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ORIGINAL ARTICLE

Taiwanese Population Prevalence of Frontal Sinus Architecture Variations and Relationships with Frontal Sinusitis in Comparison to Worldwide Prevalence

Ting-Wei Chang[1], Pin-Zhir Chao[1], Hsing-Won Wang[1,2,3]

[1]Department of Otolaryngology, Shuang Ho Hospital, Taipei Medical University, New Taipei City, [2]Department of Otolaryngology-Head and Neck Surgery, Tri-Service General Hospital, National Defense Medical University, [3]Department of Otolaryngology, The Graduate Institute of Clinical Medicine, College of Medicine, Taipei Medical University-Shuang Ho Hospital, Taipei, Taiwan

Background: Understanding the structural anatomy of the frontal sinus, frontal recess, and drainage pathway is essential for ensuring the success of frontal sinusitis surgery. **Aim:** The purpose of this study was to investigate the relationships between frontal sinus architecture variants and frontal sinusitis development in the Taiwanese and worldwide population by providing a thorough analysis of the prevalence of these variants. **Methods:** In total, 284 sides were gathered from 142 computed tomography scans in the retrospective analysis, with independent assessments for the left and right sides. The International Frontal Sinus Anatomy Classification (IFAC) was used to determine the prevalence of each kind of frontal sinus cell. In addition, the PubMed database was used to search for articles analyzing the prevalence of frontal sinus cells based on the IFAC. A total of 11 articles were analyzed, including our analysis of the prevalence in the Taiwanese population. **Results:** The results showed that with an appearance in 90.5% of the patients in the Taiwanese population and 92.5% worldwide, the agger nasi cells were the most frequently occurring cell in the population. In 17.3% of instances, frontal sinusitis was present; in 82.7% of cases, it was missing. None of the frontal cell variations were shown to be significantly associated with the development of frontal sinusitis (all $P > 0.05$). **Conclusion:** This study documents the prevalence of frontal cell types based on the IFAC system in a Taiwanese population and the global population. While this article did not establish a direct association between frontal sinus cells and frontal sinusitis, these frontal sinus cells do indeed influence the drainage of frontal sinus secretions.

Key words: Frontal sinus cell, frontal sinusitis, International Frontal Sinus Anatomy Classification

INTRODUCTION

The frontal sinus presents a challenging region for surgical access due to its complex and variable anatomy, as well as its proximity to critical structures such as the cribriform plate, orbit, and anterior ethmoid artery, which are at risk of injury during surgical procedures.[1-3] One of the primary concerns during endoscopic sinus surgery in this area is the incomplete clearance of diseased cells around the frontal recess, potentially leading to obstruction of the frontal sinus outflow tract and resulting in persistent inflammation and clinical symptoms.[1,2] Understanding the structural anatomy of the frontal sinus, frontal recess, and drainage pathway is essential for ensuring the success of surgical interventions while avoiding complications and disease recurrence.[4]

Therefore, various classification systems have been proposed over the years to categorize these anatomical variants and provide surgeons with a clear understanding of the complexities of this region.[4,5] The International Frontal Sinus Anatomy Classification (IFAC), introduced in 2016, provides standardized nomenclature of cells in the frontal recess and frontal sinus to enhance surgical precision and clinical communication.[1-3]

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Corresponding Author: Prof. Hsing-Won Wang, Department of Otolaryngology, Taipei Medical University-Shuang Ho Hospital, No. 291, Jhong-Jheng Road, Jhonghe District, New Taipei City 23561, Taiwan. Tel: +886-2-22490088 ext 2903; Fax: +886-2-66007866. E-mail: w0512n@ms15.hinet.net

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The IFAC defines three cell types.[6] First, anterior cells, which push the drainage pathway of the frontal sinus medially, posteriorly, or posteromedially. These include agger nasi cells (ANCs), supra agger cells (SACs), and supra agger frontal cells (SAFCs). Second, posterior cells, which push the drainage pathway anteriorly, including supra bulla cells (SBCs), supra bulla frontal cells (SBFCs), and supraorbital ethmoid cells (SOECs). Third, medial cells, which push the drainage pathway laterally, including frontal septal cells (FSCs).

