Original Article

Assessment of International Frontal Sinus Anatomy Classification among senior residents through inter- and intra-rater reliability

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ABSTRACT

الأهداف: دراسة صُممت لتقييم مصداقية التصنيف الدولى لتشريح الجيوب الأنفيه الأمامية بين أخصائي طب وجراحة الأذن والحنجرة في المملكة العربية السعودية.

المنهجية: هذه الدراسة المستعرضة قد صممت بين أبريل 2019 وديسمبر 2019 فى مستشفى جامعة الملك عبدالعزيز شملت 32 أخصائي. تم استخدام استبيانات مع أربع صور تصوير مقطعى لأنواع خلايا الجيوب الأمامية. شملت الصور مقاطع محورية وعرضيه وأفقية مع الإشارة إلى كل نوع بسهم. اختار الأخصائيون الإجابة من خيارات متعددة وفقاً للتصنيف الدولى. ملئ الأخصائيون الاستبيان مرتين مع فاصل أسبوعين مدته أسبوعي
ن.

النتائج: وافق ما يقرب من 68.8% من السكان على أن التصنيف كان قابلاً للتطبيق الإكلينكى. أبدى 65.6% من الأخصائيون الإهتمام ناحية فهم التصنيف الدولى. زادت معدلات اختيارهم للتصنيف الصحيح بشكل ملحوظ بعد أسبوعين مقارنة بفترة البداية.

الخاتمة: ليس من السهل علاج الجيوب الأنفية الأمامية جراحياً، كما أن العلاج بشكل غير كافي يؤدي إلى فشل الإخراج ، كما هو الحال في التهاب الجيوب الأنفية المزمن. لذلك ، يجب على الجراحين فهم نظام التصنيف الدولى بشكل كامل لتجنب المضاعفات الرئيسية والثانوية.

Objectives: To evaluate the International Frontal Sinus Anatomy Classification (IFAC) reliability among Saudi board otorhinolaryngology senior residents.

Methods: This cross-sectional study was carried out at King Abdulaziz University Hospital, Riyadh, Saudi Arabia between April 2019 and December 2019, included 32 senior residents. Questionnaires with 4 computed tomography images showing the different frontal cell types were used in this survey. All scans included 3 planes (axial, sagittal, coronal) and the tested cell was marked with arrows. Residents chose the answer from multiple choices according to the IFAC system. All residents filled the same questionnaire twice with 2 weeks interval.

Results: Approximately 68.8% of residents agreed that the classification was applicable clinically. The resident's attitude toward the importance of understanding IFAC was 65.6%. Residents' correct classification of the marked cells increased significantly for most of the questions from baseline to 2 weeks.

Conclusion: The frontal sinus is not easy to treat surgically, and its inadequate treatment causes the failure of drainage, as in the case of chronic rhinosinusitis. Therefore, surgeons must fully understand the IFAC system to avoid major and minor complications.

Keywords: frontal sinus, International Frontal Sinus Anatomy Classification, otolaryngology residents, computed tomography, chronic rhinosinusitis

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Chronic rhinosinusitis (CRS), is a sinonasal mucosa status characterized by inflammation, presents with symptoms of nasal blockage, mucopurulent discharge, decreased smell sensation, and facial pain or pressure.[1-3] The recently published American Academy of Otolaryngology Clinical Practice Guideline defines CRS as 2 or more typical symptoms mentioned above that persists for 12 weeks or longer, with one or more documented evidence of inflammation as follows; 1) purulent discharge or edema in the middle meatus, 2) polyps, and 3) positive imaging signs declaring

opacification or swelling of the sinus mucosa.[4] The best management plan of CRS includes the use of antibiotics, topical or systemic steroids, anti-inflammatory agents, and antihistaminic drugs. However, if the condition resists medical management, endoscopic sinus surgery becomes the ideal choice.[4]

The frontal sinus location behind and above the frontal beak necessitates an angulated endoscopic approach; thus, it is difficult to reconnoiter it surgically. Inadequate surgical clearance of the frontal sinus drainage pathway is a common reason for endoscopic frontal sinus surgery (EFSS) failure in CRS. To avoid complications or surgical failure related to the frontal sinus, the surgeon needs to conceptualize the anatomy fully and draft a surgical plan. This approach will allow adequate preparation and precise placement of dissecting instruments with minimal risk while enabling complete clearance of the frontal recess and frontal ostium.

