NARRATIVE REVIEW

Anthropological significance of sexual dimorphism and the unique structural anatomy of the frontal sinuses: Review of the available literature

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Abstract

Frontal sinuses have unique anatomical features that are distinct to every individual. Radiographic measurement of the frontal sinus is becoming popular in identifying deceased persons in cases where soft tissue remains are not found such as in cases of mass explosions and natural disasters. The aim of this review article is to highlight the significance of employing the method of radiography of frontal sinuses in the process of identification of human bodies. With the use of Pubmed, Medline and Embase, articles on frontal sinus anthropological significance were analyzed from 2015 till 2018. Sexual dimorphism was evident between the two genders. The dimensions are bigger for the males as compared to the females. The left sinus has bigger dimensions as compared to the right frontal air sinus. The reliable use of the radiographic technique is a simple and cost effective method of knowing identity even when the body is severely decomposed.

Keywords: Frontal sinus, Anthropology, Forensic science, Radiography, Sexual dimorphism.

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Introduction

Our society demands identification of individuals. Proof of identity is imperative for both the living and the dead. With the passage of time catastrophes like earthquakes, tsunamis, bomb blasts, fatal road and air crash accidents along with mass explosions have increased and identity of severely mutilated bodies has become a challenge. Identification of the deceased is of utmost importance for both the social as well as medico-legal reasons. The identification of the bodies is not only required merely for the social and the medicolegal purpose but also for religious reasons. The way of burial of the bodies vary among the different religions. The burial remain pending till the identification process is completed.[1] The field of forensic science along with anthropology is employed in doing this onerous and demanding task. The forensic science experts are able to identify the individuals on the basis of their distinct anatomical features.[2] The use of technology in the field of forensic science with great expertise has led to great assistance in determining the identity of the deceased.[3] Different techniques are incorporated in the process of identification. Humans can be identified by facial features. In instances when facial features are not appreciated due to disfigurement of the face soft tissue sampling technique using finger and lip printing can be employed for the identification purpose. The deceased can also be identified by DNA sampling but in occurrences when the body is highly putrefied, skeletonized and disintegrated, soft tissue and DNA technique cannot be incorporated due to chemical modification of tissue structures.[4] In such cases hard body structures like teeth and bones can be used for the purpose of identification. Those bony parts can be used for identification which resist destruction even when substantial detonation or raise of temperature occurs.[5] Other than the property of toughness of the structure, there are two other factors which help in identifying the unknown persons. One is the unique morphology of the structure that makes it an identity tool, the other being the stability of the structure over the period of time.[6-8] In anthropological radiographic identification, the skull has proved to be having a very useful value. The forensic experts are employing the structural anatomy of paranasal sinuses for detection of the unknown persons.[5] Research articles have proved the significance and distinctive anatomical features of frontal sinus in human identification.[9,10] The aim of this review article is to highlight the significance of employing simple yet cost effective method of frontal air sinus radiography in the process of identification of human bodies when they are in a state of disfigurement. The method is an easy alternate to the complex, expensive and time consuming procedures like finger printing and DNA analysis.

Importance of frontal sinus in forensic anthropology

Forensic anthropology deals with the identification of individuals based on variation in the structural anatomy. This discipline caters the perplexing job of identification through the presence of human remains. A study

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published in Annals of International Medical and Dental Research documented that frontal sinuses have very resilient and tough walls which safeguard the frontal sinuses anatomy even in adversities like massive explosions and bomb blasts. Other than the thickness of the frontal bone, the convexity of its structure keep it safe within the skull.[11] The two sinuses develop separately by the process of pneumatization and that becomes the basis for the characteristic features of frontal sinus in every individual.[12] In a radiographic study, Patil N reported distinctiveness of frontal sinuses even when they were matched by the blind technique involving three different onlookers. This research clearly demonstrates the reliability of frontal sinus unique anatomy in identification of human beings. It was also mentioned in the study that frontal sinuses structure is so safely located within the skull that even it resists damage and destruction when there are multiple skull fractures present.[13] A study article published by Kirk N also highlighted the reliability and accurateness of frontal sinus radiographic matching between the ante-mortem and post-mortem radiography. The study also emphasized the importance of good quality imaging that is the prerequisite for correct matching procedure.[14] Many researches have been conducted which testify the peculiar characteristics leading to sexual dimorphism of frontal air sinuses in males and females.[15-19] Nethan proposed environmental as well as genetic factors contributing to the variation of frontal sinus structural dimensions.[15,20,21] The basic difference which is reported in many articles is the presence of large frontal sinus in males as compared to the females.[15-19] On the contrary few articles have reported no statistically significant differences between the two genders.[15,22] A Saudi study research article published in 2017 by Tatlisumak E documented bigger sizes in females as compared to males in the age group between forty to forty nine years while bigger sizes were documented for males in the age group of more than seventy years.[7] There are many research articles which indicate the differences of frontal sinus dimensions between the left and the right sides.[11,13,18] The left frontal sinus measurements in terms of width, height and area were found to be larger in dimensions as compared to the right side.[21,22]