Given the intricate nature of frontal sinus anatomy, its variations, and their potential impact on frontal sinusitis,[1-11] this study aimed to provide a comprehensive examination of the prevalence of frontal sinus anatomy variants according to the IFAC and explore their associations with the development of frontal sinusitis in the Taiwanese population. Many studies have reported the prevalence of frontal sinus anatomy variants according to the IFAC from various regions, and this study also analyzes the global prevalence of frontal sinus anatomy variants based on the IFAC.

MATERIALS AND METHODS

This retrospective computed tomography (CT) scan study was conducted at Shuang-Ho Hospital (SHH), Taipei Medical University, Taiwan, between January 2019 and April 2019. The CT scans were performed in the coronal plane with 3 mm thick slices and without contrast. Subsequently, the data was reconstructed to create volumetric CT scans in both the coronal and sagittal planes, with a slice thickness of 1 mm, using computer software. The research project was approved by the Institutional Review Board of the Taipei Medical University - Shuang Ho Hospital, Taipei, Taiwan, and the number was N202305004, the requirement for informed consent was waived by the Institutional Review Board and all experiments were performed in accordance with relevant guidelines and regulations.

A total of 142 CT scans from patients were analyzed, with separate assessments for the left and right sides, resulting in a total of 284 sides. Patients with the history of prior nasal or sinus surgery, neoplastic diseases, nasal trauma, and those under 18 years of age were excluded from the study. These exclusions were made because a history of surgery, neoplastic diseases, or nasal trauma might influence the natural frontal sinus cells. In addition, patients under 18 years of age were excluded as their frontal sinus development is not complete.

The Digital Imaging and Communications in Medicine images were reviewed and analyzed at SHH using the Picture Archiving and Communication System software, which is the standard software utilized by this institution. In accordance with the IFAC, the prevalence of each type of frontal sinus cells was assessed based on coronal, sagittal, and axial views.

Frontal rhinosinusitis was diagnosed through CT scans of the paranasal sinuses and evaluated using the Lund-Mackay score. The Lund-Mackay score was calculated based on the results of a sinus CT scan 1–3 mm axial slice thickness with coronal and sagittal reconstruction. The sinuses are grouped into the frontal sinus, anterior ethmoidal cells, posterior ethmoidal cells, maxillary sinus, sphenoid sinus, and ostiomeatal complex. Each side is graded separately, with score 0 meaning no abnormality, score 1 meaning partial opacification, and score 2 meaning complete opacification.[12] In our study, we only assessed the frontal sinus, so the scores ranged from 0 to 2. In addition, if there is no frontal sinus (aplasia), the score is 0.

Statistical analysis was carried out using Microsoft Excel 2022 (Redmond, WA, USA). Prevalence was calculated with the formula of the number of CT scans with the frontal sinus cells, divided by the total number of CT scans. Chi-square tests assessed the association between frontal sinus cells and frontal sinusitis, and the results were considered significant if $P < 0.05$.

The PubMed databases were searched using the keywords "The International Frontal Sinus Anatomy Classification," limited to English-only articles. Book chapters, textbooks, and published oral or poster conference abstracts were excluded. All studies analyzed the prevalence of frontal sinus cells based on IFAC through CT scan. A total of 23 articles were retrieved, and references of each article were screened to include those matching our criteria. Finally, 11 articles were analyzed, including our analysis of the prevalence in the Taiwanese population.

RESULTS

Demographics

This study group consisted of 142 CT scans (total of 284 sides) and included 72 men (51%) and 70 women (49%). Since patients aged <18 years were excluded from the study, the youngest patient was 18 years old and the oldest was 96 years old. The mean age of the patients was 46.9 years.

Cell prevalence in the Taiwanese population

The prevalence of frontal cells [Table 1] was described, according to the new IFAC system, in terms of anterior, posterior, and medial cells. Agger nasi cells were the most commonly occurring cells, seen in 90.5% of the patients. The prevalence of SOECs was lowest, seen in 8.5% of patients. The prevalence of SACs, SAFCs, SBCs, SBFCs, and frontal septal cells were 31.7%, 20.1%, 69.0%, 29.2%, and 20.1%, respectively.

