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# COMPUTED TOMOGRAPHIC ANALYSIS OF FRONTAL RECESS CELL PREVALENCE ACCORDING TO INTERNATIONAL FRONTAL SINUS ANATOMY CLASSIFICATION

## *ULUSLARARASI FRONTAL SİNÜS ANATOMİ SINIFLAMASINA GÖRE FRONTAL RESES HÜCRE PREVALANSININ BİLGİSAYARLI TOMOGRAFİK ANALİZİ*

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**ABSTRACT**

**Objective:** To examine the prevalence of frontal recess (FR) cells based on the International Frontal Sinus Anatomy Classification (IFAC) in healthy sinuses, as well as evaluate the interrater agreement of the IFAC system.

**Methods:** Five hundred nine adult patients with non-diseased paranasal sinuses on computed tomography (CT) were retrospectively included in this study. Two researchers independently identified FR cells on 1018 sides using triplanar CT reconstructions. The prevalence of each cell type was assessed, and interobserver agreement was measured using the Kappa coefficient (κ).

**Results:** In our population, the agger nasi cell (ANC) had the highest prevalence (88.0%), followed by supra bulla cell (43.0%), supra agger cell (SAC) (25.0%), frontal septal cell (22.0%), supraorbital ethmoid cell (17.1%), supra agger frontal cell (SAFC) (8.3%), and supra bulla frontal cell (SBFC) (7.1%). Bilateral incidence was highest for the ANC (80.4%) and lowest for the SBFC (2.2%). The prevalence of most IFAC cells was similar between males and females, except in SAC (27.8% in females vs. 22.2% in males) and SAFC (11.6% in males vs. 5.1% in females). FR cells that pneumatize into the frontal sinus were observed in 28.6% of cases, with a significantly higher prevalence in male patients compared to females. Excellent interrater agreement was found for all FR cells, with κ values ranging from 0.94 to 1.0.

**Conclusion:** The prevalence of FR cells demonstrates variations specific to the population. Gender differences appear to influence the presence of cells pneumatizing into the frontal sinus. The IFAC is a reliable tool for identifying cells in the FR.

**Keywords:** International frontal sinus anatomy classification, sinus anatomy, frontal cells, computed tomograpy

**ÖZ**

**Amaç:** Sağlıklı paranazal sinüslerde frontal reses (FR) hücrelerinin prevalansını Uluslararası Frontal Sinüs Anatomisi Sınıflandırmasına (IFAC: International frontal sinus anatomy classification) dayalı olarak incelemek. Ayrıca, IFAC sisteminin gözlemciler arası uyumunu değerlendirmek.

**Yöntem:** Bu çalışmaya bilgisayarlı tomografik görüntülemelerinde (BT) paranazal sinüsleri hastalık bulunmayan 509 yetişkin hasta retrospektif olarak dahil edildi. İki araştırmacı birbirinden bağımsız olarak üç düzlemli BT rekonstrüksiyonlarını kullanarak 1018 taraftaki FR hücrelerini tanımladı. Her hücre tipinin prevalansı değerlendirildi ve gözlemciler arası uyum Kappa katsayısı (κ) kullanılarak ölçüldü.

**Bulgular:** Popülasyonumuzda, agger nasi hücresi (ANH) en yüksek prevalansa sahipti (%88,0), bunu supra bulla hücre (%43,0), supra agger hücre (SAH) (%25,0), frontal septal hücre (%22,0), supraorbital etmoid hücre (%17,1), supra agger frontal hücre (SAFH) (%8,3) ve supra bulla frontal hücre (SBFH) (%7,1) izledi. Bilateral insidans ANH için en yüksek (%80,4) ve SBFH için en düşük (%2,2) idi. SAH (kadınlarda %27,8; erkeklerde %22,2) ve SAFH (erkeklerde %11,6; kadınlarda %5,1) dışında diğer IFAC hücrelerinin prevalansı erkekler ve kadınlar arasında benzerdi. Vakaların %28,6'sında frontal sinüse pnömatize olan FR hücreleri gözlendi. Bu hücrelerin prevalansı erkek hastalarda kadınlara göre anlamlı derecede daha yüksekti. Tüm FR hücreleri için 0,94 ile 1,0 arasında değişen κ değerleri ile mükemmel bir gözlemciler arası uyum bulunmuştur.

