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Original Research Article

Radio-anatomical observation of volume, anterior wall thickness and pneumatisation pattern of frontal sinus

Venkatesh G[1], **Gugapriya T S**[2], **Vinay Kumar N**[3], **Arun Kumar A**[2]*, **Snehal Deulkar**[2]

[1]*Dept. of Anatomy, K.A.P. Viswanatham Government Medical College, Tiruchirappalli, Tamil Nadu, India*
[2]*Dept. of Anatomy, All India Institute of Medical Sciences, Nagpur, Maharashtra, India*
[3]*Dept. of Anatomy, Government Medical College, Palakkad, Kerala, India*

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ABSTRACT

Introduction: Frontal sinus occupies anatomically vital position in the cranium. Variations in dimension of the sinus between sides, gender were available. The functional role of the sinus was much debated in literature. Occurrence of frontal bone fracture in a significant proportion of facial trauma necessitates the study of anatomical structural and dimensional parameters of frontal sinus.

Materials and Methods: Computerised tomography of 119 paranasal images were finally studied after excluding paediatric, pathological and trauma cases. In axial and sagittal planes antero-posterior (AP), width, height, anterior wall thickness at orbital roof level were measured. Volume of sinus was computed for both sides using AP x width x height x 0.52. Independent "t" test and person's correlation coefficient were used for analysis statistically.

Result: The Mean AP, width and height were found to be 20.46 mm, 26.92 mm, 24.29 mm respectively. The mean volume of frontal sinus was 6.4 ± 3.4 cm^3, 7.6 ± 3.6 cm^3 on the right and left side respectively and showed significant value (P<0.05). The mean anterior wall thickness of frontal sinus was 2.5 0.8mm on right and 2.7 0.8 mm on left side with significant difference (p<0.05). Corelation between volume and anterior wall thickness was found to be weakly positive. Bilateral agenesis/aplasia was seen in 12.61% and unilateral agenesis/aplasia was observed in 19.32% with male predominance.

Conclusion: The width, anterior wall thickness and volume of frontal sinus showed statistically significance difference between sides. Weakly positive correlation was found between volume and anterior wall thickness. Aplasia was observed more in prevalence with male preponderance.

1. Introduction

A paired mucus lined asymmetrical cavities within tables of frontal bones behind the super-ciliary arches, the frontal sinuses are not fully developed till 2 years of age. The pneumatization of frontal sinus begins by 4 years and the sinus becomes radiologically visible by around the 5^{th} year.[1] By twenty years, frontal sinus attains its maximum dimensions determined by the extent of pneumatization. The degree of prominence of superciliary arches was refuted to be associated with dimensions of frontal sinus.[2] The sinus is floored by orbital roof and bony intersinus septum medially. The frontal cerebral lobes and anterior cranial fossa are vital posterior relations that need to be cared for during posterior frontal sinus repairs.[3]

The functional role of the frontal sinuses in humans still remains as a debated area. Literature mentions reduction in weight of the skull, resonance of voice and air conditioning of inspired air as the few reasons for the existence of all the paranasal sinuses including frontal sinus.[4] The cancellous

* *Corresponding author*.
E-mail address: arivalaganarun@gmail.com (Arun Kumar A).

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nature of the frontal bone and air between its cortical plates were ascribed as the reason for the strength against force exhibited by anterior wall of frontal sinus.[3,5]

Study observed 35% increase in stress to the adjacent intra cranial region in models with frontal sinus.[6] The inverse relation between volume of frontal sinus and the resulting frontal brain contusion following head trauma clearly showed the protective function of well-formed frontal sinuses.[7]

Structural and dimensional variations of the frontal sinus were claimed to impact the outcomes of the diagnosis, imagining and surgical management of frontal sinus pathologies.[8] The dimensional variation observed in frontal sinus was claimed due to the independent development of each frontal sinus, unequal reabsorption of diploe during sinus development, environmental factors, pathologies and the extent of pneumatisation.[9,10] Volumetrically, 5-7 ml frontal sinus has normal dimensions of about 28–30 mm, 24–28 mm, 20 mm in height, width and depth respectively.[11]

An osteological study reported that the dimensions of pyriform nasal aperture and degree of nasal cavity aeration positively impacted the growth and development of frontal sinus.[12] The total absence of such pneumatisation of frontal bone results in frontal sinus aplasia which was found to differ based on ethnicity, climate and geographical location.[4,13,14] A cadaveric study of frontal sinus outflow tract in Indians had not reported hypoplastic or aplasia of the frontal sinus.[15] A finite element analysis found that the distribution of stress and pattern of fracture depends on the volume of frontal sinus.[16]

The volume of the frontal sinus is an indication of the aeration and pneumatisation of the sinus. There were limited reports on normative values for the volume of the frontal sinus and anterior frontal wall thickness in Indian ethnicity. Thus, this radiological observational study was done to measure frontal sinus volume, thickness of anterior frontal bone and study the prevalence of hypo plastic or aplastic frontal sinus and to find out any significant association between volume and anterior wall thickness of frontal sinus.

