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Original Research Article

Computed Tomographic Analysis of Frontal Sinus Recess Anatomy and Its Relation with Frontal Sinusitis

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Abstract:

Aims and Objectives: This study focused on identifying the prevalence of frontal cells on CT scans in individuals with chronic rhinosinusitis, using the "International Frontal Sinus Anatomy Classification (IFAC)" system. It also explored how certain types of frontal cells may be linked to the development of frontal sinusitis.

Methods: CT images from 50 patients, covering 100 sinus sides, were examined. All frontal cell types defined by IFAC were identified, and logistic regression analysis was conducted to compare their presence between patients with and without frontal sinusitis.

Results: Agger nasi cells were the most commonly detected, found in 92% of the cases. Other types of frontal cells observed included supra agger cells (28%), supra agger frontal cells (19%), supra bullar cells (32%), supra bullar frontal cells (11%), supraorbital ethmoid cells (6%), and frontal septal cells (9%). Among individuals diagnosed with frontal sinusitis, there was a significantly higher prevalence of supra agger frontal cells (25%), supra bullar cells (46.4%), and supra bullar frontal cells (14.3%) compared to those without sinusitis, who exhibited these cells at rates of 16.7%, 26.4%, and 9.7%, respectively. These differences were statistically significant ($p < 0.01$), indicating a strong correlation with frontal sinusitis.

Conclusion: Based on the IFAC classification, there is a significant link between frontal sinusitis and the presence of supra agger frontal, supra bullar, and supra bullar frontal cells.

Keywords: IFAC, supra agger frontal, supra bullar, and supra bullar frontal cells.

Introduction

The frontal sinus is widely regarded as one of the most challenging of the paranasal sinuses to access surgically due to its highly variable anatomy and its close anatomical relationship with the critical structures such as the cribriform plate, the orbit, and the anterior ethmoidal artery. This intricate region can be pneumatized by a variety of adjacent cells. While these cells are commonly considered normal anatomical variants, they may contribute to the development of frontal sinusitis, potentially by obstructing the frontal sinus drainage pathway.

Various classification systems have been developed over time to categorize frontal recess cells. The initial system, introduced by Bent and Kuhn [1] in 1994, identified four types of frontal cells. This was later refined in Kuhn's 1996 [2] modification and further expanded by the Kuhn–Citardi–Lee classification in 2004 [3]. The most widely adopted system today is the International Frontal Sinus Anatomy Classification (IFAC), established in 2016, which offers a standardized, anatomy-based approach for identifying frontal cells in relation to sinus drainage. This study used the IFAC system to identify how common different frontal cells are and their link to frontal sinusitis. It also looked at whether cell types vary by gender and how they affect key sinus structures like agger nasi cell, frontal ostium, frontal recess, and the thickness of the frontal beak related to sinusitis.

Materials and Methods

This study was carried out in the Department of Radiology at Silchar Medical College and Hospital, Silchar, Assam. Participants were excluded if they were under 18 years of age, had a history of prior surgery or malignancy in the sinuses, maxillofacial trauma, sinonasal polyposis, or if the triplanar reconstruction of their CT scans are inadequate.

All imaging was performed using a Philips Ingenuity Elite 128-slice multidetector CT scanner, utilizing overlapping axial slices with a thickness of 0.6 mm and applying bone window settings. Frontal cells were classified according to the International Frontal Sinus Anatomy Classification

(IFAC) independently on the right and left sides at the corresponding frontal recess.

CT scans were divided into two groups: those showing evidence of frontal sinusitis and those without frontal sinusitis. Frontal sinusitis was characterized by mucosal thickening exceeding 3 mm, affecting either the entire frontal sinus or its gravity-dependent areas.

The identification of frontal cells was carried out using magnification and optimal window adjustments across coronal, axial, and sagittal views, following the criteria established by the IFAC.