**Sonuç:** FR hücrelerinin prevalansı popülasyona özgü farklılıklar göstermektedir. Cinsiyet farklılıkları, frontal sinüse pnömatize olan hücrelerin varlığını etkiler. IFAC, FR'deki hücreleri tanımlamak için güvenilir bir araçtır.

**Anahtar Kelimeler:** Uluslararası frontal sinüs anatomisi sınıflandırması, sinüs anatomisi, frontal hücreler, bilgisayarlı tomografi

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## Introduction

The frontal sinus presents a significant challenge in endoscopic sinus surgery (ESS) due to its location and complex anatomy. In particular, access to the frontal sinus requires dissection across the intricate frontoethmoid region using angled optics and instruments, making it one of the most difficult areas to address during ESS.[1] Furthermore, the proximity of the frontal sinus to critical structures such as the orbit and skull base complicates the procedure.[2]

The frontal sinus drains through the frontal recess (FR), which is a funnel-shaped space containing a number of cells that determine the direction and position of its drainage pathway. Accurate identification of these cells is essential for determining the appropriate surgical intervention and can only be achieved through careful analysis of preoperative computed tomography (CT) imaging.[1] By tailoring the surgical approach to the unique configuration of each patient's FR cells, the surgeon can ensure the most effective and individualized treatment.

Since the first detailed description of FR cells by Van Alyea[3] in 1941, numerous attempts have been made to classify these cells using various nomenclatures and classifications.[4-8] However, these attempts have resulted in inconsistencies in nomenclatures, overlapping definitions, and inadequate anatomic detail across different classifications. To address these challenges, the International Frontal Sinus Anatomy Classification (IFAC) was developed in 2016 as an international consensus document to precisely characterize FR cells in a reproducible and surgically relevant manner. IFAC has significantly enhanced our understanding of various FR cell variants, improved surgical planning, facilitated accurate teaching of surgical steps, and standardized reporting of ESS outcomes.[1]

Many studies have investigated the prevalence of FR cells using different frontal sinus classification systems. However, there is limited research utilizing the newly developed IFAC. In this radiological study, our aim was to assess the prevalence of FR cells in an adult population using the IFAC system and to evaluate the interrater agreement of this classification for FR cells.

## Methods

The study involved a retrospective analysis of paranasal sinus CT scans from adult patients with healthy paranasal sinuses to establish the prevalence of FR cells using the IFAC system (Table 1). CT scans conducted from February 2021 to November 2021 were acquired from the database of our Department of Radiology, regardless of the indication. Adult patients over 18 years old with non-diseased paranasal sinuses and fine-cut axial image acquisition CT scans (0.5 mm) were included in the study. Patients with chronic rhinosinusitis, paranasal sinus pathology, unilateral or bilateral frontal sinus aplasia, maxillofacial trauma, congenital anomalies, or prior sinus surgery were excluded. Moreover, CT scans with significant motion or beam hardening artifacts that impeded proper evaluation were also eliminated.

The CT images were captured using a multidetector CT scanner (Aquilion 64; Canon Medical, Tokyo, Japan) featuring a 64-channel, 0.5 mm detector row. A single acquisition was performed following the standard diagnostic protocol for paranasal sinus examination: collimation 0.5–2 mm, 120 kV, 50–80 mAs, pitch 0.84, acquisition FOV 150 mm. The scans, all stored in Digital Imaging and Communications in Medicine (DICOM) format, were retrieved from our radiology database. Utilizing the Picture Archiving and Communication System (PACS) (Sectra, Linköping, Sweden), two experienced researchers (AY and HMD, with 20 and 15 years of practice in the field, respectively) independently assessed the FR cells in triplanar fashion. The left and right sides were assessed independently. A consensus was reached if both researchers agreed on the presence of an IFAC cell on the CT scan. In the case of a tie, another rhinologist in our department was consulted, and his decision was used to break the tie. The prevalence, lateral symmetry, and interrater agreement of each IFAC cell were all evaluated.

The present study was submitted to and approved by the local ethics committee of Kocaeli University Faculty of Medicine in accordance with protocol number KU-GOKAEK-2022/224. As this study involved a retrospective design, the ethical committee determined that informed consent was not required. All procedures conducted in this study adhere to the ethical standards for human research established by institutional and/or national research committees, as well as the principles outlined in the 1964 Helsinki Declaration and its subsequent amendments or comparable ethical standards.