Many classification systems aim to assort the different air cells in the frontal area. However, a system that addresses both the number and position of air cells and its effect on the frontal drainage passage will assist in understanding the surgical anatomy and approach. The International Frontal Sinus Anatomy Classification (IFAC) system, a consensus document, provides expert opinion on how to treat frontal sinus diseases based on computed tomography (CT)-based classification of frontal air cells (**Appendix 1**). Thus, the evaluation of the anatomy and pathway of the frontal sinus requires access to high-quality CT scans. To date, only a single study has assessed the inter- and intra-rater reliability of the IFAC system among an international class of rhinologists by using different analytical methods.[5] The study reports pairwise inter-rater reliability of 0.72 to 1.0 (mean: 0.92, SD [standard diviation]: 0.05), intraclass correlation coefficient (ICC) of 0.98, intra-rater reliability (κ) of 0.86 to 1.0 (mean: 0.94, SD: 0.04), and within-rater ICC of 0.98. Therefore, this study aimed to assess the reliability and consistency of the use of the IFAC system among otorhinolaryngology residents.

Methods. This cross-sectional questionnaire-based study was performed in King Abdulaziz University Hospital, Riyadh, Saudi Arabia between April 2019 and December 2019. The inclusion criteria included otorhinolaryngology-head and neck surgery (ORL-HNS) senior residents of the King Saud University, Riyadh, Saudi Arabia. The study protocol was checked and signed by the Institutional Review Board, Medicine Research Center, King Saud University (reference number 19/4036/IRB). The study has also followed the Helsinki declaration. Each questionnaire included 4 CT images showing different types of frontal cells. Each CT image presented all 3 planes (axial, sagittal, coronal), and arrows were used to indicate air cells. The residents were asked to choose the best answer from the choices according to the IFAC system (**Figure 1**). Other questions were developed as needed to gather necessary information. The primary investigator distributed the questionnaire during resident-education activities and subsequently collected the data. A second questionnaire was filled after a 2-week interval. The residents were asked to fill out the questionnaire by themselves and hand it to the primary investigator.

Scoring comprised of one point for correct classification or response and zero points for incorrect classification by the resident. The overall classification score was calculated by summing the discrete scores for the 7 images. The overall resident score of less than 60% (4 correct answers or less) was considered to be poor classification grade.

Statistical analysis. Statistical analysis of coded data was performed through the IBM SPSS Statistics for Windows, version 22 (IBM Corp, Armonk, NY, USA). Continuous variables were expressed as mean and SD, while categorical variables as percentages. Statistical significance was set at $p \leq 0.05$. Association between residents' characteristics and their classification accuracy was tested using the Fisher exact probability test due to small frequency cells. Inter/intra-rater reliability and rate of the agreement were assessed by intraclass correlation and Cohen's kappa (κ) for all possible rater pairs.

Results. The study included 32 residents (male, 81.3%) with a mean age of 29.8 ± 1.4 (range, 27 to 34) years. More than half (53.1%) of the included residents were in their 4th year of training (R4) (**Table 1**).

Table 2 demonstrated the attitude of the residents regarding the IFAC and was measured twice with a 2-week interval. At baseline, 40.6% of residents agreed that the classification is applicable clinically, and this agreement rate increased significantly to 68.8% after 2 weeks (p=0.035). The residents' agreement rate on the importance of IFAC to understand the EFSS approach increased significantly from 37.5% at baseline to 71.9% after 2 weeks (p=0.001). Approximately 40.6% of residents agreed that IFAC enabled consistent

Disclosure. Authors have no conflict of interests, and the work was not supported or funded by any drug company.