2. Materials and Methods

The CT images from adult patients of both sexes for paranasal sinuses during the sampling frame duration from December 2016 to January 2017 were included in this retrospective observational study. The CT scans were done using the 3 mm, 8 slice GE Healthcare ultra-Light speed Machine. All the 130 CT paranasal scans done during the sampling frame were included as the sample for this study. The sample images were screened with the following exclusion criteria: Age <18 years, history of frontal sinus surgery, history of frontal head trauma and frontal fracture, destructive frontal sinus pathology.

The Antero-posterior (AP) dimension was measured in axial plane as the longest distance between anterior and posterior walls of the sinus (Figure 1) The width was measured as the longest dimension between the medial septum and lateral wall in axial plane (Figure 1) The height was measured as the longest dimension between floor and roof of the sinus in sagittal plane (Figure 2) The volume was calculated by using the formula: Antero-posterior x width x height x 0.52.[17]

The thickness of anterior wall of the frontal sinus was measured in the axial plane in the well pneumatised part of the sinus at the level of orbital roof (Figure 3). The extent of pneumatisation and incidence of aplasia/agenesis were noted. The observations were compared between sides and gender. The study was done after getting ethical clearance. This study was done with institutional ethical committee approval IEC No:34/20/09/16/CMCHRC. The data were collated and descriptively analysed using IBM SPSS Statistics for Windows, version 26.

3. Results

Of the 119 CT images included for analyses, 59 were males and 60 were females. The anterior posterior, width and height of the frontal sinus were measured using digital tools (Figures 1 and 2) The mean AP length, width and height were 20.46 mm, 26.92 mm, 24.29 mm respectively. The right and left side dimensions were recorded and mean was calculated. All three dimensions on right side were 20.6 ± 3.46 mm, 25.1 ±7.72 mm, 23.8 ± 8.71mm. The measure for all the dimensions on left were 20.4m ± 3.13m, 28.73 ± 7.69mm, 24.78 ± 8.85mm. Width and height of the frontal sinus were found to be more on left than right. The frontal sinus AP dimension was more on right side. The difference observed was statistically tested by independent "t"test. The width dimension showed significant difference between sides with a p=0.000198 ($p<0.05$), while the other two dimensions were not significant between sides.

The mean volume of frontal sinus was calculated and it was found to be 6.4 ± 3.4 cm^3, 7.6 ± 3.6 cm^3 on the right and left side respectively. The difference between two sides was found to be statistically significant with p=0.007491($P<0.05$).

The mean anterior wall thickness of the frontal sinus was found to be 2.5 ± 0.8mm on right and 2.7 ± 0.8 mm on left side of frontal sinus (Figure 3). On independent "t" test, the difference between sides was found to be significant with p=0.026095 ($p<0.05$).

The association between volume of the frontal sinus and the anterior wall thickness was done by applying Pearson's correlation Coefficient. The correlation coefficient on the right and left side was r(119) = 0.1411 and r(119)=0.0109 respectively. This correlation coefficient denoted a weak positive correlation between volume and anterior wall thickness of frontal sinus.

Table 1: Comparison of dimensional measurements of frontal sinus

STUDY	Mean () AP (mm)		Mean Width (mm)		Mean Height (mm)	
	Right	Left	Right	Left	Right	Left
Tatlisumak Ertugrul et al [18]	11.66	13.15	25.47	27.04	24.84	26.15
Panagiotis Kousoulis et al [19]	38	40	35	43	49	53
Present study	20.61	20.36	25.12	28.73	23.81	24.78
Cristiane Regina Ruiz [8]	45.95		25.80		14.13	
Lee MK et al [20]	24.5		52.2		8.0 to 9.3	
Mean present study overall	20.46		26.92		24.29	

Table 2: Comparison of incidences of unilateral and bilateral aplasia of frontal sinus

Study	Unilateral aplasia	Bilateral aplasia
Nikam SS et al [5]	3 (2.75%)	6 (5.5%)
Tatlisumak E et al [18]	4 (1 male & 3 female)	0
da Silva Filho AF et al [12]	9.1% (n = 3)	18.2% (n = 6)
Soman BA [21]	In right frontal sinus 6 cases (3%)	(6.5%) in 9 cases F (9%) & 4 cases M (4%)
Ruiz CR [8]	4% (2 cases)	-
Rubira-Bullen, IRF et al [10]	3.8% (6 cases)	1.3% (2 cases)
Verma P et al [22]	8.70%	5.30%
Present Study	19.3%	12.6%

