Original Article

Frontal Sinus Dimensions: An Aid in Gender Determination in Adult Nigerians

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ABSTRACT

Background: The morphometry of the frontal sinus (FS) is important in the diagnosis, surgical treatment, and follow-up of sinus pathology. It is also reliable in the forensic identification of skeletonized, charred, and dismembered human remains. This study aimed at determining the morphometry of the FS in adult Nigerians.

Materials and Methods: This retrospective study used computed tomography images of 292 adult patients aged ≥20 years and archived in the radiology department of a tertiary hospital in Nigeria. Following ethical approval, the dimensions of the FS were measured. The axial and coronal sections were used to measure the thickness of the anterior and posterior walls, the width, depth, the distance between the most lateral points of the FS, height, and distance between the highest points of the FS bilaterally. Data were analyzed using the Statistical Package for the Social Sciences software version 23. Paired *t*-test and independent *t*-test were used to evaluate for the side and gender differences in the morphometric parameters, respectively. $P < 0.05$ was considered statistically significant.

Results: The thickness of the anterior and posterior walls, depth, width, height, the distance between the most lateral points, the distance between the highest points of the FS, and volume showed a statistically significant gender difference (P =0.001). The dimensions of the FS showed statistically significant side differences (P =*0.001*).

Conclusion: The FS morphometric parameters showed sexual dimorphism and can be used for sex determination of unknown human remains in forensic investigations.

KEY WORDS: *Depth, frontal, height, sinus, volume, width*

INTRODUCTION

The frontal sinuses (FSs) are bilateral air cavities housed in the squamous part of the frontal bone and separated by a thin bony septum.[1] Each FS develops independently as an invagination from the nasal cavity wall in the 4th–5th week intrauterine life. It is not radiographically evident at birth but can be visualized by 7–9 years.[2] The FS attains its maximum size by 20 years, thereafter, it remains stable.[3] The thick outer cortical layer of the frontal bone forms the anterior wall of the FS while the thin inner frontal table is separated from the frontal lobe of the brain posteriorly by a thin layer of dura mater.[4]

The frontal bone is recovered intact in cases where the skull is disfigured or fragmented.[5] The thick strong anterior wall of the FS protects it from the effects of external forces and decomposition.[6] The FS has a distinctive unique nature in each individual.[1] It also has the ability to sustain very high temperatures, therefore, preserved in burnt corpses after mass disasters such as air crashes.[5] These features make the FS reliable in forensic identification and can be used for the estimation of age and sex determination.[2,7] Computed tomography (CT) provides an accurate analysis of the FS that aid in the comparison of forensic data.[8]

The FS is the most symptomatic sinus and has multiple morphological variations that may increase the risk of intraoperative complications.[9] Assessment of the FS morphometry using CT is essential before endoscopic sinus surgery to prevent inadvertent penetration into the brain and orbits.[10] Accordingly, this study aimed at determining the morphometric parameters of the FS of adult Nigerians on CT images.

MATERIALS AND METHODS

This study was conducted at the Radiology Department of a Tertiary Hospital in Nigeria. It was a descriptive, cross-sectional, retrospective study that adopted the purposive sampling technique. We obtained ethical approval (EREC/PAN/2020/030/0371) from the Hospital's Research and Ethics Committee before the commencement of this study. Brain CT

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images taken between June 1, 2015 and June 30, 2020 and stored in picture archiving communications system (PACS) were used. CT images of patients aged below 20 years, images with artifacts, facial trauma, sinonasal pathology, and evidence of surgery were excluded from the study. Out of the remaining 336 images, we further excluded 44 images due to the presence of FS aplasia either unilaterally or bilaterally. The FS dimensions were therefore measured on images of 292 patients (177 males and 115 females) aged 20–99 years. Our study used adults aged ≥20 years since the FS is fully developed and reaches its maximum size at 20 years.[3]

Measurements were taken on the FS bilaterally using the distance measuring tool available in the PACS calibrated in cm. The axial sections were used to measure the thickness of the anterior and posterior walls, anteroposterior (AP) dimension/depth, width, and the distance between the most lateral points of the right and left FS. The maximum height and the maximum distance between the highest points of the right and left FS were measured on coronal sections. The FS dimensions were measured using the method described by Chalkoo *et al*.[1] [Figure 1].