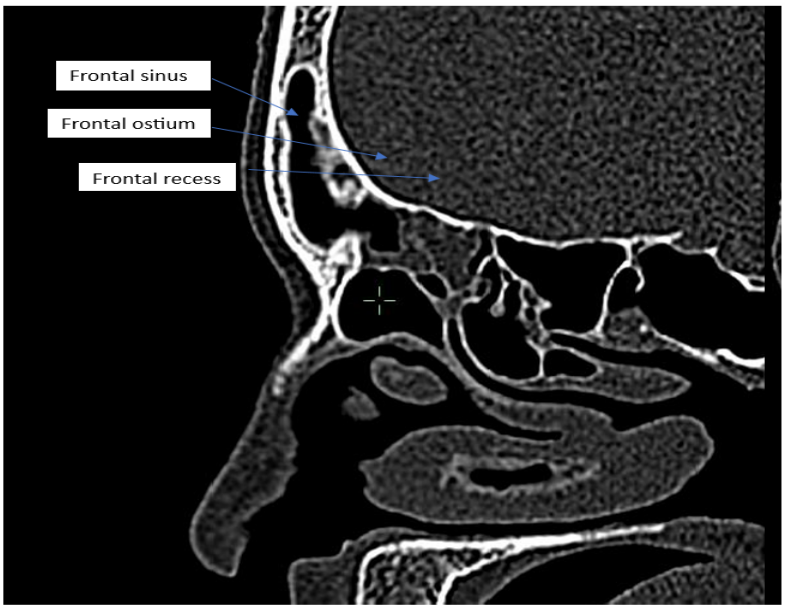

Figure 1: NCCT paranasal sinus (bone window) showing frontal sinus, ostium and recess. Agger nasi cell marked by asterisk.

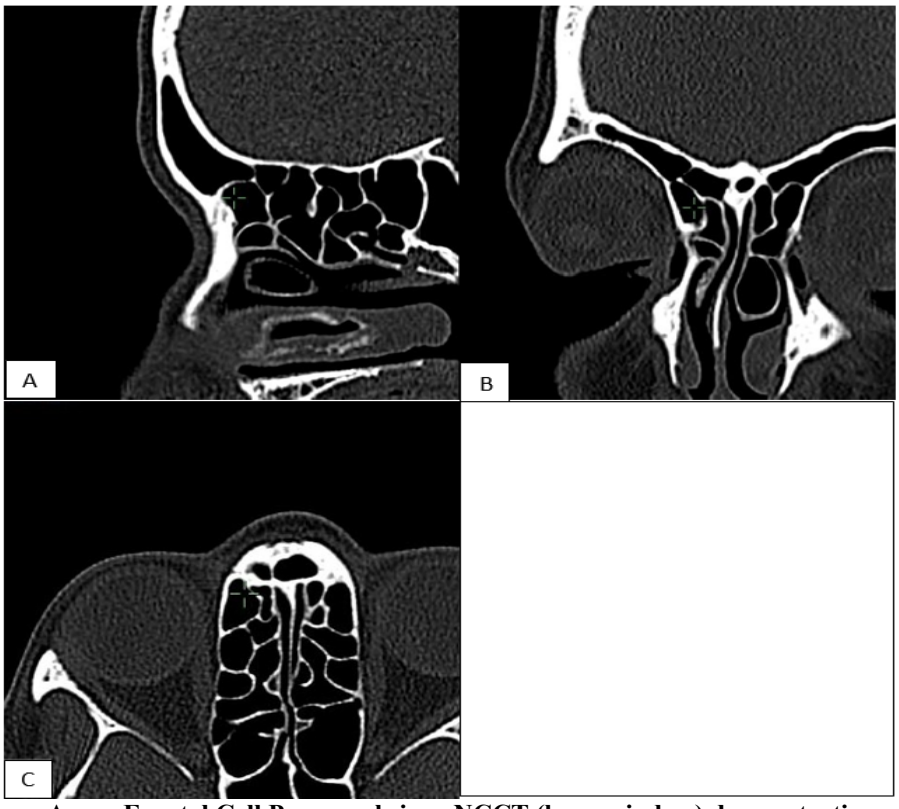

Figure 2: Supra Agger Frontal Cell Paranasal sinus NCCT (bone window) demonstrating a supra agger frontal cell (marked with an asterisk) visible in all planes: (a) sagittal, (b) coronal, and (c) axial views.