Radiographic imaging for frontal air sinuses morphology

The identification of individuals on the basis of matching of radiographs dates back to 1928 when two researchers Culbert and Law used radiography for that purpose.[23] Forensic radiology is a field that is a sub part or category of the forensic sciences. From the beginning of the 20th century radiography has been employed by forensic experts for detection and identification of human remains. The advantage of this technique lies in the fact that humans can be identified based on distinct anatomical structures that are unique to every human being. The radiological imaging serve as an efficacious yet economical tool to recognize distinctive human structures like paranasal sinuses, teeth, pelvis and long bones.[24] The cost effectiveness, quickness and ease of the procedure make it superior to DNA identification technique especially in cases where body is extremely charred and scorched. Frontal sinus morphology spotted on radiographs is unique to every individual as is the case of finger printing.[25] The distinct and diverse morphological characteristics of frontal sinus were for the very first time studied by Schuller. The article was published in 1943 in the Medical Journal of Australia.[26] The ante-mortem radiographs of a person taken for ruling out paranasal sinusitis or taken for dental and routine faciocranial diagnostic procedures assessment can be compared with the post-mortem radiographs to show characteristic features common to both. Many research articles have documented the significance and importance of frontal sinus radiography in forensic anthropology.[26-30] There are two radiographic views which are used to visualize frontal air sinuses.[11,16] One is the Caldwell view and other is known as the Water's view. Caldwell view is also known as occipitofrontal view.[16] The other name for Water's view is occipitomental view. In the clinical setting it is the Water's view which is mostly prescribed for ruling out para nasal sinusitis and therefore can be used for the purpose of comparing the antemortem with the post mortem radiographs.[11]

Methods

The articles were searched on the search engines PUBMED, MEDLINE and EMBASE from the period of January 2015 till December 2018. The key words used were frontal sinus, anthropology, forensic science, radiography and sexual dimorphism. The inclusion criteria for the articles were to be in English language, frontal sinus radiography in humans and anthropological importance of frontal sinus. The exclusion criteria was articles in languages other than English and cadaveric measurement of frontal sinus. The articles which did not mention the methodology and statistics were not included. In total 20 articles were selected for the research article. No approval was taken from the Ethical review committee as it was a research article.

Result

Literature review presented results that were similar to the ones that were published earlier by other

Table-1: Comparison of frontal air sinuses height.

Name of the author	Year of publication	Number of participants	Right frontal sinus		Left frontal sinus	
			Males	Females	Males	Females
Chaudhary[11]	2016	50	1.75	1.47	1.85	1.54
Soman[19]	2017	200	1.12	1.19	1.50	1.32
Eboh[16]	2017	129	3.86	3.63	397	3.59
Nethan[15]	2018	100	1.6	1.4	1.9	1.66
Sheikh[21]	2018	100	3.43	3.03	3.47	3.15

Table-2: Comparison of frontal air sinuses width.

Name of the author	Year of publication	Number of participants	Right frontal sinus		Left frontal sinus	
			Males	Females	Males	Females
Chaudhary[11]	2016	50	2.62	2.16	2.97	2.58
Soman[19]	2017	200	2.36	2.24	2.92	2.61
Eboh[16]	2017	129	3.41	3.36	3.65	3.21
Nethan[15]	2018	100	2.58	2.48	2.90	3.1
Sheikh[21]	2018	100	2.85	2.69	3.29	3.01

Table-3: Percentage of unilateral and bilateral aplasia of frontal air sinuses.