Association with frontal sinusitis

Frontal sinusitis was seen in 17.3% of cases (49 out of 284) and absent in 82.7% of cases (235 out of 284). The incidence of the SAFCs, the SBCs, and the SOECs were greater in patients with frontal sinusitis (24.5%, 79.6%, and 10.2%, respectively) than in those without (18.8%, 71.1%, and 8.1%, respectively) [Table 2 and Figure 1]. However, there was no significant association observed between all frontal cell variants with the development of frontal sinusitis (all $P > 0.05$).

Cell prevalence in worldwide prevalence

From the total of 11 articles analyzed[1-5,7-11] including our analysis of the prevalence in the Taiwanese population, 2715 CT scans from 9 different countries were collected.

Table 1: Prevalence of International Frontal Sinus Anatomy Classification cell types

IFAC cell type	Total, *n* (%)	Right, *n* (%)	Left, *n* (%)
Anterior cells			
ANCs	257 (90.5)	129 (90.9)	128 (90.1)
SACs	90 (31.7)	43 (30.3)	47 (33.1)
SAFCs	57 (20.1)	24 (17.0)	33 (23.2)
Posterior cells			
SBCs	196 (69.0)	105 (73.9)	91 (64.1)
SBFCs	83 (29.2)	37 (26.1)	46 (32.4)
SOECs	24 (8.5)	12 (8.5)	12 (8.5)
Medial cells			
FSCs	57 (20.1)	23 (16.2)	34 (23.9)

IFAC=International Frontal Sinus Anatomy Classification; ANCs=Agger nasi cells; SACs=Supra agger cells; SAFCs=Supra agger frontal cells; SBCs=Supra bulla cells; SBFCs=Supra bulla frontal cells; SOECs=Supraorbital ethmoid cells; FSCs=Frontal septal cells

Table 2: The association of the frontal cell variants with frontal sinusitis

IFAC cell type	Frontal sinusitis		
	Yes (*n*=49), *n* (%)	No (*n*=235), *n* (%)	*P*
Anterior cells			
ANCs	42 (85.7)	215 (91.5)	0.21
SACs	13 (26.5)	77 (32.8)	0.39
SAFCs	12 (24.5)	45 (18.8)	0.40
Posterior cells			
SBCs	29 (79.6)	167 (71.1)	0.10
SBFCs	13 (26.5)	70 (29.8)	0.65
SOECs	5 (10.2)	19 (8.1)	0.63
Medial cells			
FSCs	9 (18.4)	48 (20.4)	0.74

IFAC=International Frontal Sinus Anatomy Classification; ANCs=Agger nasi cells; SACs=Supra agger cells; SAFCs=Supra agger frontal cells; SBCs=Supra bulla cells; SBFCs=Supra bulla frontal cells; SOECs=Supraorbital ethmoid cells; FSCs=Frontal septal cells

The global prevalence of frontal cells is described in Table 3 and Figure 2, according to the IFAC, in terms of anterior, posterior, and medial cells. The agger nasi cells were the most commonly occurring cells, seen in 92.5% of the patients. The prevalence of SOECs was lowest, seen in 16.8% of patients. The prevalence of SACs, SAFCs, SBCs, SBFCs, and frontal septal cells were 36.8%, 23.2%, 61.5%, 24.1%, and 19.4%, respectively.

DISCUSSION

Anatomical variations in the frontal sinus cells and their drainage pathways have been the subject of extensive research, as they significantly impact surgical approaches and outcomes.[1-3] Several studies have evaluated the prevalence of each cell type using the IFAC system.[1-5,7-11] However, this study was the first to evaluate a Taiwanese population and summarize the global prevalence of frontal sinus cells.