Figure 3: Supra Bullar Cell NCCT scan of the paranasal sinuses (bone window) demonstrating the presence of a supra bullar cell (marked with an asterisk) visible in all views: (a) sagittal, (b) coronal, and (c) axial sections.

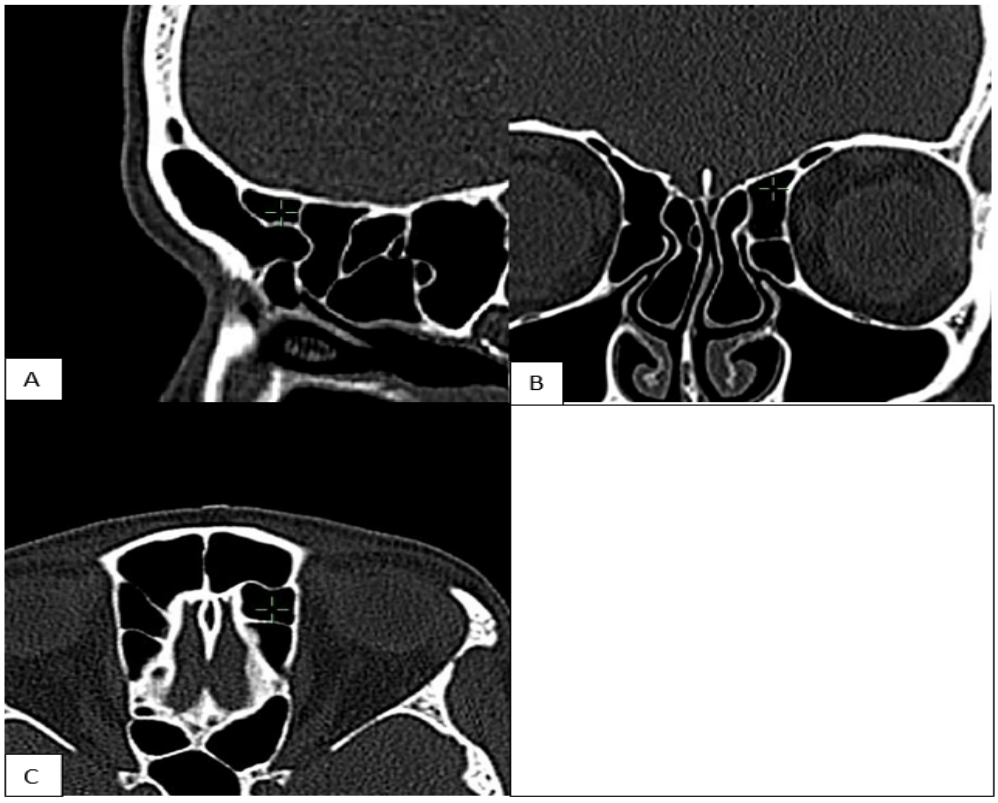

Figure 4: Supra Bullar Frontal Cell NCCT scan of the paranasal sinuses (bone window) illustrating a supra bullar frontal cell (indicated by an asterisk) in all views: (a) sagittal, (b) coronal, and (c) axial sections.

Results

Demographics: The study included 50 patients, comprising 25 males (50%) and 25 females (50%), resulting in a male-to-female ratio of 1:1. The largest proportion of patients (20%) belonged to the 41–45-year age group. Since individuals under 18 years were excluded, the age range of participants was 18 to 68 years, with a mean age of 40 years.

Table 1: Patient Distribution by Gender and Age (N=50)

Age (yrs)	Males	Percentage	Females	Percentage	Total	Percentage
18-25	6	12.00%	2	4.00%	8	16.00%
26-30	3	6.00%	4	8.00%	7	14.00%
31-35	2	4.00%	1	2.00%	3	6.00%
36-40	2	4.00%	3	6.00%	5	10.00%
41-45	7	14.00%	3	6.00%	10	20.00%
46-50	4	8.00%	2	4.00%	6	12.00%
51-55	0	0.00%	4	8.00%	4	8.00%
56-60	1	2.00%	4	8.00%	5	10.00%
>60	0	0.00%	2	4.00%	2	4.00%
TOTAL	25	50.00%	25	50.00%	50	100.00%

Cell prevalence: Based on the International Frontal Sinus Anatomy Classification system, the study reported the frequency of various frontal sinus cells, categorized as anterior, posterior, and medial (Table 2). The Agger Nasi cell was the most prevalent, seen in 92% of patients. In contrast, the Supraorbital Ethmoid Cell was the least common, present in just 5%. Other cell types were observed with the following frequencies: Supra Bulla Cell (32%), Supra Agger Cell (28%), Supra Agger Frontal Cell (19%), Supra Bulla Frontal Cell (11%), and Frontal Septal Cell (9%).

