Original Article

Frequency of frontal cells according to the International Frontal Sinus Anatomy Classification

Engin Başer[1], Orkun Sarioglu[2], Cem Bulut[1], İlker Burak Arslan[1], İbrahim Çukurova[1]

[1]Department of Otorhinolaryngology Head and Neck Surgery, University of Health Sciences, Izmir Tepecik Training and Research Hospital, Izmir, Turkey
[2]Department of Radiology, University of Health Sciences, Izmir Tepecik Training and Research Hospital, Izmir, Turkey

ABSTRACT

Objectives: This study aims to determine the regional frequency of frontal cells classified by the International Frontal Sinus Anatomy Classification (IFAC) in local population radiologically.

Patients and Methods: Between February 2018 and May 2019, a total of 300 frontal recess regions of 150 adults (88 males, 62 females; mean age 33.5±9.4 years; range, 18 to 54 years) eligible for the inclusion criteria and undergoing paranasal sinus (PNS) computed tomography (CT) were included in the study. In CT analysis; agger nasi cells, supra agger cells, supra agger frontal cell, suprabullar cells, suprabullar frontal cells, supraorbital ethmoid cells and frontal septal cells were evaluated.

Results: For anteriorly based cells, there were agger nasi cells, supra agger cells, and supra agger frontal cells with rates of 94.3% (n=283), 40.0% (n=120), and 14.7% (n=44), respectively. For posteriorly based cells, there were suprabullar cells, suprabullar frontal cells, and supraorbital ethmoid cells with rates of 59.7% (n=179), 7.3% (n=22) and 7.3% (n=22), respectively. For medially based cells, there were frontal septal cells with a rate of 29.3% (n=44).

Conclusion: Our study results suggest that the regional prevalence of frontal cells classified by the IFAC in Turkish population can be determined radiologically, providing contribution to the generation of estimates of the global prevalence of frontal cells.

Keywords: Computed tomography, endoscopic sinus surgery, frontal sinus classification, frontal sinus, International Frontal Sinus Anatomy Classification.

The most important causes for the development of frontal rhinosinusitis are the abnormalities leading to obstruction in the frontal sinus drainage pathway. Frontal recess is the narrowest and longest part of this drainage pathway.[1] The area where the frontal sinus drains is called the frontal recess. This space is located behind the beak of the frontal bone (the nasal process of the frontal bone), between the lamina papyracea and the vertical lamella of the middle turbinate as extending to the lateral wall of the olfactory fossa and anterior to the basal lamella of the middle turbinate. With the aim of anatomical classification of these cells, the cells or space above and anterior to the bulla ethmoidalis are included in this space.[2,3] Due to its narrow confines and variable anatomy as well as adjacency with the orbita, cribriform plate, and anterior ethmoidal artery, the frontal sinus has been defined as the most challenging sinus regarding its surgery. Therefore, endoscopic approaches in this region should be planned

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Correspondence: Engin Başer, MD. SBÜ İzmir Tepecik Eğitim ve Araştırma Hastanesi Kulak Burun Boğaz Kliniği, 35020 Konak, İzmir, Türkiye.
e-mail: dr.enginbaser@hotmail.com

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carefully and its anatomy should be evaluated thoroughly during the preoperative period.[4] Recently, an interest in surgical approaches of the frontal sinus has increased the rate of frontal sinus surgery.[5]

The frontal recess is the area where the frontal sinus drains and including various cells that can affect this drainage.[2] To describe the cells in this region and to define the outlet of the frontal sinus, many classifications were recommended.[6] There are also different classification methods for discrimination of frontal recess cells and frontoethmoidal cells. Schaeffer, for the first time, defined this interesting anatomical area in 1916 and called it the "nasofrontal region".[7] However, van Alyea preferred using the term "frontal recess" rather than "nasofrontal region" in 1941.[7] Until today, the most frequently used classification of frontoethmoidal cells was the one described by Bent et al.[15] in 1994 which categorizes frontal cells as type I-IV.