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) Version 23.0 (IBM Corporation, Armonk, New York, USA). Data were classified according to gender. Paired *t*-test and independent *t*-test were used to evaluate for the side and gender differences in the morphometric parameters, respectively. $P < 0.05$ was considered statistically significant. The frontal sinus index (FSI) was calculated by dividing the FS height by FS width.[8] The volume of the FS was calculated as a product of height, AP dimension, and width.[10]

Results

Brain CT images of 292 patients comprising 177 males (60.6%) and 115 females (39.4%) were evaluated. These participants had an age range of 20–99 years and an average age of 51.47 ± 17.22 years. The anterior wall thickness of the FS measured 0.306 ± 0.151 cm. It was thicker on the left FS (0.310 ± 0.166 cm) than the right FS (0.297 ± 0.163 cm) and in males (0.35 ± 0.16 cm) than in females (0.24 ± 0.11) [Table 1]. The thickness of the anterior wall showed a statistically significant association with gender and side (*P =0.001*). The thickness of the posterior wall of FS was smaller than that of the anterior wall bilaterally. It measured 0.244 ± 0.111 cm and thicker in males (0.27 ± 0.11 cm) than females (0.21 ± 0.11 cm). The right FS had a thicker posterior wall (0.245 ± 0.121 cm) than the left FS (0.238 ± 0.115 cm). The thickness of the posterior wall showed a statistically significant association with the side of the FS and gender (*P =0.001*) [Table 1].

The average width of the FS was 2.749 ± 1.163 cm with the males having statistically significant larger widths (2.98 ± 1.12 cm) than the females (2.41 ± 1.45 cm) (*P =0.001*). The left FS width was significantly larger (2.830 ± 1.316 cm)

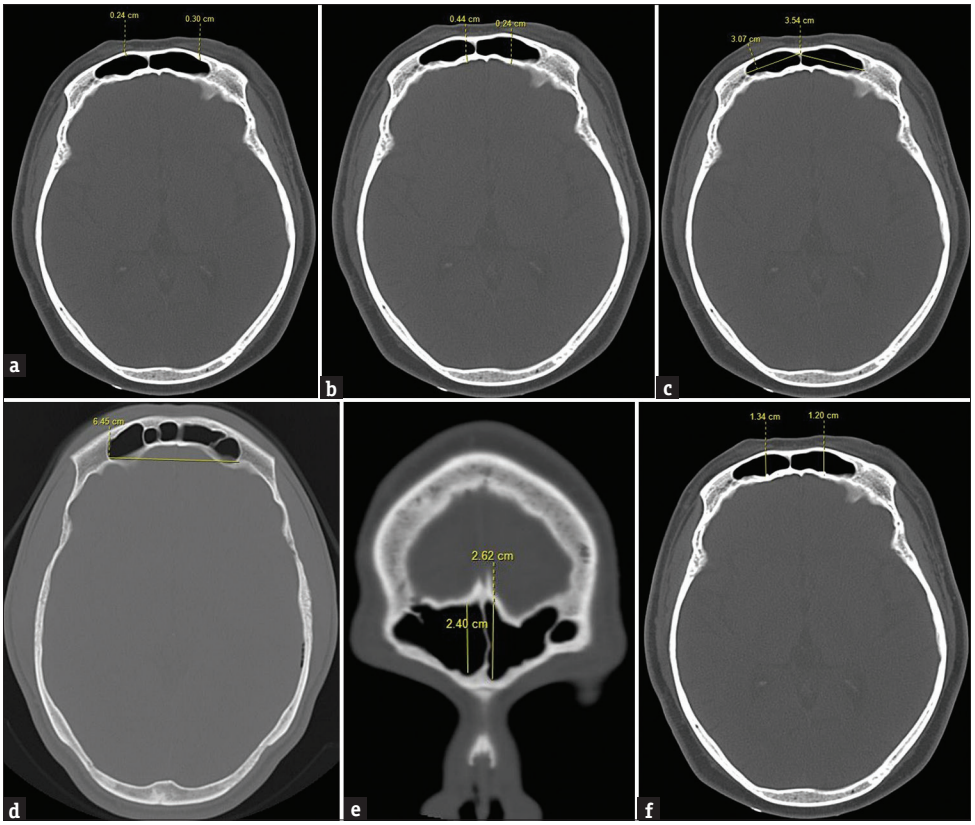

Figure 1: Computed tomography images showing the measurements of the FS dimensions bilaterally (a) Thickness of the anterior wall of FS on axial section (b) Thickness of the posterior wall of FS on axial section (c) Width of the FS on axial section (d) Distance between the most lateral points of the right and left FS on axial section (e) Height of the frontal sinus on coronal reformatted image (f) anteroposterior dimension/depth of the FS on axial section