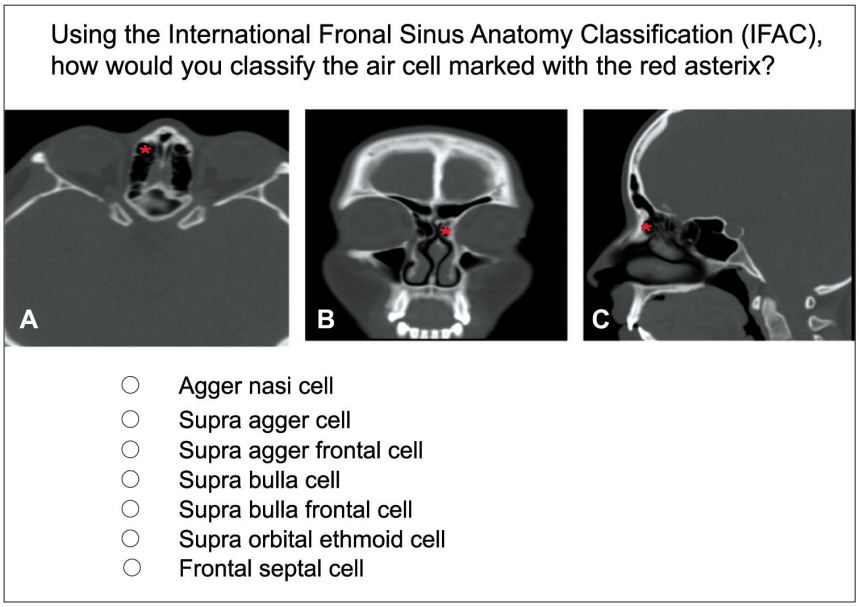

Figure 1 - Computed tomography scan of a single agger nasi cell showing the **A)** axial plane, **B)** coronal plane, **C)** sagittal plane

Table 1 - Basic data of otolaryngology-head and neck surgery senior residents.

Characteristics	n	(%)
Age, years		
<30 years	15	(46.9)
>30 years	17	(53.1)
Gender		
Male	26	(81.3)
Female	6	(18.8)
Residency level		
R4	17	(53.1)
R5	15	(46.9)

communication between otorhinolaryngologist residents, and this agreement improved significantly to 71.9% in the second questionnaire (p=0.002). The resident's attitude toward the importance of understanding the classification system improved from 37.5% at baseline to 65.6% after 2 weeks (p=0.012).

Regarding residents' correct classification of the marked cells (Table 2), the classifcation of agger nasi cell is not signifcantly different between the first and second questionnaire (p=0.715). The classification of supra agger cell, improved significantly from 53.1% for questionnaire one to 87.5% for questionnaire 2 (p=0.002). Supra agger frontal cell, was correctly classified by 43.8% residents at baseline and improved significantly 81.3% after 2 weeks (p=0.001). The classification of supra bulla cell (53.1% vs. 84.4%; p=0.002), supra bulla frontal cell (37.5% vs. 59.4%; p=0.036), and supra orbital ethmoid cell (43.8% vs. 81.3%; p=0.001) improved significantly from baseline to after 2 weeks, among residents (Figure 2). Frontal septal cell correctly classified by 18.8% residents and this rate improved significantly to 37.5% at 2 weeks (p=0.001). The overall rate of correct classification among residents improved from 34.4% at baseline to 43.8% at 2 weeks (p=0.036) (Figure 3).

There were no age-related or gender-related differences in the classification of air cells (Table 4). That is, 52.9% of residents above 30 years had a good classification score compared to 33.3% of residents below the age of 30 years (p=0.265). In addition, 66.7% of female residents had good classification score compared to 38.5% of males (p=0.209). R5 residents had significantly better classification score than R4 residents (60% vs. 24.9%; p=0.049). Cronbach's alpha, a reliability measure, was 0.985, with a number of items equal 32. Intraclass correlation coefficient, another measure of reliability, was significant for most questions for the 32 raters (Appendix 2). The average correct response rate was 50 ± 25.7 for the first questionnaire and 62.54 ± 28.33 for the second questionnaire.

Discussion. In 1905, Turner[6] claimed the nonrecognition of one or more diverticula or recess

Table 2 - Agreement rate for different items of the International Frontal Sinus Anatomy Classification (IFAC).

