% for sex determination is reported by Prabhat et al using the anthropometric measurements of maxillary sinuses, in a study conducted on 30 patients[1]. An accuracy of 69.3% for sex determination, using anthropometric measurements of CT scans of maxillary sinuses of 127 patients, was reported by Teke et al in a study conducted in Turkish population[3]. An over all accuracy of 88% was reported by Bangi et al, using anthropometric measurements of CT scan of maxillary sinuses of 100 patients[6]. The variations in some of the results of maxillary air sinus dimensions and volume in these studies are probably due to the combination of many factors like the effect of ethnicity on the sinuses or different methodologies applied in those studies. Genetic and environmental factors and anatomical variations of sinus also play a role in these variations. However, the method is not considered to be error free. Moreover, no such study is conducted in our population, hence, this study was conducted to determine the diagnostic accuracy and reliability of CT based anthropometric measurements of maxillary sinuses in sex determination in Pakistani population.

METHODOLOGY

This prospective cross-sectional study was conducted in Institute of Radiology after approval by the Institutional Review Board of Dow University of Health Sciences. CT paranasal sinuses of males and females aged 20-50 years, having morphologically intact maxillary sinuses without any disease, were included using consecutive sampling technique. Patients having facial / maxillary deformity, sinus inflammatory disease or surgery were excluded from study.

After informed consent, examination was performed on 64 slices GE CT scanner using 3mm slice thickness with scan parameters of 120 kv and 60-220 Ma ranges, keeping patient steady during examination. The images were then transferred to workstation for post processing and reporting to be performed on picture archiving and communication system (PACS). A consultant radiologist with eight years of experience after fellowship in diagnostic radiology reviewed the scans for the following parameters:

Anthropometric measurements:

The mediolateral (ML) and superoinferior (SI) measurements were taken at the widest part of sinuses on coronal view, while anteroposterior (AP) diameter was measured on axial view. (Fig.1) Volumes and

coefficients were derived using the formulae described by Bangi et al.

Following equation was used to calculate Sinus volume individually
$$\text{Volume} = (\text{width} \times \text{depth} \times \text{height}) \times 0.5^{1}$$
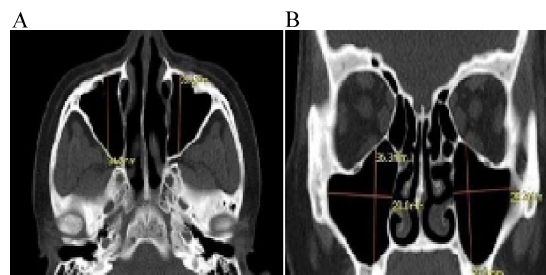

Fig 1: Axial CT scan showing AP measurement of right and left maxillary sinus (A), coronal CT scan showing SI and ML measurements of right and left maxillary sinuses (B)

Sex determination:

The resulted values based on anthropometric diameter were put in the formula given below for discriminative analysis of sex by Bangi et al.

Sex from Right Maxillary Sinus= -11.919 + 0.204 × SIR+ 2.330 × APR - 0.180 × MLR + 1.906 × VR

Sex from Left Maxillary Sinus= -8.552 + 0.347 × SIL + 1.376 × APL - 0.015 × MLL+1.020 × VL

A numeric value was obtained when the derived values were placed in the formulae. A positive (+ve) value predicted the sex as *male* and a negative (-ve) value predicted as *female*. The sex predicted by this formula was then compared with actual sex of the same patient. All these calculations were inserted into the formulae by the radiologist.

Assuming 88% accuracy of CT scan[6] in determination of sex with bound on error of 6.5%, for the sake of achievement of the sample as due to covid 19 the desired sample size was not achieved, a sample size of 97 was required based on 95% confidence interval as per WHO software. The data was entered and analyzed in SPSS. Continuous variables i.e. age and maxillary sinus dimensions were analyzed as means with standard deviation and compared between the groups by students' t-test. The categorical variables i.e. sex were analyzed as proportions. The agreement of the sex determination by the CT scan with the original sex of participants, was checked by kappa statistics. The diagnostic accuracy and predictive values were calculated by 2x2 table by following formula:

Accuracy of CT scan (Females) = Females correctly detected by CT scan/total females

Accuracy of CT scan (Males) = Males correctly detected by CT scan/total males

Accuracy of CT scan (Over all) = True females+ True males detected by CT scan/total patients

Predictive Value (Females)= Females correctly detected by CT scan/Total number of females predicted by CT scan dimensions

Predictive Value (Males) = Males correctly detected by CT scan/Total number of males based on CT scan dimensions

RESULTS

We reviewed CT scans of 97 patients (194 sinuses): 45 females and 52 males. Most of the patients were between 20-40 years of age (75.6%). All the dimensions and volumes were larger in males than in females and statistically significant (Table1) and there was no overlapping of coefficients between males and females (Fig. 2).

