Computed tomographic analysis of the frontal sinus morphology and structures that affect the size of the frontal sinus outflow tract in Vietnamese people

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SUMMARY

The frontal recess is a relatively small and narrow area with many neighboring structures and is very diverse in each body. Surgical intervention in this area is still challenging for surgeons. The International Frontal Sinus Anatomy Classification (IFAC) helps classify frontal cells on computed tomography (CT) scans for surgical purposes and anatomical accuracy. This study aims to investigate the morphology of the frontal sinus, the anteroposterior (A-P) diameter of the frontal sinus ostium and the A-P diameter of the frontal recess, the frontal cells classified by IFAC and the relationships between frontal sinus characteristics and A-P diameter of frontal sinus ostium and frontal recess on CT scans. Descriptive cross-sectional study on all CT scans of nasal cavities and paranasal sinuses of patients ≥ 20 years old at the Examination Department of Minh Duc Hospital — Ben Tre and Can Tho University of Medicine and Pharmacy Hospital.

In terms of morphology, we found that the most common type was large-sized frontal sinus (40.7%), followed by medium (35.4%) and small (23.9%), respectively. The three dimensions of the frontal sinus in men were larger than in women ($p<0.05$). The mean A-P diameter of frontal sinus ostium was 6.41±2.66 mm. The mean A-P diameter of frontal sinus recess was 3.23 ± 2.59 mm. The agger nasi cells accounted for the highest proportion (93.6%) and supraorbital ethmoid cells accounted for the lowest proportion (2.9%). There was a statistically significant relationship between ostium diameter and frontal sinus morphology with $p<0.001$. The A-P diameter of the frontal sinus ostium and frontal recess became narrower with the appearance of the frontal cells. From the study's results about the frontal sinus morphology, the relationship between the frontal recess cells and the structures affecting the anteroposterior diameter of the frontal sinus drainage pathway can assist surgeons in planning effective and safe surgical interventions in the frontal sinus area.

Key words: *IFAC – Frontal ostium – Frontal recess – Frontal sinusitis*

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INTRODUCTION

Endoscopic surgical intervention in the sinonasal area in general and the frontal sinus area, in particular, is increasing. The anatomical structure of this area is relatively complex, the access space is quite narrow, involving many important nearby structures and making it difficult to manipulate. Besides, there are many types of cells with different sizes, arrangements, and extents in frontal recess. It has a critical role in successful functional endoscopic sinus surgery (FESS), and most causes of failure are related to it (Nofal et al., 2022). In 2016, the International Frontal Sinus Anatomy Classification (IFAC) was published based on the work of van Alea, Kuhn, Wormald, and other authors (Wormald et al., 2016). This classification provides a more precise nomenclature for the cells located in the frontal recess and in the frontal sinus, not only suggesting to surgeons the location of the frontal cells but also providing sufficient information about the relationships between cells in the frontal sinus and its opening, significantly aiding in frontal sinus and frontal recess surgery.

Computed tomography is required for the understanding of the anatomy of the frontal sinus, the size of frontal sinus ostium and the frontal recess in each patient to make the most appropriate individual surgical planning. It is suggested to evaluate the A-P diameter in the sagittal plane, while the mediolateral diameter is best assessed in the coronal plane. These measurements usually describe the degree of difficulty in dissecting the frontal recess. The wider the diameter between the frontal beak and the posterior edge formed by the skull base, the easier the surgical dissection (Dassi et al., 2020).

In Vietnam, there has been currently no research focusing on describing the morphology of the frontal sinus, frontal ostium, recess diameter, and frontal cells according to IFAC (2016) on CT scans. The purpose of our study was to clarify the variety in frontal sinus and frontal cell morphology according to the IFAC (2016), and to determine the diameter of the frontal recess and frontal sinus and cells that affect the size of two of these areas.

MATERIALS AND METHODS

Research subjects

The study was performed on all sinus computed tomography scans of patients ≥ 20 years old from April 2023 to November 2023 at the Examination Department of Minh Duc Hospital – Ben Tre and Can Tho University of Medicine and Pharmacy Hospital.