Table 1: Morphometry of the frontal sinus

Parameter	Side	Mean±SD	Female	Male	*P*
Anterior wall thickness (cm)	Right	0.297±0.163	0.22±0.11	0.35±0.18	0.001*
	Left	0.310±0.166	0.25±0.12	0.35±0.18	0.001*
	AV	0.306±0.151	0.24±0.11	0.35±0.16	0.001*
Posterior wall thickness (cm)	Right	0.245±0.121	0.21±0.11	0.27±0.12	0.001*
	Left	0.238±0.115	0.20±0.11	0.26±0.11	0.001*
	AV	0.244±0.111	0.21±0.11	0.27±0.11	0.001*
Width (cm)	Right	2.663±1.253	2.33±1.22	2.89±1.22	0.001*
	Left	2.830±1.316	2.48±1.22	3.07±1.33	0.001*
	AV	2.749±1.163	2.41±1.45	2.98±1.12	0.001*
AP/depth (cm)	Right	0.906±0.445	0.76±0.43	1.0±0.43	0.001*
	Left	0.949±0.498	0.77±0.40	1.07±0.52	0.001*
	AV	0.930±0.427	0.77±0.39	1.04±0.41	0.001*
Height (cm)	Right	1.842±1.051	1.56±0.94	2.03±1.08	0.001*
	Left	1.938±1.060	1.73±0.97	2.08±1.10	0.002*
	AV	1.892±1.001	1.65±0.92	2.06±1.02	0.001*
Volume (cm3)	Right	6.221±5.32	6.165±4.95	6.260±5.57	0.043*
	Left	7.134±5.84	6.864±5.68	7.32±5.96	0.018*
	AV	6.678±5.03	6.515±4.84	6.790±5.17	0.026*
FS index	Right	0.650±0.39	0.628±0.36	0.665±0.41	0.399
	Left	0.651±0.41	0.678±0.47	0.632±0.37	0.317
	AV	0.639±0.38	0.644±0.39	0.636±0.38	0.852
Right to left most lateral points (cm)		5.125±2.296	4.72±2.19	5.40±2.33	0.007*
Distance between R and L highest points (cm)		1.948±1.179	1.59±1.00	2.19±1.23	0.001*

*P<0.05 significant. AP: Anteroposterior, AV: Average, SD: Standard deviation, FS: Frontal sinus

than the right (2.663 ± 1.253 cm) (P =*0.001*). The distance between the most lateral points of the right and the left FS measured 5.125 ± 2.296 cm and was significantly longer in males (5.40 ± 2.33 cm) than in females (4.72 ± 2.19 cm) (P = 0.007) [Table 1]. The depth of the FS was 0.930 ± 0.427 cm and was significantly larger in males (1.04 ± 0.41 cm) than in females (0.77 ± 0.39 cm) (0.001). The left FS had a greater AP dimension (0.949 ± 0.498 cm) than the right FS (0.906 ± 0.445 cm), and the side difference was statistically significant (P = 0.001) [Table 1].

The height of the FS was 1.892 ± 1.001 cm and was significantly greater in males (2.06 ± 1.02 cm) than females (1.65 ± 0.92 cm) (P = 0.001). The left FS height (1.938 ± 1.060 cm) was larger than the right FS height (1.842 ± 1.051 cm) (P = 0.001). The distance between the highest points of the left and the right FS was 1.948 ± 1.179 cm. This distance was longer in males (2.19 ± 1.23 cm) than in females (1.59 ± 1.00 cm) and showed a statistically significant association with gender (P 0.001) [Table 1].

The average volume of the FS was 6.678 ± 5.03 cm^3, significantly larger on the left (7.134 ± 5.84 cm^3) than on the right (6.221 ± 5.32 cm^3) (P = 0.004). It showed a statistically significant gender difference with the males having larger FS volume (6.790 ± 5.17 cm^3) than females (6.515 ± 4.84 cm^3) (P = 0.026). The FSI was 0.639 ± 0.38; larger in females (0.644 ± 0.39) than in males (0.636 ± 0.38). The association between FSI and gender was not statistically significant (P = 0.852).

Discussion

The anterior wall of the FS was thicker on the left FS than the right FS and in males than in females. Furthermore, it showed a statistically significant association with side and gender (P = 0.001). On the contrary, an Indian CT study by Panshewdikar *et al*.[11] reported a thicker anterior wall on the right than the left FS besides no statistically significant association with gender. The posterior wall in our study was smaller than the anterior wall bilaterally and showed statistically significant side and gender differences (P = 0.001). According to Verma *et al*.,[2] the anterior wall is thick, strong with an arched convexity of its internal body structure which protects it from destruction and decomposition.[2] A force of approximately 800–1600 foot-pounds, produced by high impact accidents or gunshots, is required to fracture the anterior wall of the FS.[6] It is, therefore, well preserved in dismembered corpses and this makes it useful in identification.