Table 1: Distribution of Maxillary Sinus Dimensions Measured on CT and Their Standard Deviation Dimensions:

Dimensions	All Patients	Female	Male	p-value
VR	14.1±5.6	10.4±3.8	17.3±4.8	0.001*
VL	14.01±5.7	10.04±3.6	17.4±5.01	0.00*
MLR	2.4±0.54	2.0±0.5	2.5±0.5	0.002*
SIR	3.1±0.64	3.5±0.5	3.2±0.3	0.001*
APR	3.5±0.43	3.2±0.35	3.8±0.35	0.001*
MLL	2.3±0.53	2.2±0.46	2.5±0.54	0.001*
SIL	3.1±0.64	2.6±0.41	3.5±0.5	0.001*
APL	3.5±0.46	3.2±0.41	3.8±0.35	0.00*

*Student's t-test

VR: Volume of right maxillary sinus; VL: Volume of left maxillary sinus; MLR: Mediolateral dimension of right maxillary sinus; SIR: Superoinferior dimension of right maxillary sinus; APR: Anteroposterior dimension of right maxillary sinus; MLL:Mediolateral dimension of left maxillary sinus; SIL: Superoinferior dimension of left maxillary sinus; APL: Anteroposterior dimension of left maxillary sinus

When using the dimensions of right maxillary sinuses on CT scans, the over all diagnostic accuracy to determine sex is 87%. From forensic point of view, reliability (predictive value) is more important than accuracy. The reliability (predictive value) for females and males is 100% and 81%, respectively, which means, when the CT scan suggests that the skull belongs to a female or a male, the probability that it would turn out to be so is 100% and 81%, respectively.
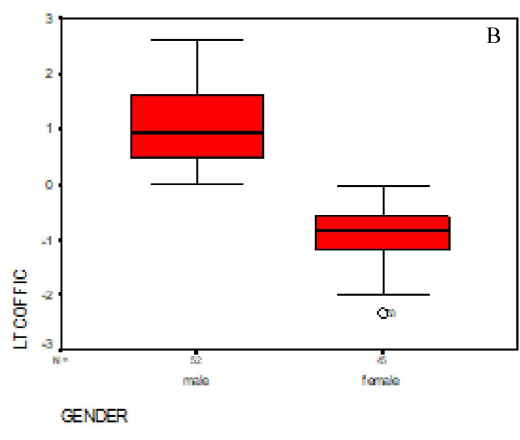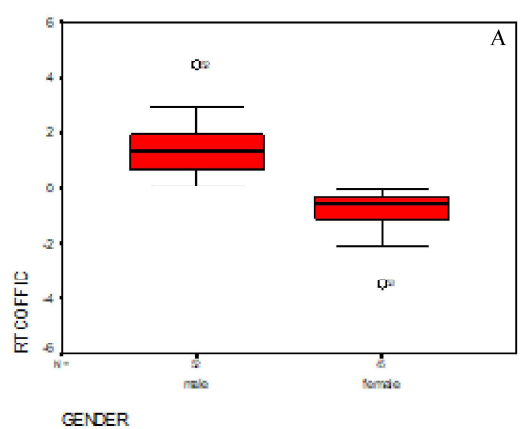

Figure 2: Box plot displaying the distribution of coefficients derived from different volumes and dimensions of right (A) and left (B) maxillary sinuses

When using the dimensions of left maxillary sinuses on CT scans, the over all diagnostic accuracy to determine sex is 92%. The reliability (predictive value) for females and males is 100% and 88%, respectively. So, when the CT scan suggests that the skull belongs to a female or a male, the probability that it would turn out to be so is100% and 88%, respectively.

When using the dimensions of both maxillary sinuses on CT scans, the over all diagnostic accuracy to determine sex is 90%. However, the reliability (predictive value) for females and males is 100% and 84.5%, respectively. So, when the CT scan suggests that the skull belongs to a female or a male, the probability that it would turn out to be so is100% and 84.5%, respectively.

Over all, there was a high degree of agreement between the actual sex of the human participant and sex based on the dimensions of CT scan was 74.7%, 85.5% and

80% for right, left and both maxillary sinuses, respectively, based on kappa statistics (Table 2).

