ISSN- O: 2458 - 868X, ISSN–P: 2458 – 8687
Index Copernicus Value: 49. 23
PubMed - National Library of Medicine - ID: 101731606

International Journal of Medical Science and Innovative Research (IJMSIR)
IJMSIR : A Medical Publication Hub
Available Online at: www.ijmsir.com
Volume – 3, Issue – 5, October - 2018, Page No. : 102 - 110

Role of frontal sinus in gender determination and personal identification using PA view of skull - A digital radiographic study

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Type of Publication: Original Research Paper

Conflicts of Interest: Nil

Abstract

Introduction: identification of a person is very important after an unfortunate natural calamity or criminal cases. If the body is decomposed and only skeletal fragments are available, identity of an individual is retrieved from the skeletal remains and provides the opportunity for gender determination and personal identification. Forensic radiology plays a vital role in identification of a person. Among various skeletal features, frontal sinuses are found to be unique and showed various variations.

Aim of study: To determine whether frontal sinus measurements can be used for gender determination and personal identification.

Materials & method: 300 digital PA Cephalometric view radiographs obtained from 150 males and 150 females aged between 20-45 years. The measurements were carried out by transferring the image to Adobe Photoshop7.0 software. Parameters considered were height, width and area of right & left sinus along with bilateral symmetry or asymmetry, the outline of the upper border of the sinus (no. of scalloping) and the presence or, absence & no. of the partial septa. Comparisons of values were done using unpaired t test and chi square test and accuracy of sex determination was assessed through Logistic regression analysis.

Result and conclusion: Among 300 individual, 8% showed absence of frontal sinus. The area of frontal sinus had a significant p-value for gender determination along with the symmetry of sinuses and the presence of number of partial septa in them. Stepwise regression analysis showed the right area of the frontal sinus being the most suited regression in gender determination with the accuracy rate in the classification of males and females being 64.7%. Also different morphological parameters of frontal sinus being different and specific in different

individuals proved the uniqueness of frontal sinus in personal identification if ante-mortem records exist.

Keywords: frontal sinus, forensic radiology, gender determination, personal identification.

Introduction

Personal identification is defined as establishing the identity of an individual. The need for personal identification arises in mass disasters like earth quakes, tsunamis, landslides, floods etc, apart from terrorist attacks and bomb blasts etc.[1]When human remains are found, the first priority of investigators is to identify who the individual was in life for social, religious and criminal investigation purpose. It can be identified through a series of methods including fingerprints analysis which is still considered to be the most widely adopted method of personal identification when the soft tissues are preserved. However, when the cadaver is carbonized or, in skeletal form, where the remains are completely or, mostly skeletonized or, in which decomposition or, deformation of soft tissues negates the probability to perform an autopsy or, collect fingerprints, identification of the deceased is chiefly achieved by utilizing physical anthropological procedures including forensic radiology and odontology.[2] The importance of imaging techniques in forensic medicine is, also, widely recognized. Forensic anthropologists and odontologists routinely rely on the comparison of ante-mortem and post-mortem radiographic plates to establish the identity of an individual. Forensic sciences require an integrated, multidisciplinary approach for criminal identification and one of the most important fields in this is forensic radiology. Forensic radiology has been used enormously in conventional dental identification. It is based on the anatomy as well as the comparisons of the skeletal landmarks in both the ante-mortem and the post-mortem records.[3] Several structures like sella turcica, mastoid air cells, paranasal sinuses and particularly, the frontal sinuses have been utilized for this purpose due to their unique size and pattern with respect to every individual.[4]