The width of the FS in our study was larger than the findings from CT studies conducted in India.[1,9,11] Consistent with the reports by Tatlisumak *et al*.,[12] Chalkoo *et al*.,[1] and Vishwa *et al*,[9] the width of the FS was larger in males and showed a statistically significant gender difference (P = 0.001). The left FS width in our study was significantly larger than the right (P = 0.001) contrasting with the findings of Tatlisumak *et al*.[12] The width of the FS documented on various radiographic studies was larger than our findings mainly due to inherent magnification in radiographs.[2,13-15] These studies similarly documented significantly larger FS width in males than in females. Among Nigerians of Delta state, the right

FS width was significantly larger than the left.[13,14] We report sexual dimorphism in the distance between the most lateral points of the right and the left FS ($P = 0.007$).

The depth of the FS in our study was smaller than in Turkish patients and larger than that of Indians.[11,12,16] The males had significantly larger FS depth than the females ($P = 0.001$), consistent with the findings by Tatlisumak *et al*.[12] and Chalkoo *et al*.[1] In keeping with the reports by Tatlisumak *et al*.,[12] the left FS depth was significantly larger than the right ($P = 0.001$).

The height of the FS in our study was greater than the documented height in India and Turkey.[1,9,11,12,16] Consistent with the reports by Chalkoo *et al*.,[1] the males in our study had significantly larger FS height than the females bilaterally. Tatlisumak *et al*.[12] and Vishwa *et al*.[9] documented a significant gender difference in the height of the left FS. The left FS height was significantly larger than the right ($P = 0.001$) and this contrasted with the findings of Tatlisumak *et al*.[12]

The FS height on various radiographic studies was larger than our findings and perhaps due to the inherent magnification in radiographs.[2,13-15] Contrary to our findings, the height of the FS measured on radiographs of Edo people in Benin, Nigeria did not show a statistically significant side difference.[13] The discrepancies between the CT and radiographic measurements may also be attributed to the superimposition of structures in radiographs impeding accurate measurement. The males in our study had a larger distance between the highest points of the left and the right FS than the Indian males studied by Chalkoo *et al*.[1] On the other hand, this distance in Indian females was greater than in the Nigerian females we evaluated. We observed sexual dimorphism in this parameter ($P = 0.001$).

The FSI in our study was lower than the findings of Verma *et al*.[2] and lacked a statistically significant association with gender ($P = 0.852$). Verma *et al*.[2] and Benghiac *et al*.[8] documented sexual dimorphism in the FSI among the Indians and Romanians, respectively. These discrepancies could be attributed to the differences in the imaging modality, landmarks used to measure the FS dimensions, and the calculation of the FSI.

The volume of the FS in our study was greater than the findings by Tatlisumak *et al*.[12] and Panshewdikar *et al*.[11] Consonant with our findings, Nateghian *et al*.[3] and Tatlisumak *et al*.[12] reported significantly larger FS volumes in males than in females. These scholars also documented a significantly larger left FS than the right FS. The discrepancy in the size of the FS bilaterally has been ascribed to the independent development of each sinus and unequal resorption of diploe hence the larger sinus crosses the midline to overlap the smaller sinus.[5] The larger dimensions and volume in the males can be attributed to the differences in the genetic, muscular, nutrition, and hormonal factors.[17] Sexual dimorphism in the morphometric parameters of the FS enhances their accuracy in gender determination within a specific population.[18]

Population, individual, racial, and ethnic differences, as well as environmental factors such as nutrition play a role in the variant morphometry of the FS.[9] These factors influence the craniofacial configuration, the thickness of the frontal bone, and growth hormone levels which have an impact on the pneumatization of the FS.[17] The varied dimensions of the FS in different studies may also be ascribed to the variation in the measurements and the imaging modality used.[5,13]

Conclusion

The FS morphometric parameters showed sexual dimorphism and can be used for sex determination of unknown human remains in forensic investigations.

Strength of the study

The use of CT images to measure the dimensions of the FS ensured accuracy of the data obtained since CT, unlike conventional radiography is not affected by inherent magnification and superimposition.

Limitation of study

The use of purposive sampling technique as well as a small sample size imples that the data obtained cannot be generalized to represent the Nigerian adult population.

Future research directions

We recommend further studies to evaluate the accuracy of these FS morphometric parameters in the prediction of sex in our population.

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Conflicts of interest

There are no conflicts of interest.

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