All studies and global data demonstrated that among all frontal cell variants, ANCs had the highest prevalence. The prevalence of ANCs in each study was over 90%.[1-5,7-11] Due to their high prevalence, relatively consistent position, and easy identification, as the most anterior ethmoidal cells located above the insertion of the middle turbinate in the lateral nasal wall, ANCs serve as reliable anatomical landmarks for accessing the frontal recess during surgery. They also serve as reference cells for most frontal cell classification systems.[6]

The prevalence rankings of frontal sinus cells in Taiwan were almost the same as those in the global population, except for the fifth and sixth ranks, which were equal in Taiwan. However, except for the ANCs, other frontal cell types showed variation among different countries. SBCs had the second-highest prevalence in most countries, including Taiwan and overall, except in India,[3] where it ranked third with a prevalence of 36.1%. In India, SOECs had the second-highest prevalence. Conversely, the prevalence of SOECs was lowest in Taiwan and overall, but varied among countries, ranking from second to fourth in India,[3] Vietnam,[8] and Egypt.[4] Except in these three countries, the prevalence of SOECs was below 20%. These differences may be due to variations in the studied population (race, age, sex), sampling methods, or small sample sizes.

We also attempted to analyze whether the same continent showed similar prevalence patterns. There are five studies from Asia, including those from Singapore,[7] Malaysia,[1] Vietnam,[8] India,[3] and our data. The ANCs still had the highest prevalence. However, as noted in the previous paragraph, the prevalence of SBCs in Vietnam[8] and SOECs in Vietnam[8] and India[3] differed from other studies. The variation in prevalence does not appear to be associated with the continent.

Table 3: Comparison of frontal cell variants in different countries and global prevalence

	ANCs, *n* (%)	SACs, *n* (%)	SAFCs, *n* (%)	SBCs, *n* (%)	SBFCs, *n* (%)	SOECs, *n* (%)	FSCs, *n* (%)
Taiwan (*n*=284)	257 (90.5)	90 (31.7)	57 (20.1)	196 (69.0)	83 (29.2)	24 (8.5)	57 (20.1)
Singapore (*n*=185)[7]	168 (90.8)	46 (24.9)	22 (11.9)	84 (45.4)	41 (22.2)	6 (3.2)	51 (27.6)
Malaysia (*n*=400)[1]	382 (95.5)	200 (50.0)	144 (36.0)	243 (60.8)	212 (53.0)	22 (5.5)	33 (8.3)
Vietnam (*n*=208)[8]	199 (95.7)	34 (16.3)	27 (13.0)	96 (46.2)	9 (4.3)	36 (17.3)	22 (10.6)
India (*n*=180)[3]	172 (95.5)	60 (33.3)	40 (22.2)	65 (36.1)	38 (21.0)	71 (39.4)	38 (21.1)
German (*n*=249)[2]	237 (95.2)	122 (49.0)	62 (24.9)	221 (88.8)	66 (26.5)	23 (9.2)	69 (27.7)
Egypt (*n*=200)[4]	194 (97.0)	96 (48.0)	22 (11.0)	144 (72.0)	46 (23.0)	84 (42.0)	42 (21.0)
United states (*n*=758)[5,9,10]	715 (94.3)	274 (36.1)	180 (23.7)	462 (60.9)	97 (12.8)	123 (16.2)	127 (16.8)[#]
Brazil (*n*=206)[11]	197 (95.6)	78 (37.9)	77 (37.4)	159 (77.2)	62 (30.1)	66 (32.0)	69 (33.5)
Total (*n*=2715)	2521 (92.5)	1000 (36.0)	631 (23.2)	1670 (61.5)	654 (24.1)	455 (16.8)	508 (19.4)[#]

[#]One study in USA calculate FSCs in unilateral; and others studies in bilateral. FSCs=Frontal septal cells; SOECs=Supraorbital ethmoid cells; SBFCs=Supra bulla frontal cells; SBCs=Supra bulla cells; SAFCs=Supra agger frontal cells; SACs=Supra agger cells; ANCs=Agger nasi cells