Schuller in 1921 first studied the frontal sinus and revealed information about its uniqueness in shape, complexity and individuality which, also, included human identification in various post-mortem cases. Since then, several authors have used frontal sinus for forensic purposes.[5]The frontal sinuses are paired, irregularly shaped, pneumatized cavities located in the frontal bone deep to the superciliary arches. These sinuses develop by the age of 2 years and are visible radiographically by around the age of 5 years. The sinuses grow slowly until puberty, then, rapidly, until completing their growth at approximately 20 years of age.[6] Among the paranasal sinuses, frontal sinuses are the one that are of most interest and significance in forensic identification due to their ir-regular shape and because of individual variations which make the frontal sinus unique for every individual just as fingerprints. The major factors that can modify the normal sinus include trauma, surgery and pathology.[5] Since changes in adult sinuses are rare and sinuses remain generally stable throughout the life of an individual, they serve for stable landmarks to be compared for an individual's identification if ante-mortem and the post-mortem records exist.[5,6,7]. The present study was planned to assess the anthropological significance of frontal sinus for gender determination and personal identification using the most easy and convenient radiographic method, postero-anterior (PA) cephalometric skull view, which, also, helped in gross examination of the skull.

Materials and Method

After obtaining the institutional ethical clearance, the present study was done on 300 individuals including 150 males and 150 females, selected randomly visiting to the Out Patient Department (OPD). The inclusion criteria was healthy individuals in the age range of 20-45 years while exclusion criteria were all factors which could affect the

parameters of frontal sinus including trauma, pathology or, surgery of skull, any history or, clinical characteristics of pathology of the sinus, endocrine disturbances, nutritional deficiency or, hereditary facial asymmetry and individuals below and above the age range selected. After thorough clinical history, written informed consent was obtained and the subjects who were enrolled in the study were examined to rule-out the presence of any gross developmental anomaly and/or, systemic disease affecting the normal development and facial growth. For radiographic examination, with all protection barriers, the standard cephalometric-posteroanterior view of the skull was obtained by keeping standard manufacturer's parameters and, the image was stored in the computer. All radiographs were taken by same radiologist to overcome any technical error.

For radiographic interpretation, the radiographs with sufficient diagnostic details of the frontal sinus were selected and used to evaluate the desired indices including the height, width and area (right and left sides) along with the bilateral symmetry or, asymmetry depending upon the area of the frontal sinus studied apart from the outline of the upper border of the sinus (no. of scalloping) and the presence or, absence of the partial septa and their number were seen. All the radiographs were transferred to Adobe Photoshop 7.0 software and calculations were made. All the measurements i.e. height and width were considered from the portion of frontal sinus projected above the superior border of the orbit with reference to a baseline that was drawn from the superior border of the orbit. The height of right and left frontal sinus were evaluated from the maximum distance between the base and upper border of the sinus. Width of right and left sinus was evaluated from the maximum distance between the medial and lateral borders of the sinus. Both the height and width of the sinus were recorded in centimeters. To record the area of each frontal sinus, grids were used in the software with each cube of the grid being with an area of $1cm^2$. The number of the cubes expressed in terms of cm^2 directly gave the surface area of the sinus. To evaluate symmetry of the sinuses, the area covered by them was considered and sinuses with equal area were considered as bilaterally symmetrical. No. of scalloping seen in the sinuses were, also, counted and presence or, absence of partial septa was evaluated with their no. in each sinus.

Results

The mean age for the males was found to be 30.42 years with a standard deviation 5.716 while in case of females, the same was found to be 29.45 years with a standard deviation of 6.350 by using unpaired t test. Furthermore, the frontal sinus was studied and comparison was done for the area, width and height of right and left sinus among males and females using unpaired t-test. The mean area of the right sinus was found to be more amongst the males (5.120±3.284) than females (3.732±2.001) with the p-value being highly significant i.e. <0.001. The results, also, showed that the area of the sinus represented significant results with the p-value being highly significant i.e. <0.001 in case of right sinus while significant with p = 0.002 in case of the left sinus. The corresponding t values were found to be 4.447 and 3.172 respectively. The mean value for the area of right sinus was, also, found to be higher for males (5.120±3.284) than females (3.723±2.001). Similar results were seen for the area of the left sinus with the males having a mean value of 5.020 as against 3.970 obtained for the females with a SD of 3.435 and 2.152 respectively. In relation to the maximum width of right and left sinus, the results showed the mean of max width of right sinus being slightly higher (2.832±1.382) than that for females (2.757±1.041) while on the contrary, in case of left sinus, the mean of max width of left sinus was found to be slightly lesser in the males (2.781±1.408) than as compared to the females (2.818±1.124). The p-values were, though, found to be