Table 2: Agreement of CT Scan with Actual Sex based on Measurements of Right, Left and Both Maxillary Sinuses

		Actual Sex		PV*	Kappa statistics	p-value
		Female	Male			
Sex as Per Right Maxillary Sinus Dimensions (n=97)	Female	33	0	100%	0.74	0.001
	Male	12	52	81%		
Sex as Per Left Maxillary Sinus Dimensions (n=97)	Female	38	0	100%	0.85	0.001
	Male	7	52	88%		
Sex as Per Both Maxillary Sinus Dimensions (n=194)	Female	71	0	100%	0.8	0.001
	Male	19	104	84.5%		

*Predictive value

DISCUSSION

Personal identification of unidentified bodies is a forensic procedure which is pivotal for ethical and social reasons as well as for policy making. Sex determination of the recovered skeletal remains is an essential part of the process of identification. It has been reported in many studies that if whole skeleton is available, sex can be determined with 100% accuracy and if both pelvis and skull are available, accuracy for sex determination is 98%. Accuracy is 95% from pelvis only or the long bones and pelvis, 90–95% from both the long bones and the skull, and 80–90% from the long bones only[1,7].

Radiological identification of sex is utilized when body is putrefied and disintegrated. Different techniques which have been mentioned here, have been utilized for sex determination of corpses recovered from crime scenes or sites of mass casualties. One of the radiographic methods for sex determination using radiographs of the calcaneus, determines sex with accuracy of 84.4% based on all angles and distances[14]. Another study reported that sex can be determined from circumference and area of foramen magnum using helical CT scan with an accuracy of 67% and 69.3%, respectively[8]. In addition to these conventional methods, one of the methods suggested by many studies is sex determination from size and volume of maxillary sinus specially in cases of mass disaster and incineration as it remains intact despite severe degradation of other bones.

It has been reported that in the identification of unknown human remains computerized tomography is an appropriate imaging technique as compared with conventional radiographs[13]. Measurement of size and volume of maxillary sinuses in CT scans can be used

to determine sex when routine identification methods may be inconclusive.

Our study showed a pattern of maxillary sinuses being larger in males than in females but the difference was statically insignificant. Similar results were seen in studies conducted in other parts of the world[12,15]. Volumes of both maxillary sinuses are larger in males than females. Similar findings were observed in several other studies[6,12,15]

In the present study, the over all diagnostic accuracy of CT scan to determine sex based on dimensions of both right and left maxillary sinuses is 100 % in males and 78% in females with an over all diagnostic accuracy of 90% which matches multiple earlier studies that show good diagnostic importance of anthropometric measurements in both sexes[1,6].

Bangi et al reported sex determination by right and left maxillary sinus dimensions with 84% accuracy in males and 92% accuracy in females[6]. Prabhat et al reported that sex can be determined from the anthropometric measurements and volume of the right and the left maxillary sinuses together with 80.0% accuracy in males and 86.7% accuracy in females, and the over all accuracy of sex prediction was 83.3%[1]. Our results are also comparable with a study conducted on Indian population in which the over all accuracy rate was 86% (86% in males and 87% in females)[16]. However, the prediction accuracy in our study is comparatively greater than some studies. Amin and Hassan estimated sex from radiological measurements of maxillary sinus using CT scan among Egyptian population, with an accuracy of 62% in females and 70% in males[17]. The study done by Teke et al on Turkish population stated that sex could be determined from CT scans of the right and left maxillary sinus measurements together with an accuracy of 69.4% in females and 69.3% in males with over all accuracy of 69.3%[3]. Sharma et al reported an accuracy rate of 68.9% in females and 65% in males using CT measurements of maxillary sinus dimensions and volume[18].

The variations in some of the results of maxillary air sinus dimensions and volume in these studies are probably due to combination of many factors like the effect of ethnicity on the sinuses or different methodologies applied in those studies. Genetic and environmental factors and anatomical variations of sinus also play a role in these variations.

Our study emphasizes on the use of CT scan for prediction of sex based on maxillary sinus dimensions, which has 100% reliability if it predicts female sex and 84.5% reliability for males. The lower reliability on CT scan for male sex may be attributed to the fact

that some females (15.5%) may have higher enough dimensions of maxillary sinuses to be falsely labelled as males.

The dimensions of maxillary sinuses are affected by diseases or age due to teeth loss. In order to reduce this selection bias, we excluded the scans with other pathology and also limited the age to 20-50 years to attain a homogenous study population.

Another study has been carried out to check the reliability of the use of CT scan for prediction of sex based on maxillary sinus dimensions which reported that the sensitivity of the discriminant functional analysis was 80% (20/25) and specificity was 72% (18/25)[5].

CONCLUSION

The study concludes that CT based identification of sex is highly accurate and of utmost importance in forensic medicine. When the skull is predicted to be female based on a CT scan, the chances of it turning out to be female actually are 100%; however, for prediction as male, the chances of accuracy are 84.5%.