Inclusion criteria: Patients aged 20 years and above with CT scan of the sinuses showing uninterrupted bone structure in the sinus region. Patients consented to participate in the study.

Exclusion criteria: Patients with craniofacial deformities, bilateral frontal sinus aplasia, a history of facial trauma or current trauma affecting the sinuses, or sinonasal tumors. CT scan does not meet the required criteria.

Research Methods

The study was conducted using a descriptive cross-sectional method in convenience sampling.

Data collection

Surveying the morphology of the frontal sinus and the size of the frontal sinus.

Identifying frontal recess cells according to IFAC 2016.

We identified the A-P diameter of the frontal sinus ostium on the parasagittal CT section. It was determined with the shortest distance from the most prominent part of the frontal beak to the anterior base of the skull (Fig. 1).

On the same sagittal section of determining the frontal sinus ostium diameter, the A-P diameter of the frontal recess was measured by the shortest distance from the most protruding part of the frontal beak/Agger nasi cell to the ethmoid bulla/bulla lamella/supra bullar cells/supra bullar frontal cells posteriorly (Fig. 2).

Data processing and analysis

Data were analyzed by SPSS software version 20.0. Descriptive statistics were used including mean, standard deviation for quantitative data, frequency, and percentage for qualitative data. In terms of comparing differences between two quantitative groups, we used t-test or Chi-square