statistically insignificant being p > 0.05. The mean of the max height of the right sinus was, also, found to be lesser in males (1.286±0.854) than as compared to the females (1.442±0.750). The mean of the max height of the left sinus, on the contrary, was observed to be slightly higher in the males (1.464±0.973) as compared to the females (1.388±0.802), again, with insignificant p-values i.e. 0.094 and 0.461. (Table 2) Regarding the comparison of the symmetry of sinus among males and females, chi square test was used. Among 150 males, symmetry of sinuses was present in 21.3% (n=32) while asymmetrical frontal sinuses were present in 66.7% (n=32) of the studies sample. The notorious finding was the absence of frontal sinus in 12% (n=18) of the males. In females, 27.3% showed symmetrical sinuses while asymmetry of the sinus was observed in 68.7% (n=103) of the females. Furthermore, in 4% (n=6) of the females, frontal sinus was found to be absent. In total of 300 individuals studied, the frontals sinus was found to be absent in 8% of the studied sample while 67.7% of the sample showed asymmetry and 24.3% showed symmetrical sinuses with a significant p-value of 0.028. (Table 3) On comparison of the no. of scalloping and no. of partial septa in the sinuses using unpaired t-test, the results were found to be statistically significant in relation to the no. of partial septa in females as against the males in relation to the left sinus with the t value being 2.315 and p-value being 0.021. (Table 4) Stepwise regression analysis showed the right area of the frontal sinus being the most suited regression in gender determination with the accuracy rate in the classification of males and females being 64.7%. (Table 5)

Table 1: Comparison of age in terms of {Mean (SD)} among males and females using unpaired t test

Gender	N	Mean	Std. Deviation	t value	P value
Males	150	30.42	5.716	1.386	0.167
Females	150	29.45	6.350		

Table 2: Comparison of area, width and height of right and left sinus in terms of {Mean (SD)} among males and females using unpaired t test

	Gender	N	Mean	Std. Deviation	t value	p-value
Area of right sinus	Males	150	5.120	3.284	4.447	<0.001**
	Females	150	3.723	2.001		
Area of left sinus	Males	150	5.020	3.435	3.172	0.002*
	Females	150	3.970	2.152		
Max width of right sinus	Males	150	2.832	1.382	0.533	0.594
	Females	150	2.757	1.041		
Max width of left sinus	Males	150	2.781	1.408	0.254	0.800
	Females	150	2.818	1.124		
Max height of right sinus	Males	150	1.286	0.854	1.680	0.094
	Females	150	1.442	0.750		
Max height of left sinus	Males	150	1.464	0.973	0.738	0.461
	Females	150	1.388	0.802		

(p< 0.05 - Significant*, p < 0.001 - Highly significant**)

Table 3: Comparison of symmetry of sinuses among males and females using Chi square test

			BILATERAL SYMMETRY OF SINUSES			Total
			Symmetrical	Asymmetrical	Absent	
Gender	Males	Count	32	100	18	150
		% within Gender	21.3%	66.7%	12.0%	100.0%
	Females	Count	41	103	6	150
		% within Gender	27.3%	68.7%	4.0%	100.0%
Total		Count	73	203	24	300
		% within Gender	24.3%	67.7%	8.0%	100.0%
Chi square value: 7.154 P value: 0.028*						

(p< 0.05 - Significant*, p < 0.001 - Highly significant**)