Authors' contribution: MF worked on protocol writing, introduction, literature search, methodology, discussion, and proof reading. BR worked on Data collection, interpretation and data entry in SPSS. GM worked on statistcal analysis, results and final proof reading.

References

1. Prabhat M, Rai S, Kaur M, Prabhat K, Bhatnagar P, Panjwani S. Computed tomography based forensic gender determination by measuring the size and volume of the maxillary sinuses. J Forensic Dent Sci. 2016;8(1):40-46. doi:10.4103/0975-1475.176950

2. Saccucci M, Cipriani F, Carderi S, Di Carlo G, D'Attilio M, Rodolfino D, et al. Gender assessment through three-dimensional analysis of maxillary sinuses by means of cone beam computed tomography. Eur Rev Med Pharmacol Sci. 2015;19(2):185-93.

3. Teke HY, Duran S, Canturk N, Canturk G. Determination of gender by measuring the size of the maxillary sinuses in computerized tomography scans. Surg Radiol Anat. 2007;29(1):9-13. doi: 10.1007/s00276-006-0157-1.

4. Khaitan T, Kabiraj A, Ginjupally U, Jain R. Cephalometric analysis for gender determination using maxillary sinus index: a novel dimension in personal identification. Int J Dent. 2017; 2017:7026796. doi: 10.1155/2017/7026796

5. Sidhu R, Chandra S, Devi P, Taneja N, Sah K, Kaur N. Forensic importance of maxillary sinus in gender determination: a morphometric analysis from Western Uttar Pradesh, India. European Journal of General Dentistry. 2014;3(1):53-56. doi: 10.4103/2278-9626.126213

6. Bangi BB, Ginjupally U, Nadendla LK, Vadla B. 3D evaluation of maxillary sinus using computed tomography: a sexual dimorphic study. Int J Dent. 2017;2017:9017078.

7. Günay Y, Altinkök M, Çagdir S, Sari H. Is foremen magnum size useful for gender determination (in Turkish). Bull Legal Med.1998;3:41-5

8. Uthman AT, Al-Rawi NH, Al-Timimi JF. Evaluation of foramen magnum in gender determination using helical CT scanning. Dentomaxillofac Radiol. 2012;41(3):197-202. doi: 10.1259/dmfr/21276789.

9. Agritmis H, Celbis O. Body length and gender determination from radius and ulna (in Turkish). J Forensic Med. 16(1):7–17

10. Karadayi B, Kaya A, Koc H, Ende V, Ozaslan A. Sex determination by using hand and wrist measurements in Turkish population. Turk J Forensic Med. 28(2):132-140. DOI:10.5505/adlitip.2014.98700.

11. Kanchan T, Rastogi P. Sex determination from hand dimensions of North and South Indians. J Forensic Sci. 2009;54(3):546-50.doi: 10.1111/j.1556-4029.2009.01018.x.

12. Sahlstrand-Johnson P, Jannert M, Strömbeck A, Abul-Kasim K. Computed tomography measurements of different dimensions of maxillary and frontal sinuses. BMC Med Imaging. 2011;11(1):8. doi: 10.1186/1471-2342-11-8.

13. Vidya CS, Shamasundar NM, Manjunatha B, Raichurkar K. Evaluation of size and volume of maxillary sinus to determine gender by 3D computerized tomography scan method using dry skulls of South Indian origin. Int J Current Res Rev. 2013;5(3):97.

14. Riepert T, Drechsler T, Schild H, Nafe B, Mattern R. Estimation of sex on the basis of radiographs of the calcaneus. Forensic Sci Int. 1996;77(3):133-40. doi: 10.1016/0379-0738(95)01832-8.

15. Kanthem RK, Guttikonda VR, Yeluri S, Kumari G. Sex determination using maxillary sinus. J Forensic Dent Sci. 2015;7(2):163-7. doi: 10.4103/0975-1475.154595.

16. Angore-Khasbage S, Bhowate R. Utility of morphometry of maxillary sinuses for gender determination by using computed tomography. Dent Med Probl. 2018; 55(4): 411–417. doi: 10.17219/dmp/99622.

17. Amin MF, Hassan EI. Sex identification in Egyptian population using Multidetector Computed Tomography of the maxillary sinus. J Forensic Leg Med. 2012; 19(2): 65-9. doi: 10.1016/j.jflm.2011.10.005.

18. Sharma SK, Jehan M, Kumar A. Measurements of maxillary sinus volume and dimensions by computed tomography scan for gender determination. J Anatom Society Ind. 2014;63(1):36-42.