ORIGINAL ARTICLE

Determination of Gender from Paranasal Frontal Sinuses by Digital Radiography

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ABSTRACT

Background: Establishment of individuality of unknown person is very important in forensic medicine. When only fragmentary remains are available such as skull, the identity can be determined by taking radiographs of frontal sinuses. These radiographs can also be helpful in gender ascertainment.
Aim: To identify significant variables of frontal sinus that could be used to distinguish sex.
Methods: This cross-sectional study was carried out at Outpatient Department of Radiology of Kuwait Teaching Hospital Peshawar Pakistan over a period of six months from March 2017 to August 2017. Posteroanterior digital radiographs of frontal sinus were collected from radiology department of Kuwait teaching hospital Peshawar. Maximum height, maximum width and areas of both frontal sinuses were evaluated in 100 radiographs each for males and females with a total of 200 subjects with age range 18 years to 45 years. Radiant Dicom viewer version 3.4.2 was used to take measurements.
Results: The mean values of frontal sinuses were greater in men as compared to women. All six variables were significant predictors of gender (P<0.05). Right height was better predictor for gender estimation based on binary logistic regression with correct accuracy rate of 68.5%.
Conclusion: Radiography is a low cost and reliable tool for sex determination from frontal sinus.
Keywords: Frontal sinus, Sex determination, Forensic identification

INTRODUCTION

Frontal sinus is an aeric space present inside the frontal bone and is one of the parts of paranasal sinuses of head[1]. Individual identification is a core issue and often one of the important problems in mass disasters, air crashes, fires and road traffic accidents and even in the criminalinvestigation[2].

In the forensic work the most reliable methods of identification are fingerprinting, dental evaluation and comparison and now a day the most important method of identification is DNA profiling. Forensic anthropology is a science which deals with the identification of human remains in a legal context[3]. This specialty specially deals with extreme causes of death e.g. multiple fatality incidents, mutilation and decomposition[2]. Preliminary investigation on skeletonized body relies on age and stature variables which are profoundly dependent on determination of sex.[3] For sex determination skull is a second-best region because it is most preserved Part of the body after death[4]. Due to sexual dimorphic nature of skull and particularly the supra orbital region[5], this area is the focus for present study. The frontal sinus and surrounding supra orbital areas are very resistant to trauma[6]. Male skeletons show bigger, larger and rugged features in skull and skeletal parts such as the pelvis as compared to females, in which the skeleton is relatively small and smooth.[3] Radiography is an easily accessible method for personal identification[7].

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The frontal sinus can play important role in cases of mass disasters, air crashes and railway accidents in deciding the sex of unknown individuals[8]. The size and shape of the frontal sinus is completely formed and unchanged after the age of 20 years and remain stable during the whole life of individual until old age[9,10].

The frontal sinus plays an important role in forensic identification due to its irregular shape and individual characteristics which makes it unique for every person[11]. This morphology may be as unique as a fingerprint, making it useful to identify, even in the case of monozygotic twins[12].

This study was conducted for sex determination with the help of frontal sinus posterior-anterior radiography in Kuwait Teaching Hospital in Peshawar (Pakistan). Logistic regression analysis was done by utilizing the frontal sinus measurements for accuracy of predicting the sex within the given population age range.

MATERIALS AND METHODS

It was a cross sectional study. Digital posteroanterior (PA) radiographs were collected from Outpatient Department of Radiology of Kuwait Teaching Hospital Peshawar, Pakistan from March 2017 to August 2017. The study consisted of 200 radiographs in total, 100 of males and 100 of females. Age ranged between 18-45 years. Healthy adult male and female patients without physical features of asymmetrical skull problems were included in the study group. Patients having facial asymmetries, history of maxillo-facial trauma or any type of systemic disorder like bone diseases e. g. chronic osteomyelitis, osteoporosis or bone cancer were excluded from the study.

The present study was conducted in the outpatient department of radiology of Kuwait teaching hospital Peshawar. The subjects included in the study were patients who performed digital X-rays PA view for their own medical

and allied problems and not specifically exposed to x rays for study purposes and also fulfilling the inclusion criteria. The study approval was taken by institutional ethical committee. Informed consent was taken from all the patients who participated in the study. The study group comprised of 200 patients in the age group of 18-45 years. Out of 200 patients 100 were male and 100 were female. For all patients digital radiographs (Dicom) images in posteroanterior view were taken from Konica Menolta C R 110 x ray unit. Radiant viewer software was used to evaluate the size of frontal sinus. The distance from machine was 90 cm using exposure of 80kv for 1.2 seconds at 80mA. Digital ruler was used for taking maximum height and maximum width of each side. Later area of right and left frontal sinuses were evaluated with the help of measured height and width. The following measurements in centimeters were taken for right and left frontal sinus (i) right height (ii) right width (iii) left height and (iv) left width.