### Statistical Analysis

Statistical analyses were conducted using IBM SPSS version 20.0 for Windows (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation, and categorical variables were presented as frequencies and percentages. The level of agreement between the two observers was determined using the Kappa coefficient (κ). A κ value of 0 indicates no agreement, while values of 0–0.2, 0.21–0.4, 0.41–0.6, 0.61–0.8, and 0.81–1.0 indicate slight, fair, moderate, substantial, and almost perfect agreements, respectively.[9] The statistical significance level was set at $p<0.05$.

**Table 1.** International Frontal Sinus Anatomy Classification (Modified from: reference [1])

| Cell type | Definition |
|---|---|
| *Anteriorly based cells* | |
| Agger nasi cell (ANC) | Cell that sits either anterior to the origin of the middle turbinate or sits directly above the most anterior insertion of the middle turbinate into the lateral nasal wall |
| Supra agger cell (SAC) | Anterior-lateral ethmoidal cell, located above the agger nasi cell (not pneumatizing into the frontal sinus) |
| Supra agger frontal cell (SAFC) | Anterior-lateral ethmoidal cell that extends into the frontal sinus. A small SAFC will only extend into the floor of the frontal sinus, whereas a large SAFC may extend significantly into the frontal sinus and may even reach the roof of the frontal sinus |
| *Posteriorly based cells* | |
| Supra bulla cell (SBC) | Cell above the bulla ethmoidalis that does not enter the frontal sinus |
| Supra bulla frontal cell (SBFC) | Cell that originates in the supra-bulla region and pneumatizes along the skull base into the posterior region of the frontal sinus. The skull base forms the posterior wall of the cell |
| Supraorbital ethmoid cell (SOEC) | An anterior ethmoid cell that pneumatizes around, anterior to, or posterior to the anterior ethmoidal artery over the roof of the orbit. It often forms part of the posterior wall of an extensively pneumatized frontal sinus and may only be separated from the frontal sinus by a bony septation |
| *Medially based cells* | |
| Frontal septal cell (FSC) | Medially based cell of the anterior ethmoid or the inferior frontal sinus, attached to or located in the interfrontal sinus septum, associated with the medial aspect of the frontal sinus outflow tract, pushing the drainage pathway laterally and frequently posteriorly |

## Results

During the specified time frame, we obtained 731 paranasal sinus CT scans of adult patients, of which 509 scans (1018 sides) met the inclusion criteria for our study. The cohort consisted of almost an equal number of male (n=255; 50.1%) and female (n=254; 49.9%) subjects. The subjects' mean age was 38.35 ± 14.11 years (range: 18–83). The ethnic distribution of our cohort was predominantly mixed between European and Asian ethnicities.

### I. Prevalence of FR cells

The most common group of cells were the anterior group cells, which accounted for 57.6% of all cells. Among all IFAC cell types, ANC had the highest prevalence (88.0%), followed by SBC (43.0%), SAC (25.0%), FSC (22.0%), SOEC (17.1%), SAFC (8.3%), and SBFC (7.1%) (Table 2). In 28.6% of the frontal recesses, we observed the presence of at least one FR cell pneumatizing into the frontal sinus, such as SAFC, SBFC, and SOEC. Examples of various types of IFAC cells are illustrated in Figure 1.

**Table 2.** Prevalences of frontal recess cells in this study and previous studies employing patients with healthy sinuses

| Authors | Number of patients | Anterior group cells | | | Posterior group cells | | | Medial cell |
|---|---|---|---|---|---|---|---|---|
| | | ANC (%) | SAC (%) | SAFC (%) | SBC (%) | SBFC (%) | SOEC (%) | FSC (%) |
| Sjogren et al. [13] | 95 patients (190 sides) | 88.9 | 29.5 | 22.1 | 55.8 | 18.9 | 11.6 | 13.2 |
| Choby et al. [10] | 100 patients (200 sides) | 96.5 | 30.0 | 20.0 | 72.0 | 5.5 | 28.5 | 30.0 |
| Gotlib et al. [11] | 103 patients (206 sides) | 86.9 | 34.0 | 17.5 | 77.2 | 22.8 | 5.8 | 27.2 |
| Tran et al. [14] | 114 patients (208 sides) | 95.7 | 16.3 | 13.0 | 46.2 | 4.3 | 17.3 | 10.6 |
| Pham et al. [12] | 506 patients (757 sides with non-diseased sinuses) | 91.5 | 34.1 | 13.7 | 60.0 | 20.7 | 6.3 | 14.7 |
| Yaylacı et al. (Current study) | 509 patients (1018 sides) | 88.0 | 25.0 | 8.3 | 43.0 | 7.1 | 17.1 | 22.0 |