Table 4: Comparison of no of scalloping and septa in terms of {Mean (SD)} among males and females using un paired t test

	Gender	N	Mean	Std. Deviation	t value	P value
Outline of upper border (no of scalloping) right	Males	150	2.44	1.44	1.136	0.257
	Females	150	2.61	1.06		
Outline of upper border (no of scalloping) left	Males	150	2.34	1.40	1.012	0.312
	Females	150	2.49	1.07		
No of partial septa (in right sinus)	Males	150	0.70	0.83	0.077	0.939
	Females	150	0.69	0.65		
No of partial septa (in left sinus)	Males	150	0.6	0.69	2.315	0.021*
	Females	150	0.8	0.69		

(p< 0.05 - Significant*, p < 0.001 - Highly significant**)

Table 5: Measurements of association between estimated probabilities and observed responses.

Parameters	Logistic regression y=a + bx	P for b	-2log LL	x^2 for model fit	P value	% of overall corrected classification
Right (Area)	**Y= -0.195 + 0.855x**	**<0.001****	**396.342**	**19.546**	**<0.001****	**64.7**
Left (Area)	**Y= -0.129 + 0.579x**	**0.002***	**405.902**	**9.987**	**0.002***	**50**
Right(Width)	Y= -0.051 + 0.142x	0.593	415.602	0.286	0.593	50
Left(Width)	Y= 0.023 + (-0.065)x	0.799	415.824	0.065	0.799	50
Right(Height)	Y= 0.245 + (-0.333)x	0.096	413.048	2.840	0.092	50
Left(Height)	Y= -0.096 + 0.137x	0.460	415.341	0.548	0.459	50

Discussion

Individual identification is of prime importance in mass disasters, road traffic accidents, fire accidents and in criminal case investigations. Fingerprint analysis, DNA matching and anthropological studies can facilitate the process of individual identification. However, in cases of remains being burnt or, decomposed or, where DNA is severely damaged, finger print analysis and DNA identification cannot be used and in such cases, anthropological methods with the help of comparative radiography have proved to be a major tool.[8] The word "Forensics" come from the Latin word, "Forens (is)" which means belonging to the forum, public or, equivalent to. At present, the globally accepted definition of forensics is "the use of science and technology to investigate and establish facts in criminal or, civil courts of law."[3]

Forensic anthropology is the application of the science of physical anthropology and human osteology in a legal setting, most often, in criminal cases where the victim's remains are in their advanced stages of decomposition to assist in the recovery of remains, assess age, sex, stature, ancestry, race and analyze trauma or, disease.[9]

Personal identification is a fundamental topic of forensic sciences and technologies to identify living subjects, recently deceased bodies and human remains, often, at a crime scene by using several appropriate techniques.[10] Application of radiology in forensic sciences was introduced in 1896, just a year after the discovery of X-rays by Sir Wilhelm Conrad Roentgen, by Prof. Arthur Schuster to demonstrate the presence of bullet inside the head of a victim.[11]

Various authors have discussed the use of different skeletal components of human body for sexual dimorphism. Among the paranasal sinuses, frontal sinuses are the one that are of most interest and significance in forensic identification due to their irregular shape and because of individual variations which make the frontal bone unique for every individual just as fingerprints. The major factors that can modify the normal sinus include trauma, surgery and pathology.[5] It is widely accepted that the frontal sinus remains stable until further enlargement of the chambers occurs as a result of bone resorption only during advanced ages.[12]

Yoshino M et al[13] conducted a radiographic study in Japanese skulls by considering parameters like area, bilateral symmetry, superiority of side, outline of the upper border, presence of partial septa and the supra-orbital cells and divided frontal sinus into 20,000 possible patterns and concluded that frontal sinus allowed characterization of a person.