The emergence of endoscopic frontal sinus surgery caused an increase in interest in detailed anatomy of nose and paranasal sinuses (PNS). However, the official Terminologica Anatomica used by basic anatomists omits many of the structures of surgical importance. Although these kinds of classifications help us to recognize the region, due to incompleteness of anatomical definitions and presence of differences between the raters, they are limited. Therefore, the International Frontal Sinus Anatomy Classification (IFAC) defined by Wormald et al.[2] in 2016 was developed to establish more precise naming of frontal recess cells (Table 1). The aims of this classification are to be able to use common terminology between the surgeons, to use the same definitions in the surgery training, and to increase the sensitivity in surgical planning of the dissections.[2]

When any new anatomical classification is recommended, in addition to describing the prevalence of anatomical variants defined by the classification system, the presence of consistency between inspectors of the recommended classification system is also important. In the present study, we aimed to determine the

Table 1. IFAC classification of frontal recess cells[2]

IFAC cell type	IFAC cell name	Definition	Abbreviation
Anteriorly based cell	Agger nasi cell	Cell that sits either anterior to the origin of the middle turbinate or directly above the most anterior insertion of the middle turbinate into the lateral nasal Wall	ANC
	Supra agger cell	Anterolateral ethmoid cell, located above the agger nasi cell (but not pneumatizing into the frontal sinus	SAC
	Supra agger frontal cell	Anterolateral ethmoid cell that extends into the frontal sinus	SAFC
Posteriorly based cell	Supra-bulla cell	Cell above the ethmoid bulla that does not enter the frontal sinus	SBC
	Supra-bulla frontal cell	Cell that originates in the supra-bulla region and pneumatizes along the skull base in the posterior region of the frontal sinus	SBFC
	Supraorbital ethmoid cell	Anterior ethmoid cell that pneumatizes around, anterior to, or posterior to the anterior ethmoid artery over the roof of the orbit	SOEC
Medially based cell	Frontal septal cell	Medially based cell attached to or located in the interfrontal sinus septum	FSC

IFAC: International Frontal Sinus Anatomy Classification

regional frequency of frontal cells classified by IFAC in local population radiologically using PNS computed tomography (CT).

PATIENTS AND METHODS

A total of 300 frontal recess regions of 150 adults (88 males, 62 females; mean age 33.5±9.4 years; range, 18 to 54 years) eligible for the inclusion criteria among patients presenting to our hospital for any reason and undergoing PNS CT between February 2018 and May 2019 were included in the study. Inclusion criteria were as follows: having CT scans in ≥18-year-old adults using either the multidetector or cone beam technique; contiguous, fine-cut axial image acquisition (<2 mm), allowing for triplanar reconstruction; and scans performed without contrast administration. Exclusion criteria were as follows: CT scans with slice thickness of >2 mm, inadequate triplanar reconstruction (i.e., the viewer was unable to reconstruct axial, coronal, and sagittal planes for simultaneous viewing), a history of previous trauma, congenital anomaly, or previous sinus surgery. Axial, coronal, and sagittal reconstructions were reviewed on a triplanar viewing computer with localization ability (Centricity Universal Viewer, GE Healthcare, Chicago, IL, USA).

All CT scans were performed by using a 64-slice CT scanner (Aquilion 64; Toshiba Medical Systems, Tochigi, Japan) with 0.5 mm collimation, 120 kV, and 150 mAs. Coronal, axial, and sagittal reformatted images in 2-mm slice thicknesses were examined in the bone window. The presence of frontal cells was independently evaluated by two otorhinolaryngologists and a radiologist, each familiar with the IFAC system. After the evaluation, the naming of cells was accepted in case of deciding by unanimity or majority of votes. The same definition of the cell was considered sufficient by the two senior assessors.

A written informed consent was obtained from each patient. The study protocol was approved by the University of Health Sciences, Izmir Tepecik Training and Research Hospital Ethics Committee (No: 2019/1-14). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Statistical analysis

Statistical analysis was performed using the Number Cruncher Statistical System (NCSS) 2007 software (NCSS LLC, Kaysville, UT, USA). Descriptive data were expressed in mean ±