Abbreviations: *ANC* agger nasi cell, *SAC* supra agger cell, *SAFC* supra agger frontal cell, *SBC* supra bulla cell, *SBFC* supra bulla frontal cell, *SOEC* supraorbital ethmoidal cell, *FSC* frontal septal cell

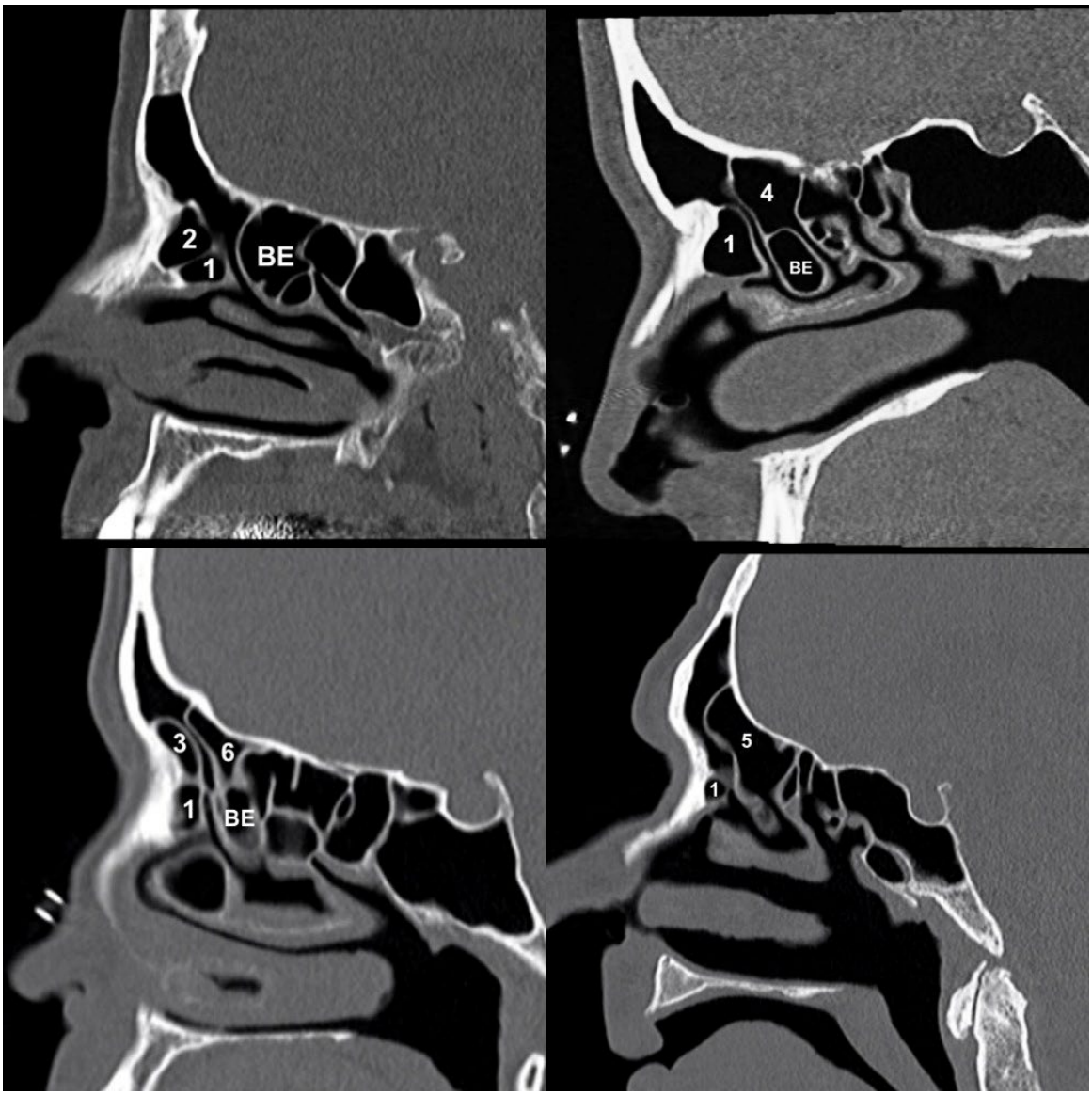


**Figure 1.** Computed tomography of paranasal sinuses showing examples of International Frontal Sinus Anatomy Classification cells. 1: Agger nasi cell, 2: Supra agger cell, 3: Supra agger frontal cell, 4: Supra bulla cell, 5: Supra bulla frontal cell, 6: Supraorbital ethmoidal cell. BE: Bulla ethmoidalis