Table 2: Prevalence of Different IFAC Cells (N=100 (50x2))

IFAC Cell Type	IFAC Cell Name	Number (N=100)	Percentage
Anterior Cells	Agger Nasi Cell	92	92.00%
	Supra Agger Cell	28	28.00%
	Supra Agger Frontal Cell	19	19.00%
Posterior Cells	Supra Bullar Cell	32	32.00%
	Supra Bullar Frontal Cell	11	11.00%
	Supraorbital Ethmoid Cell	5	5.00%
Medial Cells	Frontal Septal Cell	9	9.00%

Gender-based cell prevalence: The prevalence of various types of cells according to International Frontal Sinus Anatomy Classification system was assessed separately for males and females (Table 3), revealing differences in the distribution of cell types between the two genders. Agger nasi cell was the most frequently observed cell in both males and females, with a prevalence of 94% in males and 90% in females. The least frequent cells were the supraorbital ethmoid cell and frontal septal cell, observed in 8% of males, while in females, the least prevalent cell was the supraorbital ethmoid cell at 2%. Among males, the supra agger cell, supra agger frontal cell, supra bulla cell, and supra bulla frontal cell were seen in 24%, 20%, 30%, and 12% respectively.

In females, the supra agger cell was seen in 32%, the supra agger frontal cell in 18%, the supra bulla cell in 34%, the supra bulla frontal cell in 10%, and the frontal septal cell in 10% of cases. The prevalence of IFAC cells in males and females did not differ statistically significantly.

Table 3. Prevalence of Ifac Cell Type in Males and Females

IFAC Cell Type	IFAC Cell Name	MALES (50)		FEMALES (50)		p value
		No.	Percentage	No.	Percentage	
Anterior Cells	ANC	47	94.00%	45	90.00%	0.459
	SAC	12	24.00%	16	32.00%	0.373

	SAFC	10	20.00%	9	18.00%	0.802
Posterior Cells	SBC	15	30.00%	17	34.00%	0.667
	SBFC	6	12.00%	5	10.00%	0.749
	SOEC	4	8.00%	1	2.00%	0.167
Medial Cells	FSC	4	8.00%	5	10.00%	0.726

Relationship between Different IFAC Cell Types and Frontal Sinusitis: In this study, frontal sinusitis was present in 28% of the cases (28 out of 100) and absent in 72% (72 out of 100). The occurrence of supra agger frontal cells, supra bullar cells, and supra bullar frontal cells was higher among the individuals suffering from frontal sinusitis—25%, 46.4%, and 14.3%, respectively—compared to those without sinusitis, where the rates were 16.7%, 26.4%, and 9.7%, respectively, showing a statistically significant difference (Table 4).

However, no statistically significant differences were found when overall prevalence of individual cell types classified by the "International Frontal Sinus Anatomy Classification" were compared between patients with and without frontal sinusitis, (all p-values > 0.05).

Table 4: Correlation between Various IFAC-Defined Frontal Cells and Frontal Sinusitis

IFAC Cell Type	IFAC Cell Name	Frontal Sinusitis		Univariate Analysis			
		NO (72)	YES (28)	Odds Ratio	95% CI		p value
					Lower	Upper	
Anterior Cells	ANC	66 (91.7%)	26 (92.9%)	0.333	0.067	1.652	0.178
	SAC	20 (27.8%)	08 (28.6%)	0.962	0.365	0.253	0.937
	SAFC	12 (16.7%)	07 (25%)	1.350	0.213	0.575	**<0.001**
Posterior Cells	SBC	19 (26.4%)	13 (46.4%)	1.283	0.16	0.502	**<0.001**
	SBFC	07 (9.7%)	04 (14.3%)	1.369	0.231	0.59	**<0.001**
	SOEC	04 (5.6%)	01 (3.6%)	2.015	0.225	18.058	0.531
Medial Cells	FSC	07 (9.7%)	02 (7.1%)	1.400	0.273	7.188	0.687