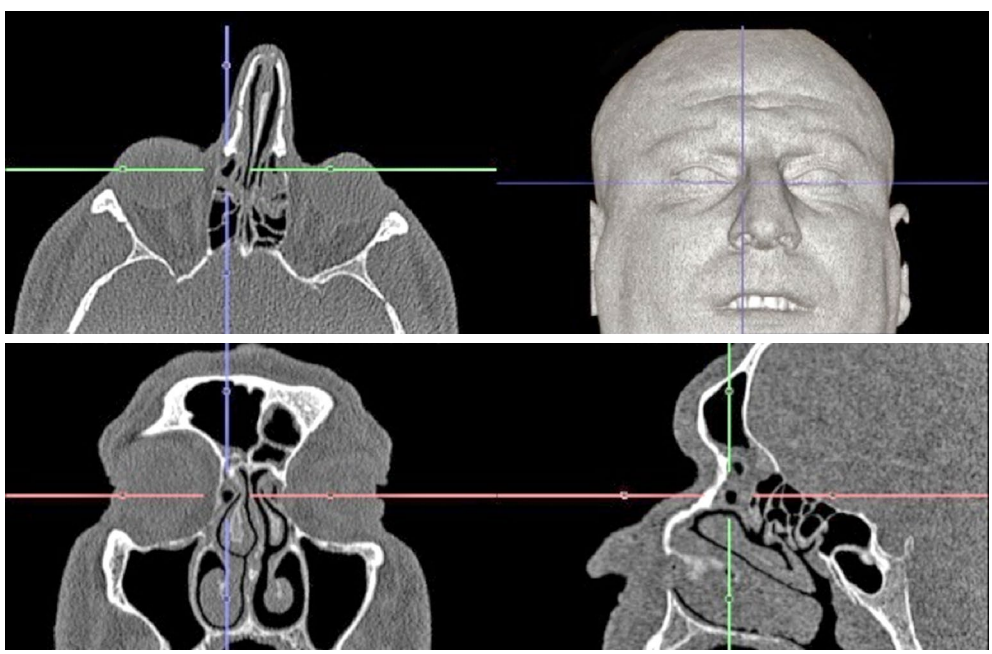

Figure 1. *Agger nasi cell.*

standard deviation (SD), median (min-max), or number and frequency. The Pearson chi-square test and Fisher-Freeman-Halton test were used to compare qualitative data. A p value of <0.05 was considered statistically significant.

RESULTS

For anteriorly based cells, there were agger nasi cells (Figure 1), supra agger cells, and supra agger frontal cells with rates of 94.3% (n=283), 40.0% (n=120), and 14.7% (n=44), respectively. For posteriorly based cells, there were suprabullar cells, suprabullar frontal cells, and supraorbital ethmoid cells with rates of 59.7% (n=179), 7.3% (n=22) and 7.3% (n=22), respectively. For medially based cells, there were frontal septal cells (Figure 2) with a rate of 29.3% (n=44) (Figure 3).

A total of 124 cells of 62 female patients included in the study were observed to distribute as follows: agger nasi cells, supra agger cells, supra agger frontal cells, suprabullar cells, suprabullar frontal cells, supraorbital ethmoid cells, and frontal septal cells with rates of 95.2% (n=118), 39.5% (n=49), 12.9% (n=16), 60.5% (n=75), 4.8% (n=6), 3.2% (n=4), and 29.0% (n=18), respectively. A total of 176 cells of 88 male patients included in the study were observed to distribute as follows: agger nasi cells, supra agger cells, supra agger frontal cells, suprabullar cells, suprabullar frontal cells, supraorbital ethmoid cells, and frontal septal cells with rates of 93.8% (n=165), 40.3% (n=71), 15.9% (n=28), 59.1% (n=104), 9.1% (n=16), 10.2% (n=18), and 29.5% (n=26), respectively (Figure 4).

The rates of agger nasi cells, supra agger cells, supra agger frontal cells, suprabullar cells, suprabullar frontal cells, and frontal septal cells were not significantly different according to sex (p>0.05). The rate of the supraorbital ethmoid cell was found to be significantly higher in males compared to females (p=0.022 and p<0.05, respectively).

While agger nasi cells were observed bilaterally in 91.3% (n=137) and unilaterally in 6.0% (n=9) of patients, they were not present bilaterally in 2.7% (n=4) of patients. While supra agger cells were observed bilaterally in 18.0% (n=27) and unilaterally in 44.0% (n=66) of patients, they were not present bilaterally in 38.0% (n=57) of patients. While supra agger frontal cells were observed bilaterally in