Attitude item	Baseline	After 2 weeks	*P*-value*
The IFAC easy to understand	16 (50.0)	20 (62.5)	0.056
The IFAC can be applied clinically	13 (40.6)	22 (68.8)	0.035†
The IFAC is an important tool to understand the frontal sinus endoscopic operation step approach	12 (37.5)	23 (71.9)	0.001†
The IFAC aid a consistent communication between otolaryngologist residents	13 (40.6)	23 (71.9)	0.002†
Comprehensive understanding of the IFAC would decrease the complication related to endoscopic frontal sinus surgery	12 (37.5)	21 (65.6)	0.012†
Comprehensive understanding of the IFAC would decrease frontal cell retain rate and decrease frontal sinus disease recurrence rate	17 (53.1)	19 (59.4)	0.241
The IFAC should be part of otorhinolaryngology curriculum training	20 (62.5)	20 (62.5)	1.000
The IFAC better than other frontal cell classification kuhan classification	13 (40.6)	15 (46.9)	0.352

Values are presented as numbers and percentages (%). *Mc-Nemar test, †significant *p*-values

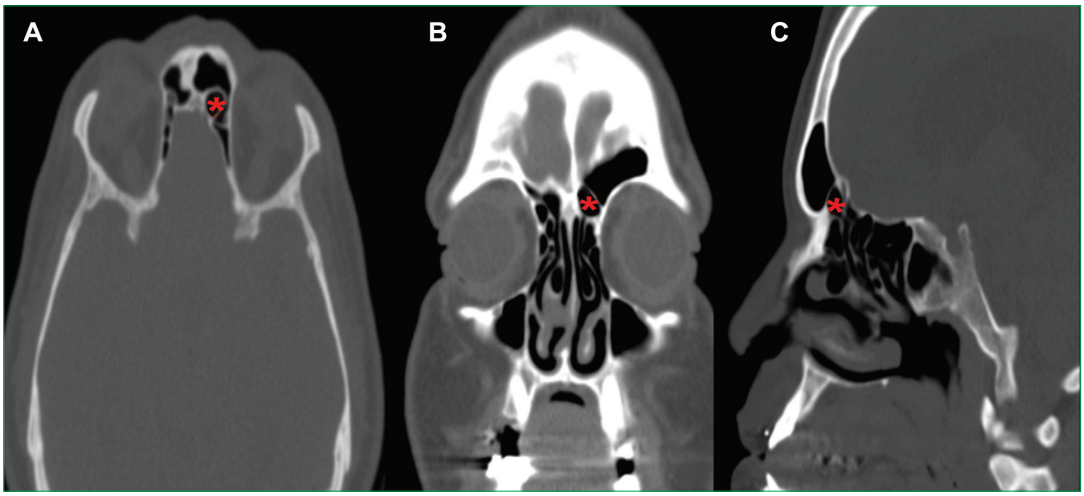

Figure 2 - Computed tomography scan of frontal septal cell showing the **A)** axial plane, **B)** coronal plane, **C)** sagittal plane .

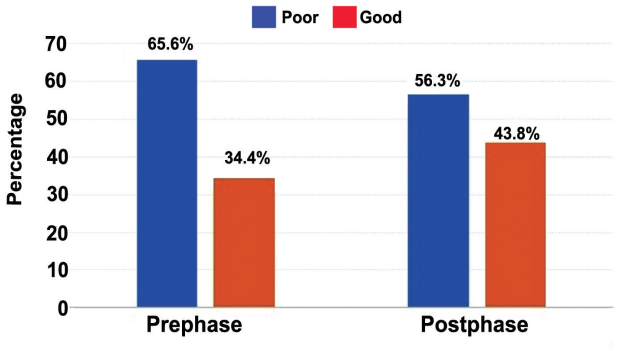

Figure 3 - Overall classification accuracy for the different images using the International Frontal Sinus Anatomy Classification. Poor: score = less than 60%; good: score = 60% or more.

Table 3 - Correct image classification by otorhinolaryngology–head and neck surgery senior residents.