The prevalence of individual IFAC cells did not differ significantly between males and females in ANC, SBFC, SOEC, SBC, and FSC ($p>0.05$ for all), but statistically significant differences were found in the prevalences of SAC (27.8% in females vs. 22.2% in males; $p=0.043$) and SAFC (11.6% in males vs. 5.1% in females; $p<0.001$). Additionally, there was a significant difference in the rate of any FR cell that pneumatizes into the frontal sinus between genders (32.5% in males vs. 24.6% in females; $p=0.006$).

**II. Lateral symmetry of individual FR cells**

Table 3 presents the frequency of lateral symmetry in individual FR cells. The results revealed that the SBFC exhibited the highest rate of lateral symmetry (90.2%), indicating the presence or absence of the cell in both the right and left FRs of each patient. This was followed by the SAFC (88.0%), ANC (84.7%), SOEC (81.9%), SAC (71.7%), and SBC (69.7%). The ANC had the highest incidence of bilateral presence (80.4%), followed by SBC (28.1%), SAC (10.8%), SOEC (8.1%), SAFC (2.4%), and SBFC (2.2%), as illustrated in Figure 2. Furthermore, the odds ratio (OR) was calculated to determine the likelihood of a cell being present on the contralateral side if it is present on the ipsilateral side. The results showed that SBFC had the highest OR (8.78; 95% CI, 3.81–20.28), while SAC had the lowest OR (3.23; 95% CI, 2.13–5.10).

**III. Interrater agreement of FR cells**

The level of agreement among researchers for FR cells was very high, as indicated by κ values of 0.94 for SAFC, 0.95 for ANC, 0.97 for SAC, 0.98 for SBFC, 0.99 for SBC, 0.99 for SOEC, and a perfect score of 1.00 for FSC.

**Table 3.** Frequency of frontal recess cell symmetry

| IFAC cell group | IFAC cell name | Bilateral presence n (%) | Unilateral presence n (%) | Absent on both sides n (%) | Odds ratio* | Confidence interval (95%) |
|---|---|---|---|---|---|---|
| Anterior group cells | ANC | 409 (80.4) | 78 (15.3) | 22 (4.3) | 6.02 | 3.24–11.18 |
| | SAC | 55 (10.8) | 144 (28.3) | 310 (60.9) | 3.23 | 2.13–5.10 |
| | SAFC | 12 (2.4) | 61 (12.0) | 436 (85.6) | 5.99 | 2.76–12.96 |
| Posterior group cells | SBC | 143 (28.1) | 154 (30.2) | 212 (41.7) | 5.16 | 3.52–7.55 |
| | SBFC | 11 (2.2) | 50 (9.8) | 448 (88.0) | 8.78 | 3.81–20.28 |
| | SOEC | 41 (8.1) | 92 (18.1) | 376 (73.8) | 7.46 | 4.42–12.60 |

Abbreviations: IFAC International Frontal Sinus Anatomy Classification, n number of patients, ANC agger nasi cell, SAC supra agger cell, SAFC supra agger frontal cell, SBC supra bulla cell, SBFC supra bulla frontal cell, SOEC supraorbital ethmoidal cell
*Odds ratio represents the likelihood that a cell will be present on the contralateral side if the cell is present on the ipsilateral side