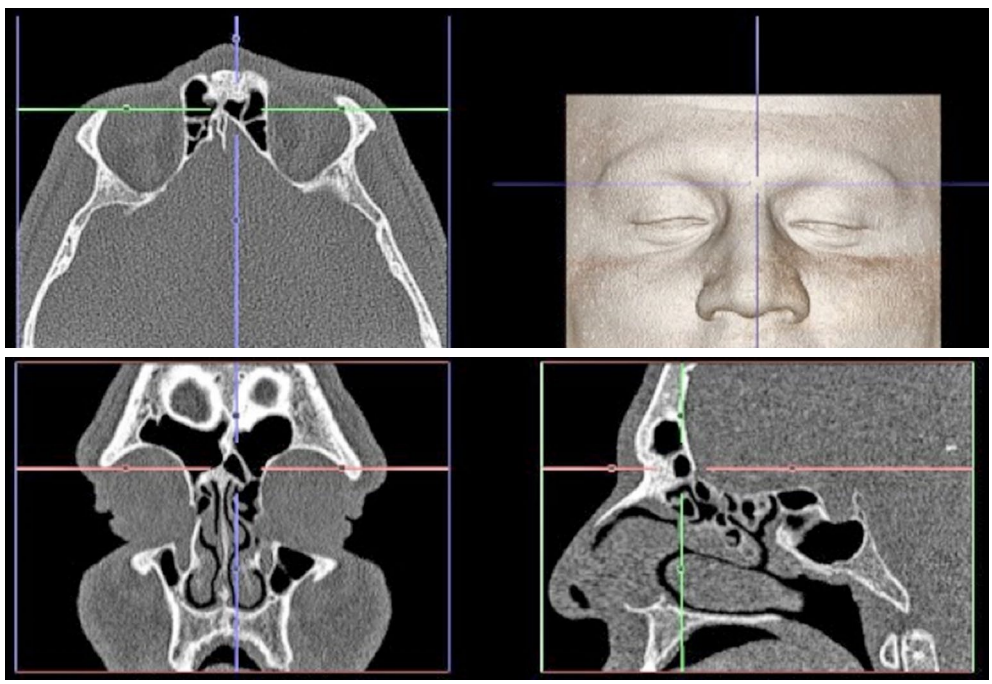

Figure 2. Frontal septal cell.

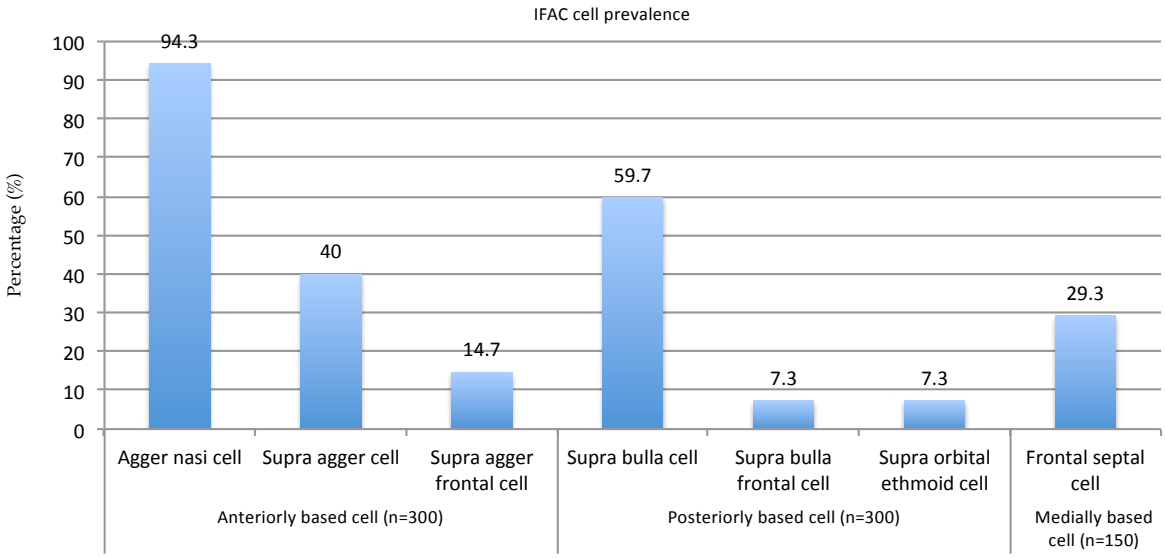

Figure 3. *Distribution of cell types.*

5.3% (n=8) and unilaterally in 18.7% (n=28) of patients, they were not present bilaterally in 76.0% (n=114) of patients. While suprabullar cells are observed bilaterally in 41.3% (n=62) and unilaterally in 36.7% (n=55) of patients, they were not present bilaterally in 22.0% (n=33) of patients. While suprabullar frontal cells were observed bilaterally in 1.3% (n=2) and unilaterally in 12.0% (n=18) of patients, they were not present bilaterally in 86.7% (n=130) of patients. While supraorbital ethmoid cells were observed bilaterally in 0.7% (n=1) and unilaterally in 13.3% (n=20) of patients, they were not present bilaterally in 86.0% (n=129) of patients. While the frontal septal cells were observed bilaterally in 29.3% (n=44) of patients, they were not present bilaterally in 70.7% (n=106) of patients.