Image	Baseline	After 2 weeks	*P*-value*
Image 1	29 (90.6)	31 (96.9)	0.715
Image 2	17 (53.1)	28 (87.5)	**0.002**
Image 3	14 (43.8)	26 (81.3)	**0.001**
Image 4	17 (53.1)	27 (84.4)	**0.002**
Image 5	12 (37.5)	19 (59.4)	**0.036**
Image 6	14 (43.8)	26 (81.3)	**0.001**
Image 7	6 (18.8)	12 (37.5)	**0.001**

Values are presented as numbers and percentages (%).
*Mc-Nemar test, significant *p*-values are in bold

Table 4 - Distribution of correct image classification based on otorhinolaryngology–head and neck surgery senior resident characteristics.

Characteristics	Image classification		*P*-value*
	Poor	Good	
Age			
<30 years	10 (66.7)	5 (33.3)	0.265
>30 years	8 (47.1)	9 (52.9)	
Gender			
Male	16 (61.5)	10 (38.5)	0.209
Female	2 (33.3)	4 (66.7)	
Residency level			
R4	12 (70.6)	5 (29.4))	0.049†
R5	6 (40.0)	9 (60.0	

*Fisher exact probability, †significant *p*-value

within the frontal sinus caused by incomplete bony septa as a potential reason for sinus surgery failure.

In 1941, Van Alyea[7] explained that "frontal cells" are air cells that extend to the frontal sinus from the frontal recess. Numerous recent studies agree that frontal recess is the "key" area for the management of frontal sinus disease. In 1993, Bent et al[8] classified the frontal recess cells into 3 frontal cell types (types 1-4 or K1-K4), which was later on adjusted by Wormald and Chan[9] in 2003 (**Appendix 3**). Lee et al[10] proposed the frontal recess pneumatization criteria for aiding endoscopic sinus surgery; and characterized the supra bulla cell (SBC) and frontal bulla cell (FBC), which were poorly described before. Wormald et al[11] described the IFAC system (**Appendix 1**) and named each cell according to its anatomic position. This allowed easy communication between surgeons and presented clear anatomy of the frontal sinus.

Wormold[12] emphasized that agger nasi cells, with a prevalence of 94%, were crucial for understanding the anatomy of the frontal recess. In a review of more than 200 CT scans of the paranasal sinuses, Bolger et al[13] found that approximately 98.5% of patients had the agger nasi cells. In addition, Eweiss and Khalil[14] reported a prevalence of 78.571% for frontal cells. Various modalities are used to identify the cells. On 3 dimensional images of the frontal sinus and frontal recess, each cell around the area must be identified first on the coronal and parasagittal scan.[15] In a study involving approximately 100 scans for a small group of raters, Choby et al[16] reported a median ICC of 0.80 or significant inter-rater reliability for the IFAC system. Meyer et al,[17] found a markedly elevated incidence of frontal sinus disease in the presence of type III and IV frontal cells. One a recent study, both the inter- and intra-rater reliability for the IFAC system between 15 international groups of rhinologist fellows. Raters who used IFAC showed superior agreement over raters who used modified Kuhn classification of frontal ethmoidal cells to classify frontal cells (κ=0.7248-1.0 vs. κ=0.249-0.3.[5]

The study has evaluated the agreement between 32 ORL-HNS senior residents while employing IFAC to classify frontal cells. More than 65% of residents found IFAC clinically applicable, more than 70% considered it a tool that aids consistent communication between surgeons, and approximately 65.6% of residents agreed that it was essential to understand the classification system. Most residents (75%) agreed on the classification of a marked cell in most of the CT images. However, the agreement for the frontal septal cell was the lowest (37.5 %). Some variations in agreement occurred for the CT scan with a marked supra bulla frontal cell, where approximately 60% of residents (19 of 32) agreed, and the remaining 13 raters classified it as a supraorbital ethmoid cell. The overall correct classification among residents significantly improved from 34.4% to 43.8%. R5 residents (60%) scored significantly better than R4 residents (24.9%).