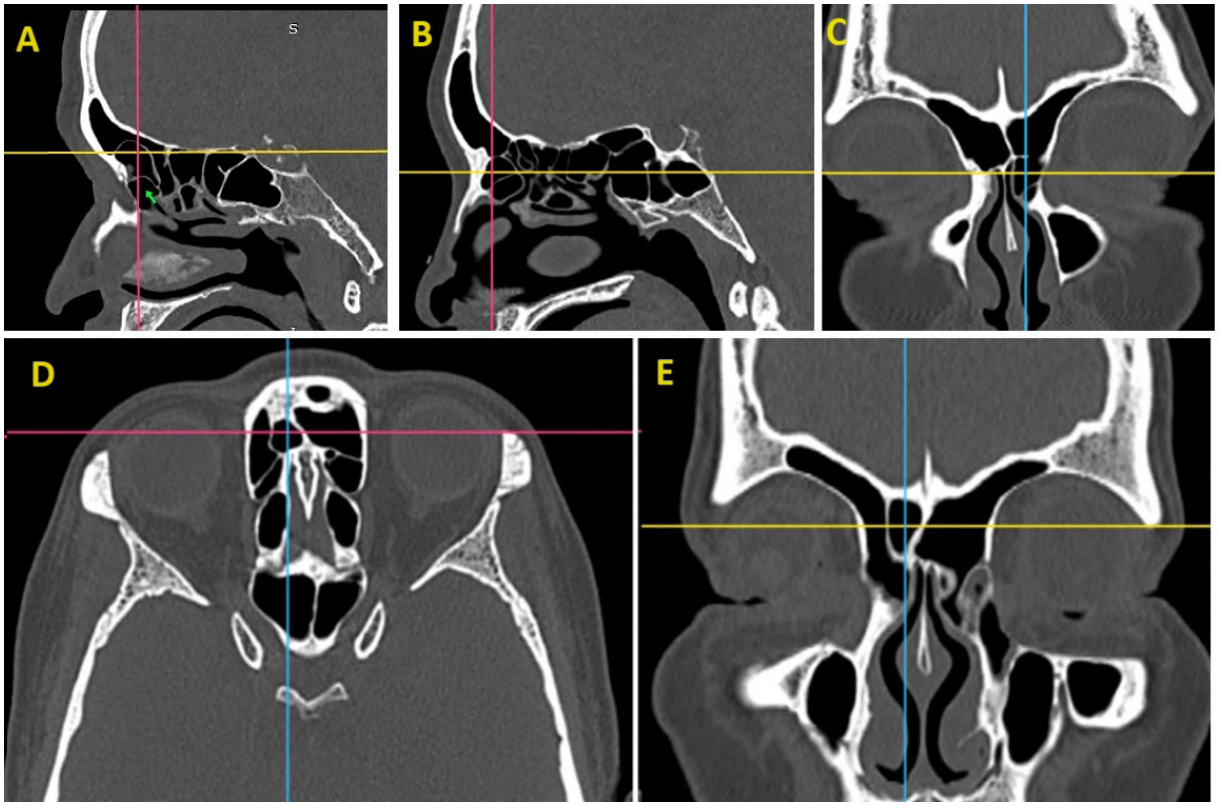

Fig. 1.- International Frontal Sinus Anatomy Classification cells. (**A**) An Agger nasi cell (green arrow) and a supra agger frontal cell (cross). (**B, C**) A supra agger cell (SAC). (**D, E**) A frontal septal cell (FSC).

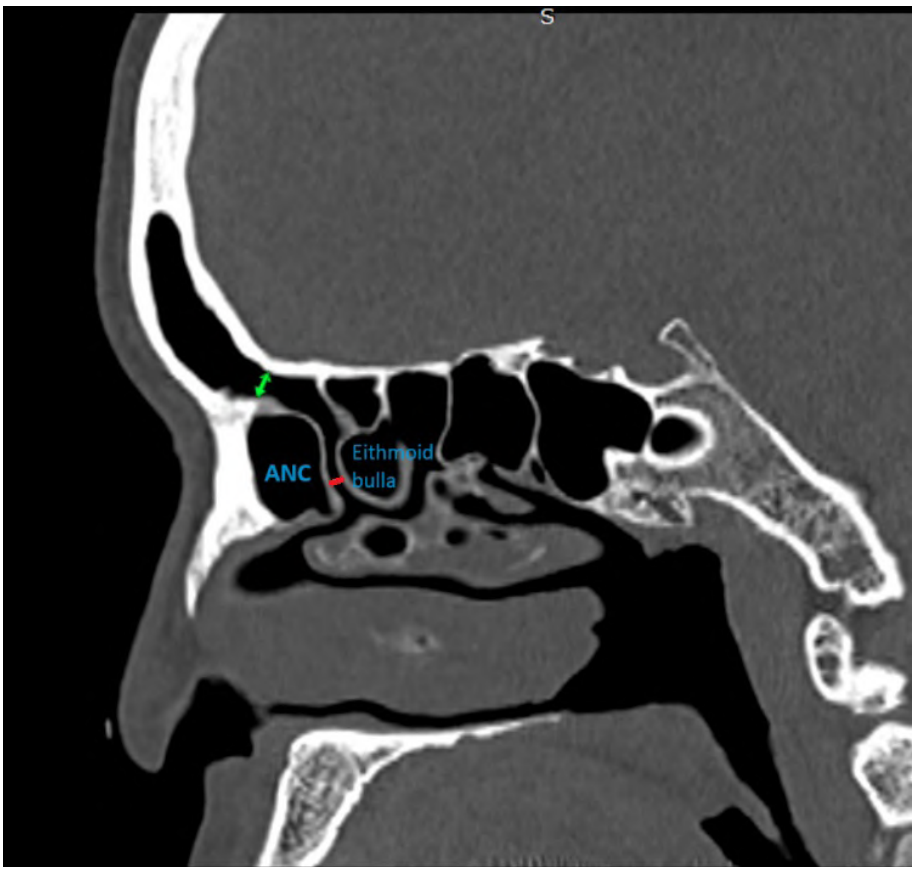

Fig. 2.- Non-contrast parasagittal computed tomography (CT) image of the paranasal sinus, showing the frontal sinus ostium (green double-headed arrow) and the frontal recess (red line) measured from the posterior wall of the agger nasi anteriorly to the ethmoidal bulla posteriorly.

tests when appropriate. Tests were statistically significant when p value < 0.05.