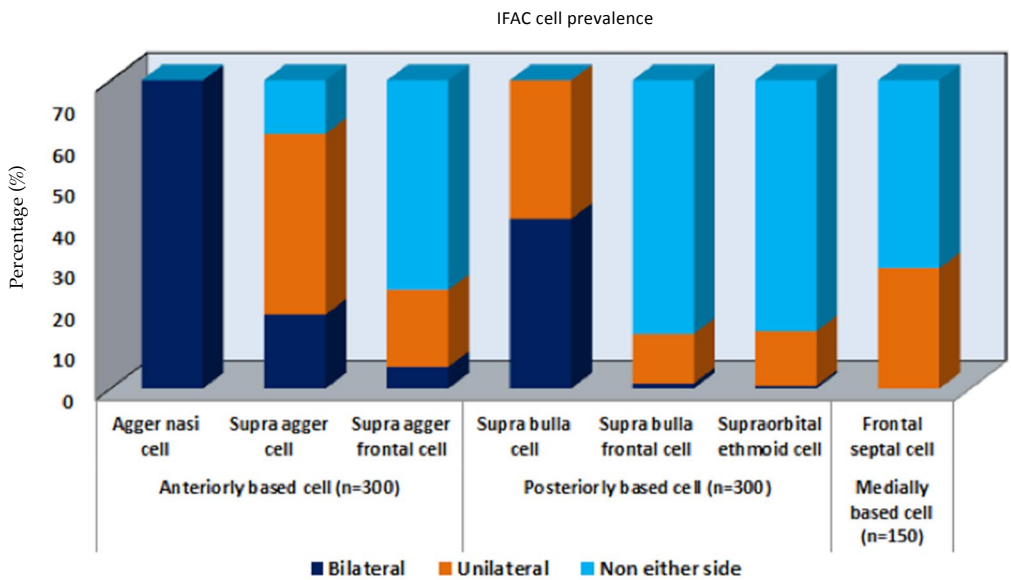

Figure 4. *Distribution of cell locations.*

The localizations of agger nasi cells, supra agger cells, supra agger frontal cells, suprabullar cells, suprabullar frontal cells, and frontal septal cells were not statistically different according to sex ($p>0.05$). The localizations of the supraorbital ethmoid cell were not statistically different according to sex ($p=0.048$; $p>0.05$). However, the rate of unilateral localization was higher in males compared to females ($p=0.025$; $p<0.05$). The rate of absence of bilateral localization was higher in females compared to males ($p=0.028$; $p<0.05$).

DISCUSSION

Functional endoscopic sinus surgery (FESS) has become one of the most commonly performed surgical procedures by otolaryngologists.[7] The widespread adoption of FESS necessitates the understanding of the anatomy of the nose nasal cavity and the PNS. The anatomy of the internal nose nasal cavity and PNS is complex. However, any of the PNS is not complex than frontal sinus which is the most complex part of the nose.[8] Frontoethmoidal cells in the frontal recess are anterior ethmoid air spaces. These cells alter the frontal sinus drainage pathway and they can localize in the frontal ostium and sinus. The existence of these cells increases the difficulty of frontal sinus surgery.[9] However, the frontal recess is still a region causing confusion for surgeons. Due to its narrow confines and variable anatomy, surgery of the frontal recess is difficult.[10]

Despite correct conservative therapy, potentially, frontoethmoidal cells may contribute to the development of recurrent acute rhinosinusitis or the persistence of inflammatory changes in PNS.[11] Due to having a complex structure, the presence of cellular variations frequently encountered, and neighborhood with vital structures (e.g., the skull base, and eye), the anatomy of the frontal recess is difficult. To manage frontal sinus diseases successfully and to reduce the complication risk in sinus surgery, radiological and surgical anatomy of this region should be known very well.[10]

Revision surgery is required with a rate of 10 to 15% in endoscopic sinus surgery.[12] Frontal sinus pathology is present in 43 to 50% of all patients undergoing revision surgery, and it is one of the most important causes of revision surgery.[13] Considering the frontal sinus drainage pathway is comprised of many cells with a quite variable pneumatization degree, frontal sinus surgery is a more difficult region in both primary and revision surgeries. The most common reasons for recurrence in frontal sinus revision surgery include recurrent mucosal disease, unopened agger nasi, and ethmoidal cells and lateralized middle turbinate. In addition, skipped frontal cells and scarring may also be observed.[14] Therefore, the definition and recognition of frontal sinus cells are important.