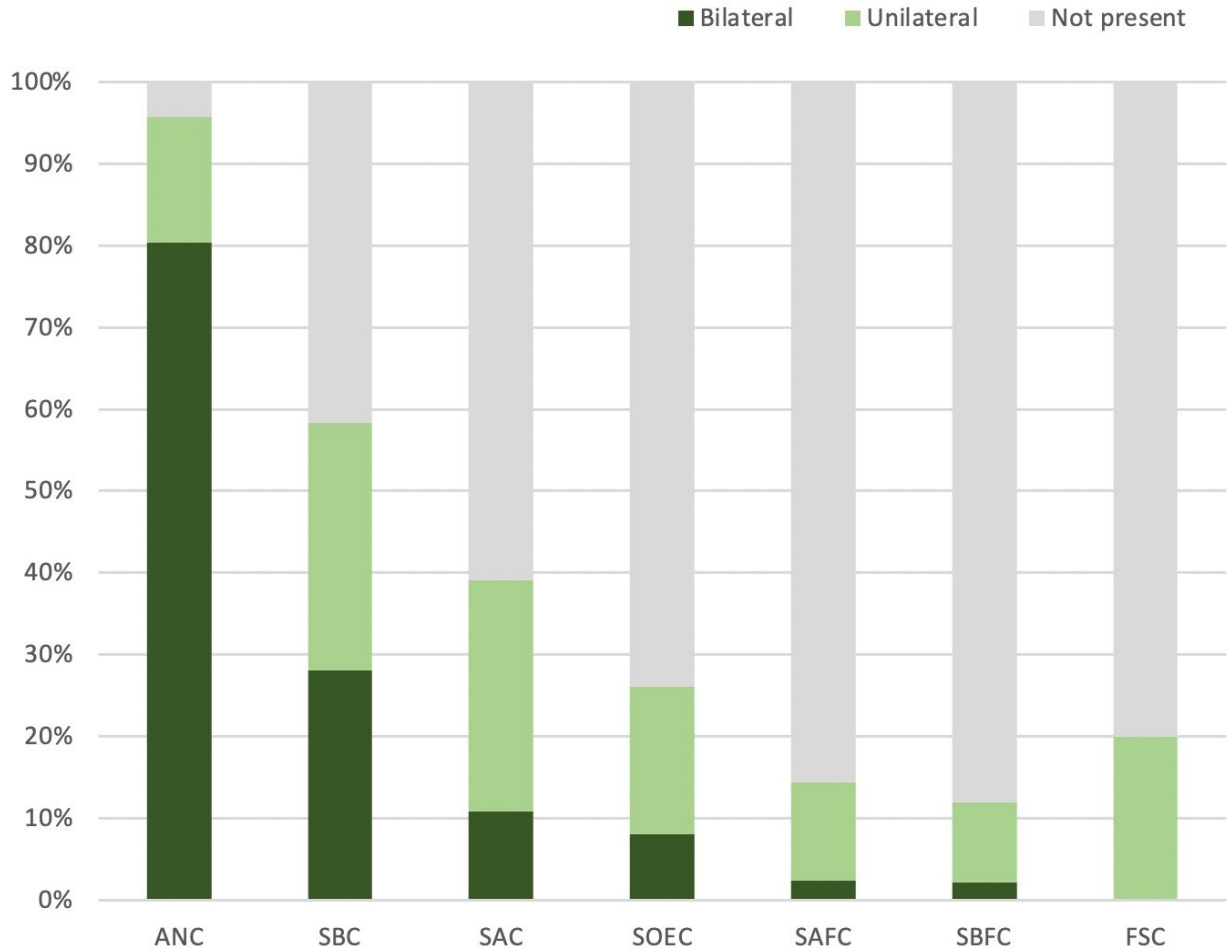


**Figure 2.** Graphic showing the frequency of frontal recess cell symmetry. *ANC* agger nasi cell, *SBC* supra bulla cell, *SAC* supra agger cell, *SOEC* supraorbital ethmoidal cell, *SAFC* supra agger frontal cell, *SBFC* supra bulla frontal cell, FSC frontal septal cell

## Discussion

In the current study, we determined the prevalence, symmetry, and interrater agreement of IFAC cell types in an adult population with non-diseased paranasal sinuses. To date, a few studies [10-14] have documented the prevalence of FR cells using the IFAC in different populations with healthy sinuses. The most frequently observed FR cell in our study was ANC, present in 88% of cases, consistent with previous literature quoting ANC incidence between 87-97%. Given its high prevalence, ANC serves as a reference cell for all anteriorly-based cells in the IFAC system and is a crucial consideration in endoscopic frontal sinus surgery. The second most prevalent cell in our study was SBC, followed by SAC, FSC, SOEC, SAFC, and SBFC in descending order. The prevalences of SAC, SBFC, and SOEC in our study were comparable to previous studies [10-14], while the prevalences of SAFC and SBC were lower. Our results confirm that the prevalence of individual FR cells other than ANC can vary significantly across different populations. Alongside ethnic composition, variations in the gender distribution among the studies could influence the overall prevalence rates.