Right area and Left area in cm^2 were computed as follows. Area=Height × Width all the measurements were considered from the portion of frontal sinus that was projected above the superior border of the orbit (form the base line). Frontal sinus was divided into right and left sides on the bases of presences of septum which is always deviated from center. Width of right and left sinus was evaluated from the maximum distance between the medial and lateral lines of the frontal sinus. Height of right and left sinus was measured from the maximum distance between base line and upper limits of frontal sinus.

Statistical analyses were performed using SAS software version 9.3. Left and right areas were computed using heights and widths as described before. Descriptive summary statistics for each variable included means (averages), range and standard deviation for overall sample and individual genders. Inferential analysis included Student's t test for comparison of two independent samples (males and females) and binary logistic regression.

RESULTS

The descriptive analyses presented in Table1 are provided for overall sample (n=200) and for individual gender (n=100 each for male and female). Descriptive summary statistics include means, standard deviations and ranges of each variable. Means of males and females for all response variables are showed in table 1. Comparison of means showed that for all variables, mean values of males were higher than those of females.

Student's t tests for two independent populations (males and females) at 95% confidence level were performed for each variable. The difference in means of genders for each variable along with 95% confidence interval and p-values are reported in Table 2. Standard deviation of difference of means and t statistic values are also provided. All variables were statistically significant with high p values ($p < 0.001$ in all cases). The comparison of t values suggested that right height could be best predictor of gender.

We carried out binary logistic regression to further analyze the data for computation of the variable that could be used for accurate classification of gender. We carried out logistic regression for each independent variable X (left height, right height, left width, right width, left area, right area). Results are shown in Table 3 which contains -2log likelihood estimates for each model along with p values for goodness of fit model. Also included are odds ratio estimates and 95% confidence intervals for odds ratios. The smaller values of -2 log likelihood indicate a better fitted model. From column of p values of Table 3 all independent variables considered were statistically significant predictors of gender. Right height appeared to be most accurate predictor of gender based on -2log likelihood values. This result was consistent with that obtained from Student's t test described above.

Correct classification percentage was determined by computing the probabilities with the cutoff criterion of >0.5 for males. Based on results presented from t test and logistic regression right height was the most suitable predictor of gender with correct classification of 68.5% correct predictions (Table 4). Correct classification results from all variables included in the model were similar to results from right height. We also carried out backward, stepwise and forward selection methods to estimate the best predictors of gender from logistic regression. All three selection methods produced the same model with left height and right height as significant predictor variable.

Table 1: Descriptive summary statistics

Gender	Mean±SD
Age (yrs) (18-45)	
Overall	28.165±8.353
Male	28.570±8.638
Female	27.760±8.082
Right width (cm) (1.28-4.45)	
Overall	2.802±0.727
Male	2.987±0.672
Female	2.618±0.737
Right height (cm) (1.0-3.44)	
Overall	1.856±0.527
Male	2.045±0.502
Female	1.667±0.474
Right Area (cm^2) (1.155-14.792)	
Overall	5.480±2.738
Male	6.369±2.839
Female	4.590±2.327
Left Width (cm) (1.20-4.78)	
Overall	3.082±0.797
Male	3.309±0.779
Female	2.856±0.753
Left Width (cm) (1.20-4.78)	
Overall	2.006±0.615
Male	2.217±0.631
Female	1.794±0.521
Left Area(cm^2) (1.493-18.512)	
Overall	6.522±3.342
Male	7.640±3.502
Female	5.406±2.770

Table 2: Difference of means between genders

Variable	Difference in Means	95% Confidence interval	Stand. Error Difference	Student's t value	P value
Right width (cm.)	0.3689	0.1722-0.5656	0.7054	3.70	0.0003
Right height (cm.)	0.3788	0.2412-0.5163	0.4931	5.43	<0.0001
Right Area ($cm.^2$)	1.7784	1.0546-2.5023	2.5955	4.84	<0.0001
Left Width (cm)	0.4538	0.2401-0.6675	0.7661	4.19	<0.0001
Left height (cm)	0.4229	0.2615-0.5844	0.579	5.17	<0.0001
Left Area($cm.^2$)	2.2339	1.3535-3.1144	3.1569	5	<0.0001

Table 3: Binary logistic regression models from individual predictors

Independent Variable	-2 Log likelihood	P value	Odds Ratio Estimate	95% Confidence Interval for Odds Ratio
Right width (cm.)	263.996	0.0003	2.093	1.384-3.164
Right height (cm.)	249.404	<0.0001	4.4875	2.542-9.351
Right Area ($cm.^2$)	254.435	<0.0001	1.319	1.163-1.495
Left Width (cm)	260.452	<0.0001	2.150	1.465-3.156
Left height (cm)	251.870	<0.0001	3.617	2.088-6.266
Left Area($cm.^2$)	253.324	<0.0001	1.257	1.137-1.389