RESULTS

Demographics

There were 143 patients (including 49 men and 94 women) with 280 frontal sinuses surveyed in this study. Age ranged from 21 to 85 years old, and the mean age was 48.70 ± 14.97 years old.

Frontal sinus morphology

Large-sized frontal sinuses accounted for the highest proportion of 40.7%, followed by medium and small with 35.4% and 23.9% respectively (Table 1). All measurements of the frontal sinus had higher values in males than in females, and the differences were statistically significant (p<0.05), except the height (p<0.0001) (Table 2).

Table 1. Classification of frontal sinus type.

Type of frontal sinus	Number	Percent %
Small frontal sinus	67	23.9
Medium frontal sinus	99	35.4
Large frontal sinus	114	40.7
Total	280	100

The A-P diameter of the frontal sinus opening and frontal recess

The mean A-P diameter of the frontal sinus ostium was 6.41 ± 2.66 mm, and the mean A-P diameter of the frontal recess was 3.23± 2.58 mm. The group of narrow frontal sinus ostium (>5 to <10 mm) accounted for the highest proportion (62.5%), followed by very narrow A-P distance (≤ 5 mm) and wide A-P distance (≥ 10 mm), respectively. The prevalence was described in Table 4.

Classification of frontal recess cells according to IFAC 2016

We classified the frontal recess cells according to IFAC system. The agger nasi cell was documented in 93.6% of the frontal sinus. The prevalence of the supra-orbital ethmoidal cells was the lowest, seen at 2.9 percent. The prevalence of the other cells was demonstrated in Table 5.

Relationships between frontal sinus morphology and frontal recess cells

There was a statistically significant relationship between the A-P diameter of the frontal sinus ostium and the type of the frontal sinus with p < 0.001, while no statistically significant

Table 2. The dimensions of frontal sinus distributed by gender.

Frontal sinus dimensions	A-P diameter (mm)	p	Longitudial diameter (mm)	p	Horizontal diameter (mm)	p
Male	11.76 ± 4.19	**0.031**	23.27 ± 10.33	**<0.0001**	30.96 ± 10.42	**0.002**
Female	10.62 ± 4.11		18.94 ± 8.32		27.22 ± 9.11	
Total	11.01 ± 4.17		20.48 ± 9.29		28.50 ± 9.73	

Table 3. A-P diameter of the frontal sinus ostium and frontal recess.

	Smallest	Largest	Mean ± SD
Frontal sinus ostium (mm)	1.08	15.60	6.41 ± 2.66
Frontal recess (mm)	0.68	15.20	3.23± 2.58

Table 4. Classification of A-P diameter of the frontal sinus ostium.

Size of frontal sinus ostium	Number	Percentage (%)
Large (≥ 10mm)	26	9.3
Narrow (>5 -<10mm)	175	62.5
Very narrow (≤ 5mm)	79	28.2
Total	280	100

Table 5. Classification of frontal recess cells according to IFAC (2016).

Type of frontal cell	Number	Percent (%)
ANC	262	**93.6**
SAC	103	**36.8**
SAFC	27	**9.6**
SBC	92	**32.9**
SBFC	32	**11.4**
SOEC	8	**2.9**
FSC	15	**5.4**

Table 6. Relationship between frontal sinus morphology types with frontal sinus opening diameter and frontal recess diameter.

Type of frontal sinus	A-P diameter of frontal sinus ostium (mm)	p	A-P diameter of frontal recess (mm)	p
Small frontal sinus	5.00 ± 1.90	**<0.0001**	3.14 ± 2.27	0.632
Medium frontal sinus	6.19 ± 2.29		3.43 ± 2.62	
Large frontal sinus	7.43 ± 2.92		3.11 ± 2.71	

Table 7. Relationship between each type of frontal recess cell and frontal ostium diameter and frontal recess diameter.