It is worth mentioning that approximately 30% of participants had negative attitudes towards IFAC in the second questionnaire. This may be attributed to the fact that the IFAC is not yet a standard to follow. Residents may argue that specialists' perspectives could be misleading owing to the potential bias and the absence of generalizability.[18] In different specialties, proposed imaging-based classifications have been set as a standard by confronting them with the intraoperative findings. Nonetheless, this may be challenging since the frontal recess is a small area. For better validation and reliability, a recent study has suggested that the IFAC should be compared with other classifications based on the findings from endoscopic sinus surgeries, along with enrolling a representative sample.[5] Thus, the authors of the present research believe that the current study has been limited by a small sample size and being carried out at a single center. Future large-scale studies are needed to clarify and to establish conclusive evidence.

In conclusion, the anatomic location of the frontal sinus poses surgical challenges. Inadequate sinus treatment causes the failure of drainage in the case of CRS. A good understanding of the IFAC system by surgeons will circumvent major and minor complications. The purpose of the IFAC, according to the principle investigators, was to provide a thorough view of the anatomy, enable better communication between surgeons, and teach the necessary EFSS steps

accurately. An elaborate checking of frontal recess anatomy using thin CT sections is vital for the surgeons performing EFSS.

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Appendix 1 - International Frontal Sinus Anatomy Classification.

Frontal air cell effect on FSDP*	Cell name	Definition
Anterior air cells push FSDP medial, posterior, or posteromedial	Agger nasi cell (ANC)	Anterior to the origin of middle turbinate or above the most anterior insertion of middle turbinate into the lateral nasal wall.
	Supra agger cell (SAC)	Anterior-lateral ethmoidal cell above ANC that does not pneumatize into the frontal sinus.
	Supra agger frontal cell (SAFC)	SAC that extends into the frontal sinus (wide range of sizes from floor up to the roof of the frontal sinus).
Posterior air cells push FSDP anterior	Supra bulla cell (SBC)	Above bulla ethmoidalis; does not enter frontal sinus.
	Supra bulla frontal cell (SBFC)	SBC that pneumatizes along skull base to the posterior frontal sinus. The skull base forms the posterior wall of the cell.
	Supraorbital ethmoid cell (SOEC)	Anterior ethmoid cell pneumatizing around, anterior, or posterior to anterior ethmoidal artery over the roof of the orbit. Often forms part of the posterior wall of extensively pneumatized frontal sinus separated only by bony septation.
Medial air cells push FSDP lateral	Frontal septal cell (FSC)	The medially based cell of anterior ethmoid or inferior frontal sinus; attached or located in interfrontal sinus septum; associated with the medial aspect of the frontal sinus outflow tract, pushing FSDP laterally and frequently posteriorly.

*frontal sinus drainage pathway

Appendix 2 - Two-way mixed effect model where people effects are random and measures effects are fixed.

Measures effects	Intraclass correlation[b]	95% CI		F test with true value 0			
		Lower band	Upper band	Value	Df1	Df2	Difference
Single measure	0.661[a]	0.498	0.837	66.523	13	403	0.000
Average measure	0.984[c]	0.969	0.994	66.523	13	403	0.000

[a]The estimator is the same, whereas the interaction is present or not. [b]Type A intraclass correlation coefficients using an absolute agreement definition. [c]This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Appendix 3 - Modified Kuhn classification of frontal ethmoidal cells.

Name	Description
Agger nasi cell (ANC)	Usually a single cell anterior to the middle turbinate
Supraorbital ethmoid cell (SOEC)	SBC protruding into the orbital roof
Frontoethmoidal cells (Bent and Kuhn frontal cells)	cells close or within the frontal process of the maxillary bone and above the ANC
K1	Single frontal recess cell above ANC
K2	Tier of cells in the frontal recess above ANC
K3	Single massive cell pneumatizing cephalad into frontal sinus occupying <50% of vertical sinus
Height K4	Single isolated cell within the frontal sinus occupying >50% of vertical sinus height
Supra bulla cell (SBC)	A cell or cells above the bulla ethmoidalis
Frontal bulla cell (FBC)	SBC protruding into frontal sinus
Interfrontal sinus septal cell (ISSC)	Cell resulting from pneumatization of interfrontal sinus septum pushing FSDP laterally and narrowing the frontal ostium