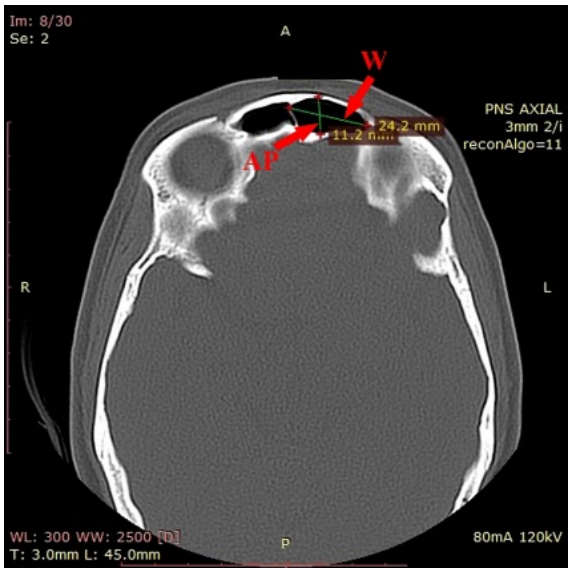

Figure 1: CT image showing measurements of anteroposterior (AP) length & width (W) of the frontal sinus.

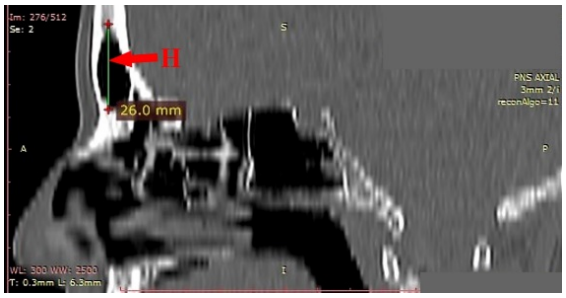

Figure 2: CT image showing measurement of height (H) of the frontal sinus.

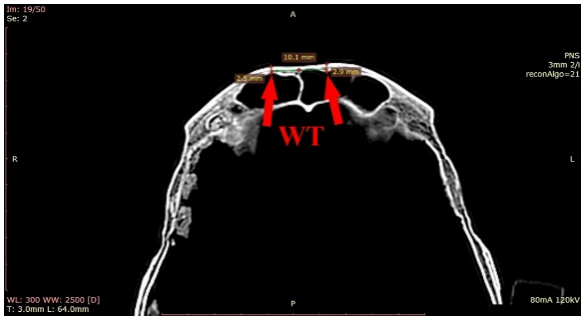

Figure 3: CT image showing measurement of anterior wall thickness (WT) of the frontal sinus at the level of orbital roof.

Bilateral agenesis/aplasia of frontal sinus was seen in 15 images (12.61%) of which 9 images belonged to male and 6 to female (Figure 4). Unilateral agenesis/aplasia of frontal sinus was observed in 23 images (19.32%) of which 14 images belonged to male and 9 to female (Figure 5).

4. Discussion

Anatomically the frontal sinus occupies a tactical position in the anterior skull because of its relation with orbito-ethmoidal, nasal and anterior cranial cavities. Frontal sinus was proposed to develop either from protuberance of infundibulum and frontonasal recess directly or through epithelial invasion of air cells. [23,24]

Each individual had unique dimension and structure of frontal sinus. This was conventionally used for personal identification in forensic diagnosis. [4,5,21] The dimensions of the frontal sinus vary widely depending on multitude of factors including growth phase and masticatory

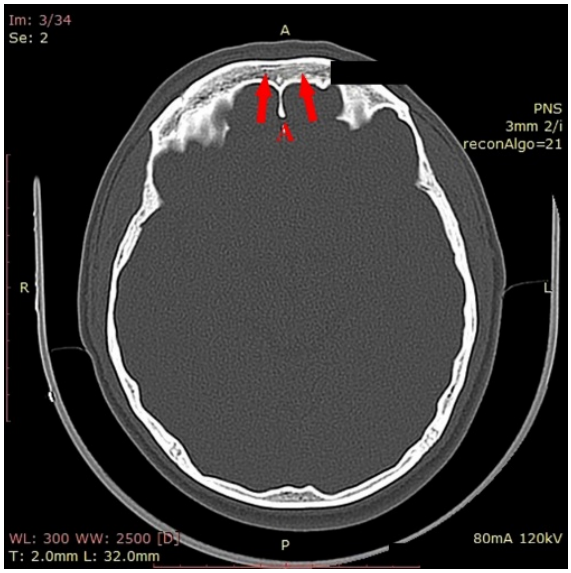

Figure 4: CT image showing bilateral aplasia/agenesis (A) of the frontal sinus.