Until today, the most widely adopted classification of frontal cells was the one described by Bent et al.[15] in 1994 which classified frontal cells as type I-IV. This classification was further extended in 1996 with the addition of the followings: agger nasi cells, frontal bullar cells, suprabullar cells, supraorbital cells, and interfrontal sinus septal cells.[16] Meyer et al.[17] performed a prevalence study of frontal cells using coronal CT scans of the sinuses according to the Bent and Kuhn classification. Accordingly, the authors found frontal sinus cells described based on the Bent and Kuhn classification in 20.4% of patients. They also found the most frequently type I (14.9%) and type III frontal sinus cells (1.7%), respectively. In recent years, the region of the frontal recess became better understandable with three-dimensional imaging. Lee et al.[18] investigated 50 PNS CT scans (100 sides) using triplanar imaging and found type I, type II, type III frontal cells with rates of 37%, 19%, and 8%; respectively. However, the authors observed no type IV frontal cells. Besides that, the authors found agger nasi cells, supraorbital ethmoid cells, suprabullar cells, frontal bullar cells, interfrontal septal cells, and recessus terminalis cells with rates of 89%, 62%, 15%, 9%, 14%, and 22%, respectively. In another study, Kew et al.[3] emphasized the importance of multiplanar imaging and underlined that the surgical plan was altered with a rate of 55 with multiplanar imaging compared to uniplanar imaging.

A recent classification system defining the pneumatization patterns of ethmoid and frontal sinuses was published in 2016 and it

was introduced as the IFAC.[2] It simplified and clarified existing terminology.[9] Since the IFAC is a new classification system, prevalence studies are rare in the literature. In an IFAC prevalence study performed by Choby et al.,[19] the authors found agger nasi cells, suprabullar cells, supra agger cells, frontal septal cells, supraorbital ethmoid cells, supra agger frontal cells, and suprabullar frontal cells with rates of 96.5%, 72.0%, 30.0%, 30.0%, 28.5%, 20%, and 5.5%, respectively. Although the prevalence rates of cells were similar to our study, the supraorbital ethmoid cells were more rarely seen (7.3%) in our study. Additionally, although they were unilateral, the agger nasi cells were seen in the study performed by Choby et al.,[19] and the agger nasi cells were not seen bilaterally in four patients of our study. Also, in the study performed by Sjogren et al.,[20] similar to our study, the most common IFAC cell types were found as follows: agger nasi cells, suprabullar cells, and supra agger cells with rates of 88.9%, 55.8%, and 29.5%, respectively. They found the supraorbital ethmoid cells to be the rarest cell type with a rate of 11.6%. In the studies performed before the IFAC system, the prevalence rate of supraorbital ethmoid cells was reported to vary between 5 and 62%.[21]

It has been hypothesized that frontal sinus pneumatization patterns may vary by race/ethnicity. To illustrate, the supraorbital ethmoid cells are more common in Caucasians, while the suprabullar cells are more common in the Asian (i.e., Korean, Taiwanese, Chinese, and Japanese) populations.[22] Therefore, further prevalence studies in different ethnic and regional groups are required. Our study findings indicate the regional frequency of frontal cells classified by the IFAC. These kinds of regional studies are also essential to obtain global prevalence estimates of frontal cells. Furthermore, the inclusion of more patients in the study population compared to IFAC prevalence studies is important.

The IFAC includes precise anatomical definitions to classify the anatomy of the frontal sinus. The IFAC has sought to provide a more detailed and surgically relevant naming system for the various frontal sinus recess cells.[8] This study defined the normative distribution of frontal recess cells observed in a normal adult population according to the IFAC. Of note, the IFAC has become a highly reliable classification with the three-dimensional CT scans. The use of IFAC enables the surgeon to easily communicate with each other, while it is useful for understanding and teaching the necessary steps for frontal sinus surgery.

The limitation of the study; the is not multi-centered may cause possible local differences to be overlooked. Also, increasing the number of cases will make the study even more valuable.

In conclusion, our study suggest that the regional prevalence of frontal cells classified by the IFAC in Turkish population can be determined radiologically, providing contribution to the generation of estimates of the global prevalence of frontal cells.

Declaration of conflicting interests

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