Frontal sinusitis and its association with frontal sinus ostium diameter, frontal recess diameter, thickness of frontal beak and AP diameter of Agger nasi cell: A significant difference was noted in the frontal sinus ostium diameter between patients with and without frontal sinusitis ($p<0.01$). On average, patients with frontal sinusitis had a smaller ostium diameter (5.40 ± 1.80mm) compared to those without the condition (6.53 ± 1.57mm), indicating a narrower passage in affected individuals. Similarly, a significant difference was observed in the frontal recess diameter between the two groups ($p<0.01$). Patients with frontal sinusitis had a mean recess diameter of 0.97 ± 0.44mm, whereas those without sinusitis had a larger diameter of 1.51 ± 0.77mm. This suggests that individuals with frontal sinusitis tend to have a more constricted frontal recess.

However, the thickness of the frontal beak and the anteroposterior size of the agger nasi cell did not differ significantly between those with and without frontal sinusitis.

Table 5. Association of Diameter of Frontal Ostium, Frontal Recess, Frontal Beak and Agger Nasi Cell Between Patients with and Without Frontal Sinusitis (n=100)

Radiological Parameters	With Frontal Sinusitis		Without Frontal Sinusitis		P Value
	Mean	Sd	Mean	Sd	
Frontal Sinus Ostium Diameter (Mm)	5.40	1.80	6.53	1.57	**0.003**
Frontal Recess Diameter (Mm)	0.97	0.44	1.51	0.77	**0.001**
Thickness Of Frontal Beak (Mm)	7.38	1.68	6.84	1.68	0.148
Ap Diameter Of Agger Nasi Cell (Mm)	7.51	2.60	7.43	2.96	0.901

A significant difference was noted in the frontal sinus ostium diameter between patients with and without frontal sinusitis ($p<0.01$). On average, patients with frontal sinusitis had a smaller ostium diameter (5.40 ± 1.80mm) compared to those without the condition (6.53 ± 1.57mm), indicating a narrower passage in affected individuals. Similarly, a significant difference was observed in the frontal recess diameter between the two groups ($p<0.01$). Patients with frontal sinusitis had a mean recess diameter of 0.97 ± 0.44mm, whereas those without sinusitis had a larger diameter of 1.51 ± 0.77mm. This suggests that individuals with frontal sinusitis tend to have a more constricted frontal recess. However, there was no notable difference in either the frontal beak thickness or the anteroposterior

diameter of the agger nasi cell between patients who had frontal sinusitis and those who did not.

Table 6. Impact of Various Ifac Cells On the Frontal Ostium and Frontal Recess Mean A-P Diameters

		Mean A-P Diameter of Frontal Ostium (mm)		P value	Mean A-P Diameter of Frontal Recess (mm)		P value
		Mean	SD		Mean	SD	
ANTERIOR CELLS	**AGGER NASI CELL**						
	Presence	6.18	1.72	0.553	1.32	0.74	0.108
	Absence	6.57	1.61		1.76	0.51	
	SUPRA AGGER CELL						
	Presence	5.92	1.89	0.291	1.43	0.89	0.514
	Absence	6.32	1.63		1.33	0.66	
	SUPRA AGGER FRONTAL CELL						
	Presence	4.96	1.57	**<0.001**	1.18	0.66	**0.037**
	Absence	6.51	1.61		1.40	0.74	
POSTERIOR CELLS	**SUPRA BULLAR CELL**						
	Presence	5.45	1.49	**0.002**	1.22	0.46	**0.024**
	Absence	6.57	1.70		1.42	0.82	
	SUPRA BULLAR FRONTAL CELL						
	Presence	4.99	1.18	**0.011**	1.10	0.32	**0.019**
	Absence	6.36	1.71		1.39	0.76	
	SUPRAORBITAL ETHMOIDAL CELL						
	Presence	6.18	1.24	0.962	1.43	0.79	0.807
	Absence	6.21	1.72		1.35	0.73	
Medial Cells	**Frontal Septal Cell**						
	Presence	5.86	1.82	0.524	1.54	0.28	0.437
	Absence	6.57	1.70		1.34	0.76	

The frontal ostium diameter and frontal recess diameter varied significantly statistically when supra agger frontal cells, supra bullar cells, and supra bullar frontal cells were present.