Type of cell		A-P diameter of frontal ostium (mm)	p	A-P diameter of frontal recess (mm)	p
ANC	Yes	6.36 ± 2.62	0.225	2.89 ± 2.15	**<0.0001**
	No	7.14 ± 3.15		8.14 ± 2.90	
SAC	Yes	6.29 ± 2.65	0.548	2.82 ± 2.13	**0.029**
	No	6.48 ± 2.67		3.47 ± 2.78	
SAFC	Yes	5.39 ± 2.59	**0.035**	3.02 ± 2.10	0.659
	No	6.52 ± 2.65		3.25 ± 2.62	
SBC	Yes	6.26 ± 2.57	0.505	3.03 ± 2.41	0.358
	No	6.49 ± 2.70		3.33 ± 2.65	
SBFC	Yes	6.26 ± 3.32	0.728	2.75 ± 2.34	0.264
	No	6.43 ± 2.59		3.29 ± 2.60	
SOEC	Yes	6.21 ± 2.71	0.826	2.54 ± 1.53	0.444
	No	6.42 ± 2.66		3.25 ± 2.60	
FSC	Yes	5.79 ± 2.31	0.357	4.16 ± 3.98	0.360
	No	6.44 ± 2.68		3.18 ± 2.47	

correlation was found between the A-P diameter of the frontal recess and frontal sinus type (p>0.05). We also found a statistically significant difference between supra agger frontal cells and the A-P diameter of the frontal sinus ostium (p<0.05), and between agger nasi cells and the diameter of the frontal recess (p<0.00001) (Tables 6 and 7).

DISCUSSION

This is the first study focusing on the total characteristic structures of the frontal sinus (including the diameter of frontal sinus ostium, frontal recess, and the size of three dimensions of frontal sinus) and the frontal recess cells that affect the wide frontal recess being done in Vietnam.

Frontal sinus morphology

According to the morphological classification of the frontal sinus by Stokovic on CT scans of the nasal cavity and paranasal sinuses, the large frontal sinus morphology in our study accounted for the highest proportion at 40.7%, followed by the medium frontal sinus at 35.4%. It differed from the study of Özdemir et al. (2021), in which the medium frontal sinus accounted for the highest prevalence (65.84%). This difference may be related to racial differences between the two study populations.

When comparing the two genders, it was shown that the A-P diameter, horizontal diameter, and longitudinal diameter of the frontal sinus in men were statistically significantly larger than those of women (p<0.05), similar to the results of many previous studies (Tatlisumak et al., 2008).

The mean A-P diameter of the frontal sinus ostium in our study was 6.41 ± 2.66 mm; similar to the results of author Lam Huyen Tran (2023) with the mean diameter of 6.3 ± 2.1 mm, lower than the study of author Nguyen Mai Phuong Trang

(2022) with a mean diameter of 7.35 ± 2.01 mm, and higher than the study of Seth et al with 5.46 ± 2.11 mm (Tran et al., 2023; Trang et al., 2022; Seth et al., 2020). The mean A-P diameter of the frontal recess was recorded as 3.23 ± 2.58 mm, wider than the study by author Seth et al. (2020) which was 1.94 ± 1.08 mm (Seth et al., 2020). This differentiation may be due to the variations of cell pneumatization in the frontal recess to the frontal sinus ostium.

Regarding the classification of the A-P diameter of the frontal sinus ostium, we relied on the classification agreed upon by the previous authors, in which the A-P diameter of the frontal sinus ostium is considered wide when the size is ≥ 10 mm, narrow 6-9 mm and very narrow ≤5 mm (Wormald et al., 2017). Our research results showed that the group with wide frontal sinus ostium diameter accounted for only 9.3% of cases and the highest was narrow frontal sinus ostium diameter with 62.5% of cases. Based on this classification accompanied with the results of this study, about the morphology and structures of frontal recess cells of Vietnamese people can be clarified. It can help surgeons predict the complexity of frontal sinus surgery, and thereby enable them to choose appropriate intervention methods.