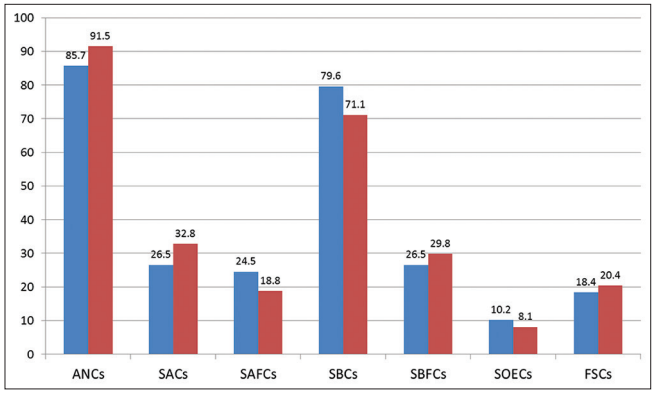

Figure 1: The association of the frontal cell variants with frontal sinusitis. Blue bar (left side) means the percentage of the frontal sinus cells with frontal sinusitis and red bar (right side) means the percentage of the frontal sinus cells without frontal sinusitis. The numbers in the chart are expressed as percentages

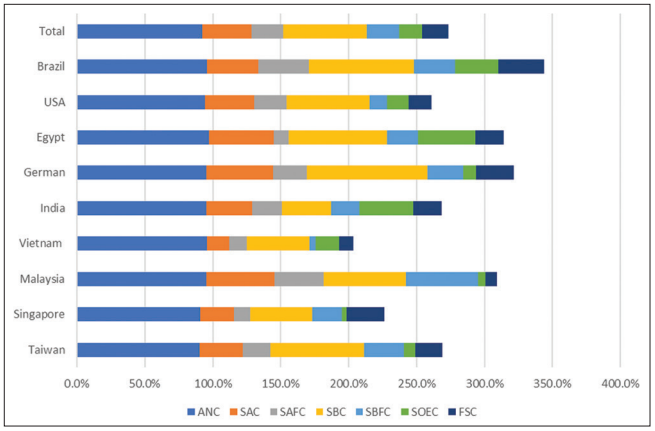

Figure 2: Comparison of frontal cell variants in different countries

In this study, there was no significant difference between frontal cell types and frontal sinusitis, consistent with several previous studies.[2-4,7-11] However, Fawzi *et al*.[1] demonstrated that SOECs and FSCs were significantly associated with frontal sinusitis, and Howser *et al*.[5] also identified a link between SOECs and frontal sinusitis. These different findings may result in varying indications for CT scans and approaches to diagnose frontal sinusitis. In Fawzi *et al*.,[1] CT scans were performed on patients with clinical and endoscopic findings of chronic rhinosinusitis. The reason our patients received CT scans is unknown.

There are several limitations in this study. First, the statistical power may be limited by the small sample size, especially when it comes to identifying correlations between frontal sinusitis and less prevalent frontal cell variations. Therefore, we expect that larger trials will be conducted to evaluate the frontal sinus cells. Second, the study does not clearly describe the indications for CT imaging. If CT scans were performed due to suspected sinonasal pathology, the included patients may not represent the general population, introducing a potential selection bias. Third, clinical symptoms and nasal endoscopic evaluations were not integrated into the diagnosis of frontal sinusitis, which was made exclusively on the basis of CT results. The actual prevalence of the disease may be overestimated or underestimated because of this situation. This study has other limitations due to the use of a regional sample in evaluating the global population. Anatomical variations can occur not only in different population but also within the same population. In the three papers analyzing the prevalence of frontal sinus cells in the United States, the prevalence of frontal cell types varied. Therefore, performing sinus CT scans before FESS is crucial for identifying the exact location of frontal sinus cells and the frontal recess.

The criteria and reasons for receiving CT scans were unknown in every study and in our data, which may have influenced the prevalence of frontal cell variants. Therefore, the prevalence of frontal cell variants found in our study may not be representative of the general population.

CONCLUSION

This study documents the prevalence of frontal cell types based on the IFAC system in the Taiwanese and global population. While this study does not establish a direct association between frontal sinus cells and frontal sinusitis, these frontal sinus cells do indeed influence the drainage of frontal sinus secretions. The structural variations of the nasal sinuses can be highly diverse. Therefore, a comprehensive categorization of frontal sinus cells through the IFAC system, can provide valuable insights for future related surgery and research.

Data availability statement

The data that support the findings of this study are available from the corresponding author, H-W Wang, upon reasonable request.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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