Name of the author	Year of publication	Number of participants	Unilateral aplasia Reported numbers with percentage	Bilateral aplasia Reported numbers with percentage
Verma P[22]	2015	149	11 (7.38%)	8 (5.36%)
Nikam[17]	2015	109	3 (2.75%)	6 (5.50%)
Saraswathi[29]	2016	80	2 (2.5%)	4 (5%)
Nagaraj T[12]	2017	280	16 (5.7%)	13 (4.6%)
Moore K[10]	2017	392	9 (2.29%)	8 (2.04%)

authors.[13,14] All the research articles documented the measurement of height of right and left frontal sinus to be more in males as compared to the females. The mean height for the left and right sinuses were closer in range in articles published by Chaudhary,[11] Soman[19] and Nethan.[15] The dimensions were found to be more in South Nigerian population and in Maharashtra population (Table-1). The articles reported the dimensions of left frontal air sinus to be more in comparison to the right frontal sinus in males as well as females. Overall, in all the articles the parameter of the width was also measured to be more in males as compared to the females (Table-2). The dimensions for the left side were calculated to be more as compared to the other side between the two genders. Aplasia or agenesis of frontal air sinuses can be unilateral as well as bilateral. Like the parameters of height and width, aplasia of frontal air sinus also carries significance in the identification of the unknown bodies as there is variability in the presence of aplasia in individuals (Table-3). A research article published in the Annals of International Medical and Dental Research, documented presence of both bilateral as well as unilateral aplasia when analysis of the radiographs was done. The frequency unilateral aplasia was reported to be more as compared to the presence of bilateral aplasia. The unilateral agenesis was reported in 6 percentage of the research subjects, while the bilateral aplasia was documented to be 2 percent.[11]

Similar results were observed in a study that was published in the Journal of Medicine, Radiology, Pathology & Surgery. In the research, the unilateral aplasia of the frontal air sinuses was documented to be 5.7 percent in the study subjects against the bilateral aplasia of 4.6 percent.[12] A digital radiographic study mentioned that 13 out of 117 study subjects (11.11 percent) had unilateral aplasia while eight participants (6.83 percent) had bilateral agenesis of the frontal air sinuses.[22]

Another research also documented the prevalence of unilateral aplasia to be greater against the bilateral