Table 4: Counts and Percentages for Correct Classification

Independent Variable	Male % Correct Classification	Female % Correct Classification	Overall Counts, % of Overall Correct Classification
Right width (cm.)	59	5	118, 59
Right height (cm.)	64	73	137, 68.5
Right Area ($cm.^2$)	57	68	125, 62.5
Left Width (cm)	64	66	130, 65
Left height (cm)	62	66	128, 64
Left Area($cm.^2$)	57	71	128, 64
Left & Right Heights (cm)	66	69	135, 67.5
All variables	68	69	137, 68.5

DISCUSSION

The primary goal of this study was to use digital PA radiographs of frontal sinus for assessing sexual dimorphism in a population of age ranging from 18-45 years. The left and right heights, left and right widths, and left and right areas were measured in a sample of 100 males and 100 females (n=200). The mean age of overall study cohort (n=200) was 28.2 years; whereas, the mean ages for males and females were 28.6 and 27.7 years respectively. Both genders were comparable with respect to age. Median ages were also similar between two genders (males 25 years; females 25.5 years). Means of all variables of interest were consistently higher for males as compared to females. To evaluate the statistical significance of the differences between males and females, Student's t tests were carried out for considered variables. The assumptions for validity of Student's t test were verified. All p values from Student's t test were highly significant (all p values <0.001) Comparison of t statistics for each variable suggested that right height (t=5.43) could be the single best predictor of gender. This was further confirmed from binary logistic regression analysis presented in Table 3 where -2log likelihood was smallest for right height. All variables were highly statistically significant in simple binary logistic regression models in agreement with t tests (all p values <0.001).

The number of correctly classified gender obtained from right height was 137 which accounted for 68.5% correctly classified gender in overall cohort of 200 patients (Table 4). The second-best single predictor of gender turned out to be left height (64% correctly classified gender).

With all variables in the logistic model, correct classification rate (68.5%) did not improve and was consistent with that of right height as a single predictor. Using stepwise, backward and forward selection methods for multiple logistic regression, a model containing both right and left heights as predictors turned out to be the best model.

In this study we adopted a methodology which was similar to one described in previously conducted studies including.[13-15] Our measurements of frontal sinus were little bit higher than those reported in other studies, but the results from other studies also differed from one another possibly due to some differences in patient cohorts. As an example, among females the average left width in our study was 2.86 cm; whereas Neha et al[14] reported 2.94 cm, Soman et al[15] 2.61cm and Belaldevar et al reported 1.94cm. Similarly, for males, we computed average left width to be 3.30cm; however, Belaldavar et al[11] estimated the average left width for males to be 2.33cm. Even though Table 1, difference between the means of males vs. females for all response variables each study aimed at including healthy subjects only, healthy subject selection criterion could also be attributed for variations in measurements. In addition to some differences in selection procedures, the difference in measurements of variables from different studies could also be ascribed to independent development of frontal Sinus or due to genetic disposition or changes in environment and dietary habits[16].

Our study showed that all six variables were highly significant predictors of gender (p values from all t tests and binary logistic regression models were less than 0.001). Our results were consistent with those of Neha[14] et al, Camargo et al[13] and Belaldavar et al[11] and different from Soman et al[15].

We found that the tendency of the left side to be larger than the right side in our study was in agreement with other studies.[17] Right height turned out to be best

predictor of gender. The correct classification rate was 68.5% with concordance index of 72%.

For best predictor, our study results were different from other studies conducted in regions of Southeast Asia. Different results for best predictor in studies could be explained by genetic and environmental factors which control the configuration of frontal sinus in each population.

CT scans and x-rays performed during dental and medical treatments are useful tools in forensic investigation especially in the skull.[7] There is a need to set up a reliable, low cost and easily reproducible procedure for human identification specially in reference to sex determination through elaboration of technical and accessible parameters.[7] This can be fulfilled by use of digital radiographs.

CONCLUSION

All six evaluated variables (Right and left height, Right and left width, Right and left area) were significant predictors for gender determination. Right height of frontal sinus was most suited regression for sex determination. Accuracy rates for different variables ranged between 59% (right width) to 68.5% (right height). All other variables provided accuracy rates over 62%. The results for correct prediction from some variables such as right width was modest, yet it is better than mere chance for predicting gender in severely tarnished and unrecognizable bodies or from fragmentary remains available. For sex determination, logistic regression analysis is an easier method for confirmation of gender compared with techniques such as discriminant functional analysis. Radiography can play a key role in establishing the identity of a person due to its convenience, reliability and low cost.

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