In endoscopic frontal sinus surgery, the presence of FR cells pneumatizing throughout the frontal sinus, such as SAFC, SBFC, and SOEC, can present challenges and may necessitate alternative procedures, including the axillary flap procedure, the endoscopic modified Lothrop procedure, or external approaches.[15] Our study found that at least one such cell was present in approximately 29% of frontal recesses, which is consistent with Gotlib et al.'s study[11], which reported a rate of 28%. Furthermore, we noted a higher prevalence of these cells in male patients, likely attributed to greater pneumatization of their frontal sinuses.[16]

Regarding the lateral symmetry of FR cells, our analysis demonstrated that SBFC had the highest incidence of presence or absence on both sides, followed by SAFC, ANC, SOEC, SAC, and SBC. Additionally, we found that the incidence of bilateral presence was high for ANC and SBC, which was consistent with the results of Choby et al.'s study.[10] Yet, in our investigation of the likelihood of a cell's contralateral presence when present ipsilaterally, we observed that SBFC had the highest probability. This contrasts with Choby et al.'s study, where SOEC was reported to have the highest probability of contralateral presence when present on the ipsilateral side. The variation in findings may be attributed to the challenge of distinguishing between a SBFC and a SOEC. On axial CT scans, the SOEC may appear similar to an SBFC as it ascends towards the frontal sinus. However, on the coronal and parasagittal planes, the pneumatization of the cell over the orbit distinguishes it as an SOEC rather than an SBFC. It is worth noting that the identification of this pneumatization over the orbit can be challenging at times, as highlighted in Choby's paper, where SBFC and SOEC were reported to have the lowest reliability among researchers. Consistent with our study and the results from Choby et al., SAC consistently exhibited the lowest probability of contralateral presence.

Our analysis showed that there was a high level of inter-observer agreement between researchers for nearly all IFAC cell types. Among the different cell types, the FSC demonstrated the highest level of agreement among researchers, while the SAFC had the lowest. Choby et al.[10] also found good to excellent interrater agreement in their evaluation of one hundred CT scans. However, they reported that the SAC had the highest reliability among researchers, whereas the SBFC had the lowest. The authors noted that the difficulty in distinguishing between the ethmoid skull base and the posterior plate of the frontal sinus could lead to the misidentification of some cells. In another study, Villarreal et al.[17] reported substantial to almost perfect agreement among 15 rhinologists from various centers. They found that the inter-observer agreement was slight for the SAC and SBC, fair for the SBFC and SOEC, and moderate for the ANC, SAFC, and FSC. However, in this study, the authors used sets of selected images with specific types of FR cells marked rather than multiplanar reconstruction with adjustable planes. Our findings, combined with those of Choby et al., suggest that triplanar analysis of a fine-cut CT examination can aid in accurately identifying FR cells.

The present study has several limitations that need to be acknowledged. First, the ethnic composition of our research sample may limit the generalizability of our findings. Second, the study was not conducted across multiple centers, which may have resulted in the neglect of potential local populational differences. Third, we included only patients with healthy paranasal sinuses, potentially resulting in an underestimation of the true prevalence of FR cells. However, a recent study suggested that individuals with advanced sinus disease had a significantly higher likelihood of inaccuracies in the identification of FR cells [18]. Lastly, while two independent observers analyzed the CT data and the results were compared and reviewed, the interpretation of the data is always subjective. Despite the limitations, our study utilized a considerable number of CT scans with a fine-cut slice thickness and employed multiplanar reconstruction with adjustable planes. We believe that our findings significantly contribute to estimating the global prevalence of IFAC cells and lay the groundwork for further studies across diverse ethnic groups.

As a conclusion, our study emphasizes the significance of population-specific prevalence rates of individual FR cells when planning for endoscopic sinus surgery. We found that males have a higher prevalence of FR cells that pneumatize across the frontal sinus, indicating that more complicated surgical procedures may be necessary to achieve complete access to the frontal sinus in males. With its high level of interrater agreement, IFAC proves to be a reliable tool for classifying cells in the FR.

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**Compliance of Ethical Statement**

Approval was granted by the Ethics Committee of the Kocaeli University Faculty of Medicine (KU-GOKAEK-2022/224).

**Conflict of Interest**

The authors have no financial relationships or conflicts of interest to disclose.

**Author Contributions**

AY: Designed the study, collected the clinical data, conducted data analysis, and prepared the manuscript; HMD: Data collection and analysis.

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