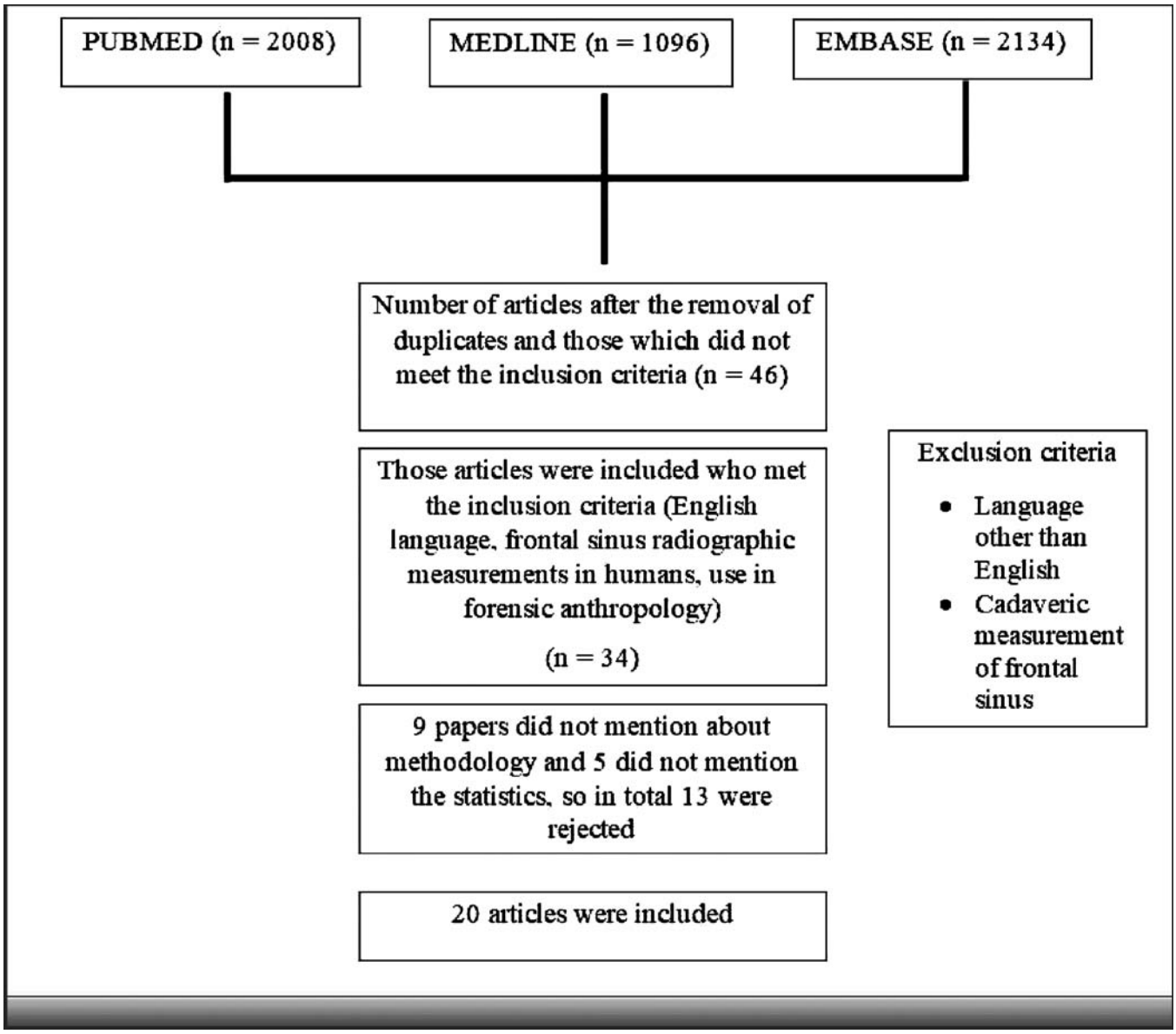

Figure: Articles search for the narrative review.

aplasia. The unilateral aplasia was observed in twenty four out of 305 study participants (10.16 percent) and bilateral aplasia was in 8 out of 305 individuals (2.62 percent).[31]

A research on the Indian subjects revealed the prevalence of the bilateral and the unilateral agenesis of the frontal air sinuses in the sample. Bilateral aplasia was observed in 10.416 percent of subjects; 9.23 percent of the males and 12.9 percent of the females. The total prevalence of unilateral left sided aplasia was documented to be 4.16 percent while on the right side the unilateral aplasia was 3.125 percent.[32]

The anatomical configuration of frontal sinus is helpful in identifying the bodies of the deceased. Both morphological as well as morphometric structures have characteristic features, which cannot be found in any other person. The morphological characteristics of frontal sinuses include presence of septa, location of midline septum as well as scallops with arcades. There were in total three persons with partial septa in the frontal air sinuses, reported in the study population out of the ninety nine study subjects. Out of the three, two were noticed in the males and only single was noted in the female participants. The partial septa in females were noted in left frontal air sinus. In the males, there was one

person with partial septa on the right and another person with left side respectively.[33]

Other than the morphometric variability between the right and the left frontal air sinuses, morphogenic chracteristics also appear to be different. A study observed the presence of partial septum in the frontal air sinuses. There were in total four hundred research participants. It was documented that a single partial septum was observed in 96 study subjects on the left side and the percentage was 26.1 percent. In total, there were 128 people with single septum on the right side (34.8 percent). In forty individuals, there were two partial septa on the left side (10.9 percent) while in the right frontal air sinuses it was 7.6 percent. Three partial septa were noted in nine individuals each on the left and the right sides; the percentage was calculated to be 2.4 for both sides individually.[34]

Discussion

The results of the above mentioned research articles clearly demonstrate the variations present between the left side and the right side. The dimensions of the left sides were more as compared to the right. Sexual dimorphism is also evident as the dissimilarities are noted between the two genders. The parameters of height, width and area in males are bigger as compared to females. In terms of proportion there are more articles which documented symmetry as compared to asymmetry between the two sinuses in an individual. The study articles on frontal sinus morphological identification clearly show the significance of knowing the anatomical knowledge and its application in forensic anthropology in disaster as well as criminal cases. As the data bank is maintained worldwide for the fingerprints, similarly there is need to maintain data software for the radiographs taken for sinusitis and dentistry diagnosis. The hospital data should be kept safe and available to the forensic team experts whenever there is a need. The data bank can be used in comparison with the antemortem and the post mortem radiographs so that in case of a disaster, identification of the bodies can be done with certainty, as this method is effective, doable and dependable. The quality of radiographs is also a matter of concern. Good quality radiographs are easier to comprehend, analyze as well as to compare. There is also a need to conduct more research on the anatomical diversity of frontal sinus morphology with greater sample size so that the results of the studies can be generalized. This way the frontal sinus radiography can become a common identification tool and can be used with authenticity.

Conclusion

World over with the advancement in forensic science and technology, different methods have been adopted by the forensic experts to identify the bodies of unknown individuals. Finger printing and DNA analysis although are effective methods but cannot be used in cases when the bodies are severely mutilated and disintegrated. In such difficult situations frontal sinus radiography can be useful for identification of the human bodies due to their unique and distinctive anatomical features.

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