The present study was, therefore, planned to assess the anthropological significance of frontal sinus for gender determination and personal identification using the most easy and convenient radiographic method, postero-anterior (PA) cephalometric skull view, which, also, helped in gross examination of the skull. In total of 300 individuals

studied, the frontals sinus was found to be absent in 8% of the studied sample while 67.7% of the sample showed asymmetry and 24.3% showed symmetrical sinuses with a significant p-value of 0.028 similar to the study conducted by Verma S[14] while the study conducted by Nikam SS et al[15] found 5.5% absence of frontal sinus and Belaldavar C et al[12]found bilateral absence in 0.6% (1 subject) of males and 2.66% (4 subjects) of females. Bilateral aplasia was reported in 13.8% of the total population studied in found in another study.[16]

The results of the present study, also, showed that the area of the sinus represented significant results that could be used in gender determination as well as personal identification similar to the plethora of studies conducted in the past[1,5,7,17,18,19,20,21,22,23] while few studies, also, reported the need for further studies to prove the role of frontal sinuses to be used for forensic anthropological procedures[14,24,25,26].

In the present study, area of frontal sinus was found to be highly significant in gender determination, a finding that was found similar to the results of the studies conducted in the past[5,7,19,21], however, the area in relation to the right sinus was found to be more in the males as against females contrary to the studies conducted by Tiwari P et al[1] and Camargo JR et al[5] who had found left area to be more significant. In few of the studies, height and width of the sinus were, also, found to be significant for gender determination[17,21,22], however, in the present study, results related to the height and width were found to be statistically insignificant.

Eboh DE et al[22] conducted a study to determine the dimorphic potential of the frontal sinuses and to ascertain the accuracy in sex determination using the logistic regression model among Edo people of Nigeria. The results of their study showed all dimensions pertaining to the sinus to be higher in males than in females with the left side height and width being with statistical significance ($p < 0.05$). Left side frontal sinus width gave the highest accuracy of 60% in sex determination using logistic regression analysis while the present study got an accuracy of 64.7% for gender determination by using logistic regression analysis.

Kullman L et al[27] had taken two radiographs with varying beam angulations and compared ante-mortem and post-mortem radiographs with 100% success. Rubelo KA et al[28] and Suman JL et al[29] studied frontal sinus by considering various parameters, also, used in the present study including the area, height, width, superiority of the upper border, outline of the upper border and the presence or, absence of partial septa seen and concluded that the said parameters represented various combinations which are unique for each individual and that they could be used for identification of an unknown individual when previous records were available.

In the present study, significant p-values were obtained in relation to the symmetry of the sinuses and for the presence of the number of partial septa seen in relation to the left sinus apart from various combinations of the scalloping with different number of arcades and presence or, absence of partial septa with various combinations revealing the uniqueness of frontal sinus in the determination of gender and for personal identification similar to the results of the previous studies conducted.[15,28,30]

In contrast to the above mentioned studies, few authors, also, found no relationship between frontal sinus and gender determination and personal identification.[24,25]To summarize, stepwise regression analysis in the present study showed the right area of the frontal sinus being the most suited regression in gender determination with the accuracy rate in the classification of males and females being 64.7% in coherence with the other such studies which got an accuracy of 64.6%[12], 67.59%[18]to 76.9% [31] to a little more on the higher end of 79.7% [5.]

Conclusion

The results of the present study revealed that the area of frontal sinus had a significant p-value for gender determination along with the symmetry of sinuses and the presence of number of partial septa in them, especially, the left sinus as was found in the present study.

In the present study, morphometric indices of the frontal sinus were able to identify correct gender in 64.7% of the cases. There was a difference in the number of scalloping of the superior border of the sinus, presence or, absence of septa and the number of partial and complete septa seen.The present study showed different morphological parameters of frontal sinus being different and specific in different individuals, thus, proving the uniqueness of frontal sinus in personal identification if ante-mortem records exist. Further studies are, however, warranted to further evaluate the role of frontal sinus for gender determination and personal identification.

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Figures