The average antero-posterior (AP) diameter of the frontal ostium in individuals with SAFC, SBC and SBFC was 4.96 +/- 1.57mm, 5.45 +/-1.49mm and 4.99 +/- 1.18mm whereas in patients without SAFC, SBC and SBFC was 6.51 +/- 1.61mm, 6.57 +/- 1.70mm and 6.36 +/- 1.71mm respectively.

The average AP diameter of the frontal recess in patients with SAFC, SBC and SBFC was 1.18 +/- 0.66mm, 6.57 +/- 1.70mm and 6.36 +/- 1.71 mm whereas in patients without SAFC, SBC and SBFC was 1.40 +/- 0.74mm, 1.42 +/- 0.82mm and 1.39 +/- 0.76mm respectively.

However, the presence or absence of specific frontal cells—including agger nasi, supra agger, supraorbital ethmoid, and frontal septal cells—had no significant impact on the anteroposterior diameter of the frontal ostium or recess.

Discussion

The Agger Nasi cell was found to be the most common among the anterior frontal cells, aligning with earlier research reporting its prevalence between 90% and 96%. Studies using the IFAC system by Tran et al. [5], Fabian Sommer et al. [6], N. Seth et al. [7], and Huu Kien Pham et al. [8] reported similar high prevalence rates of 95.7%, 95%, 95.5%, and 91.9%, respectively.

This specific cell type, due to its high prevalence across various populations and ease of identification, serves as a key anatomical landmark in preoperative imaging and surgical planning. As the most anterior ethmoidal cell, it is situated just above the attachment of the middle turbinate to the lateral nasal wall, making it particularly useful in guiding radiological assessment and surgical approaches.

In this study, supra agger cells were present in 28% and supra agger frontal cells in 19% of cases, closely aligning with findings from Choby et al. [9], N. Seth et al. [7], and Huu Kien Pham et al. [8], whose studies reported similar findings. Suprabullar cells were identified in 32% of participants, consistent with prevalence rates around 36%–37% reported by Han et al. [10], Kubota et al. [11] , and N. Seth et al. [7]. The supra bullar frontal cell was observed in 11% of subjects, comparable to the 9% rate noted by Han et al. [10]. Supraorbital ethmoid cells appeared in 5% of cases, matching closely with previously reported rates ranging from 5.4% to 9% across several studies. Lastly, frontal septal cells were found in 9% of patients, similar to the 10.6% and 14.3% rates reported by Tran et al. [5] and Huu Kien Pham et al. [8] respectively.

Prevalence of IFAC cells in males and females: Agger nasi cells were the most commonly observed in the study, found in 94% of males and 90% of females. Among males, the prevalence of other frontal cells was as follows: supra agger (24%), supra agger frontal (20%), supra bullar (30%), supra bullar frontal (12%), supraorbital ethmoid (8%), and frontal septal (8%). In females, the corresponding rates were slightly different: supra agger (32%), supra agger frontal (18%), supra bullar (34%), supra bullar frontal (10%), supraorbital ethmoid (2%), and frontal septal (10%). Males showed a statistically significant higher number of Frontal cell Type 4 (Bent and Kuhn categorization) than females, according to House et al. [12]. Consistent with the findings of N. Seth et al. [7] and Alexander J. Jones et al. [13], our study also observed no statistically significant difference in the occurrence of IFAC cells between males and females.

Frontal sinusitis and its association with IFAC cells: In this study, 28% of participants showed signs of frontal sinusitis, while 72% did not. The presence of supra agger frontal cells, supra bullar cells, and supra bullar frontal cells was significantly more common in individuals with sinusitis, with odds ratios of 1.35, 1.28, and 1.37 respectively ($p < 0.001$).