The prevalence of frontal recess cells according to the international classification in our study was different from previous studies (Table 7), but, in general, Agger nasi cells always had the highest predominance in most cases of all studies. It has been shown that Agger nasi cell is an important anatomical landmark, making them the key structure in approaching frontal sinus (Wormald, 2003). The proportion of other cells besides ANC showed differentiated rates between Vietnamese and international studies. But overall, when investigating each cell group, it showed that in the anterior cell group besides ANC, SAC had a higher occurrence rate than SAFC (36.8% and 9.6%), SBC was more dominant than other cells (SBC: 32.9%; SBFC 11.4% and SOEC 2.9%) in the posterior group (Table 8). The differences in the presence of various cell types in studies indicated the diversity in the structure of the frontal recess, requiring surgeons thorough preoperative evaluation to approach this area.

Relationship between frontal sinus characteristics with frontal ostium diameter and frontal recess diameter

The A-P diameter of the frontal sinus opening was statistically significantly related to frontal sinus morphology ($p<0.001$) while we did not find a statistically significant correlation between frontal sinus diameter and sinus morphology. This may suggest to surgeons a suitable way to access the frontal sinus ostium for each type of frontal sinus morphology.

The SAFC are the anterolateral ethmoidal cells lying above the ANC that pneumatized into the frontal sinus, and the SBFC originates from the supra-bulla area pneumatized along the skull base into the posterior area of the frontal sinus. These types of cells pneumatize through the frontal sinus opening, narrowing the frontal sinus drainage. In our study, the appearance of frontal recess cells almost made the frontal sinus ostium diameter narrower than in their absence (Pham et al., 2021). However, we only noted a statistically significant difference in the appear-

Table 8. Prevalence of frontal recess cells among studies.

	Our study (2023) n=280	*Tran et al., 2023 n=256*	*Tai et al., 2019 n=151*	*Tran et al. 2019 n=208*	*Choby et al., 2018 n=200*	*Seth et al., 2020 n=180*
ANC	**93.6**	**93**	**91.9**	**95.7**	**96.5**	**95.5**
SAC	36.8	33.2	28.7	16.3	30	33.3
SAFC	9.6	10.9	15.8	13	20	22.2
SBC	32.9	43.4	59.7	46.2	72	36.1
SBFC	11.4	7.4	25.8	13	5.5	21.1
SOEC	2.9	14.5	6.9	4.3	28.5	39.4
FSC	5.4	8.6	14.3	17.3	30	21.1

ance of SAFC narrowing of frontal sinus ostium diameter ($p<0.05$). Moreover, we recognized that the A-P dimension of the frontal recess was narrower when ANC ($p<0.0001$) and SAC ($p<0.05$) appeared. These two types of cells appear in the frontal recess, and when they are present in greater numbers, the size of the frontal recess becomes narrower. Therefore, during surgery to access the frontal sinus, the surgeon must remove these cells to open up the frontal sinus. In some uncomplicated cases, ANC alone removal may be enough to drain the inflamed frontal sinuses, especially in cases with a large ANC (Wormald, 2003).

CONCLUSION

Our study presented that the A-P diameter of the frontal sinus ostium varied among different frontal sinus morphology and the difference was statistically significant. The size of the male frontal sinus was bigger than the female ($p < 0.05$). From the above study, we have described the prevalence of cell types in the frontal recess according to a new classification – IFAC 2016 in Vietnamese people. Any cells appearing in the drainage area of the frontal sinus could narrow the frontal recess, in the presence of ANC or SAC could narrow the frontal recess with statistical significance. Therefore, for successful frontal sinus surgery, surgeons need to meticulously examine CT images to understand the anatomy of the frontal sinus area, especially the cells that obstruct the natural drainage pathway of the frontal sinus.

DECLARATIONS ETHICS

This study was accepted by the ethical board of Can Tho University of Medicine and Pharmacy (code 23.205.HV/PCT-HĐĐĐ).

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