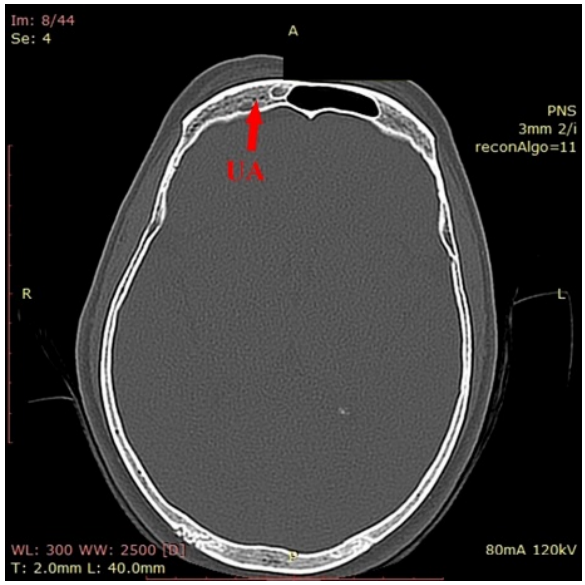

Figure 5: CT image showing unilateral aplasia/agenesis (UA) of the frontal sinus.

process.[4,9,10,13,14]

Dimensions of frontal sinus between sides was observed to vary between studies (Table 1). This could be explained due to differences in study methodology, sample size and ethnicity. The mean dimensions observed in the present study were in similarity to the dimension observed in Turkish population.[25] A case from Greece reported extreme dimensions of the frontal sinus due to hyperplastic frontal sinus.[26]

Multiple radiological and osteological studies had computed only the height and width of frontal sinus. The influence of factors like gender and side on the dimensions of the frontal sinus were repeatedly studied and found to be still inconclusive.[5,10,19,21] The independent bony reabsorption and pneumatisation on either sides justifies the difference in dimensional and structural variation observed between the sides. During the developmental process the frontal sinus was developed asymmetrically or not at all formed resulting in conditions of hypoplasia or aplasia. Unilateral and bilateral aplasia had been reported with widely varying prevalence with the present study showing greater prevalence in comparison (Table 2)

The side and gender of prevalence of aplasia of frontal sinus were correlated. The study reported that left side agenesis was common in men and right in women with an overall higher prevalence of aplasia of frontal sinus in women.[13,14] Contrary to these findings the present observation of aplasia of frontal sinus was more in male gender with no significant side to side difference. Frontal sinus showed a slower developmental rate in females when compared to male gender accounting for the gender differences noted.[20]

The normal volume of frontal sinus was reported to be 5cm.[3] In adolescent female undergoing orthodontic procedures the volume of frontal sinus was noted to be increased.[27] All the dimensional parameters including volume were found to be more in male compared to females on both the sides.[22] In comparison, the present study didn't focus on gender differences.

Frontal sinus fracture occurring due to road traffic accidents or sports injury account for 5 to 15% of documented facial trauma.[28] The thick anterior and posterior walls sandwiching the air filled cavity together was claimed to be responsible for the strength of the frontal sinus complex. With increased anterior wall thickness, more resistance to fracture was noted with a force upto one kilogram. The reported anterior wall thickness ranged 2.6-4.1mm.[18] The frontal sinus area was noted to increase with age probably claimed due to reduction in skull thickness with increasing age.[4] The "crumple zone" theory elaborates the role of sinuses as a compressible and breakable barrier. Thus the frontal sinus was proposed to protect the frontal lobe of the brain by crumbling due to absorption and dispersion of the force encountered.[16,29] The relation between the volume of frontal sinus and anterior wall thickness was analysed by finite element study. A well-developed frontal sinus with adequate volume acts as a "shock absorber" and protects vital structures in the cranium from impacting force.[16] The anterior wall thickness measurement also gains importance while performing an ultrasound examination of the frontal sinuses and frontal cranioplasty.[18,30]

5. Limitation

The weak positive correlation showed between volume and anterior wall thickness of frontal sinus would have exhibited strong correlation if the sample size would have been more. Non stratification of the sample by age was another limiting factor.

6. Conclusion

The width, anterior wall thickness and volume of frontal sinus showed statistically significant differences between sides. The higher prevalence of hypo/aplasia in male was a unique finding that needs further study. And the correlation between volume of the frontal sinus and anterior wall thickness was found to be weakly positively correlated. These structural and dimensional parameters need to be considered while interpreting, diagnosing impact of stress and trauma.

7. Source of Funding

None.

8. Conflict of Interest

None.

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Author biography

Venkatesh G, Assistant Professor https://orcid.org/0000-0002-2475-577X

Gugapriya T S, Professor https://orcid.org/0000-0002-6309-947X

Vinay Kumar N, Professor & HOD https://orcid.org/0000-0002-6532-6517

Arun Kumar A, Tutor https://orcid.org/0000-0001-6412-5150

Snehal Deulkar, Assistant Professor https://orcid.org/0009-0004-5201-6466

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