Patients with frontal sinusitis had odds ratios of 2.05 and 1.40 times greater for expressing frontal septal cells and supraorbital ethmoidal cells, respectively, than those without frontal sinusitis. But in our investigation, it fell short of statistical significance. Univariate analysis showed no correlation between the prevalence of ANC and SAC and the presence of frontal sinusitis.

The classification of frontal cells based on IFAC varied across the following studies, yielding different results. The study by Huu Kien Pham et al. [8] concluded that patients with SAFC and SBFC were far more prone than individuals without them to get frontal sinusitis. The study by Ahmed Abdelfattah Bayomy Nofal et al. [14] found a high infection rate in FSC, SAC, SAFC, and SBC in association with frontal sinus infections.

Frontal sinusitis and its association with frontal sinus ostium diameter, frontal recess diameter, thickness of frontal beak and AP diameter of Agger nasi cell: Patients with and without frontal sinusitis had statistically significant differences in frontal ostium diameter ($p<0.01$). On average, patients with frontal sinusitis had a smaller ostium diameter (5.40 ± 1.80mm) compared to those without the condition (6.53 ± 1.57mm), indicating a narrower passage in affected individuals. Similar results were reported by Lai et al. [15], who observed a significant difference in frontal ostium diameter between individuals with and without frontal sinusitis. The average diameter measured 6.2 ± 1.82 mm in affected patients, compared to 6.81 ± 1.76 mm in those without the condition.

The mean frontal recess diameter was significantly smaller in patients with frontal sinusitis (0.97 ± 0.44 mm) compared to those without (1.51 ± 0.77 mm), with a statistically significant difference ($p < 0.01$). These results align with Lai et al. [15], who also reported a reduced diameter in sinusitis cases.

The anteroposterior (AP) diameter of the agger nasi cell and the thickness of the frontal beak were slightly greater in patients with frontal sinusitis but did not show a statistically significant difference. Similar conclusions were reported by Makihara et al. [16] and Kemal et al. [17], who found no significant association between these anatomical features and frontal sinusitis.

Impact of IFAC Cell Presence on Mean Frontal Ostium and Frontal Recess Diameters (n = 100): The study found a statistically significant difference ($p < 0.05$) in the anteroposterior (AP) diameters of the frontal ostium and frontal recess based on the presence of Supra Agger Frontal Cells (SAFC). In patients with SAFC, the mean diameters were 4.96 ± 1.57 mm and 1.18 ± 0.66 mm, respectively, compared to 6.51 ± 1.61 mm and 1.40 ± 0.74 mm in those without SAFC. Patients with SBC and SBFC had mean AP diameters of the frontal ostium of 5.45 ± 1.49 mm and 4.99 +/- 1.18 mm, respectively, while those without SBC and SBFC had mean AP diameters of 6.57 ± 1.70 mm and 6.36 +/- 1.71 mm, which were statistically significant ($p<0.05$. In our investigation, the mean AP diameter of the frontal recess was 1.22 ± 0.46 mm and 1.10 +/- 0.32 mm for patients with SBC and SBFC, respectively, while it was 1.42 ± 0.82 mm and 1.39 +/- 0.76 mm for individuals without SBC and SBFC. These differences were statistically significant ($p<0.05$). This was comparable to the findings of Lien et al. [18], who showed that the frontal ostium and frontal recess diameter were significantly reduced by the presence of SBC and FBC, and N. Seth et al. [7], who showed that the frontal ostium and frontal recess diameter was greatly reduced by the presence of SBFC.

Conclusion

This study used the International Frontal Sinus Anatomy Classification (IFAC) to assess the prevalence of various frontal cells. The Agger Nasi cell was the most frequently detected, while the Supraorbital Ethmoidal cell was the least common. While the occurrence of Agger Nasi cells is consistently reported across studies, the prevalence of other frontal sinus cells varies. No significant gender-based differences were found in the distribution of these cells. However, the presence of Supra Agger Frontal Cells (SAFC), Supra Bullar Cells (SBC), and Supra Bullar Frontal Cells (SBFC) was signifi-

cantly associated with frontal sinusitis, contributing to a reduction in the dimensions of the frontal ostium and recess.

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