Frontal Recess Cell Variation and Frontal Sinusitis Development

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Chronic rhinosinusitis (CRS) can have a significant impact on quality of life. With persistent symptoms and the failure of initial medical treatments, surgical management is indicated. Despite the excellent results of endoscopic sinus surgery for persistent CRS, it is quite a challenging procedure for frontal sinusitis given the complex anatomy and location of the frontal sinus. Frontal recess cells significantly contribute to the complexity of the frontal sinus, and numerous studies have sought to establish their association with sinusitis.

frontal recess cell agger nasi sinusitis rhinosinusitis classification

1. Introduction

Chronic rhinosinusitis (CRS) poses a significant and pressing health issue, demanding our attention and understanding. It is a long-lasting condition that is characterized by inflammation of the nasal passages and the sinuses. This disease generally leads to a variety of symptoms like nasal congestion, headache, difficulty in breathing or nasal block, nasal discharge, decreased sense of smell (anosmia), and postnasal drip. Contrary to acute sinusitis, which usually lasts for a short period, chronic rhinosinusitis persists for 12 weeks or more, due to which patients suffer from reduced quality of life and financial and psychosocial burdens [1][2]. Despite the availability of medical management, surgical options might be indicated for persistent symptoms or failure of initial treatments. Endoscopic sinus surgery (ESS) has shown excellent results in persistent cases [3]. Nevertheless, it is still a challenging technique for frontal sinusitis. In fact, any surgical interventions involving the frontal sinus pose a real challenge because of its unique and complex anatomy [3]. Starting from the location, one factor of concern is that there is a risk of injuring nearby structures like the olfactory apparatus, anterior skull base, anterior ethmoid artery, cribriform plate, and medial orbital wall [4]. The anterior ethmoidal artery, for instance, is an essential anatomical landmark. It is important to be aware of its location at the skull base in the mucous membrane mesentery while performing endoscopic sinus surgeries and to access the frontal sinus. It runs through the roof of the anterior ethmoidal sinus; hence, it is prone to injuries in endoscopic sinus surgeries [5][6]. Another factor of concern is the narrow drainage tract between the orbital and the skull base, which carries the risk of serious complications [3]. The frontal sinus and the space where it drains, the frontal recess, are occupied with diverse cells [7]. Frontal recess cells are groups of air-filled cells found at the anterior ethmoid in the frontal recess. This includes agger nasi, frontal, supraorbital, frontal bulbar, suprasellar, and interfrontal sinus septal cells. They can obstruct the frontal recess outflow, leading to sinusitis [8]. Agger nasi cells, for example, are part of the anterior ethmoidal air

cells, and they are the most anterior. These cells are situated anterolaterally and inferiorly to the frontal recess and anteriorly and above the middle turbinate attachment. They are found in 90% of the population and are usually the most common among other frontal recess cells as single cells, but could be found as multiple smaller or larger cells [8]. These variations could be due to attachment of the uncinate process and an enlargement of the ethmoidal bulla, as well as the presence of a large pneumatized frontal beak and crisa galli.

Generally, frontal recess cells show anatomical variations, which can modify the sinus drainage pathway as discussed in the study carried out by Wormald et al., 2016 [7]. There is another study showing the arrangement of these cellular variations along the drainage tract which may increase the chance of obstruction and inflammation [4]. Thus, a comprehensive and clear understanding of this anatomy is required for a better management approach for safe surgery and an excellent outcome [4]. That is why multiple classifications have been proposed for better characterization since 1941 [9]. All these classifications are from a different perspective, which eventually led to a nomenclature discrepancy, and are discussed in detail further ahead in this research. However, confusion has resulted, given the nature of frontal cells, their complex anatomy, their variations between individuals and populations, and their different categorization methods, making it even more challenging to combine articles from different classifications or even to conclude their association with sinusitis.

2. Frontal Recess Cells' Prevalence in Different Populations

Multiple studies investigated frontal cells' prevalence based on IFAC within different populations [8][10][11][12][13][14][15][16][17]. Similarly, other studies investigated their prevalence based on the Kuhn classification [18][19][20][21][22][23]. When comparing prevalence results between these populations, ANCs are found to be the highest in all of them. However, the remaining frontal cells' distribution showed variability [14]. Even when comparing them based on anterior, posterior, and medial groups, there was still no agreement [14]. SBCs' prevalence was similarly high among Malaysians, Germans, and North Americans, unlike among the Indians and Vietnamese. Almost half or more of the White, Malaysian, German, and Egyptian populations had SACs, while they were lower in the rest. In contrast, SOECs were much lower among Malaysians and Caucasians. Interestingly, Turkish pediatrics showed the highest prevalence in SAFCs and SBFCs, while they were the only group not reporting any frontal septal cells (FSCs). This diversity between different populations might reflect the heterogeneity in different frontal cells [14]. Nevertheless, Fawzi et al. reported that when excluding ANCs, posterior-based groups (SBCs and SBFCs) had a higher prevalence than anterior-based cells (SACs and SAFCs) in previous studies [14], which seems to also be the case with the following studies, except with the White population. This supports Fawzi's argument to classify the cells according to their topographical arrangement rather than individually.

A study [23] compared the frequency of frontal recess cells in Caucasian and Korean subjects using the classification mentioned by Lee et al. [24]. Interestingly, they found the differences between both populations are compatible with their distinctive external facial features, which means that having a more protuberant nasion, glabella, and superior orbital rim was associated with an increased incidence of certain groups of frontal cells, which was the case with Caucasians [23]. They also concluded that these differences in some cells were more likely attributed to ethnic reasons. These were less likely to be related to the difference in the antero-posterior length of

the skull base. Howser et al. also supported the link between craniofacial development and the frontal sinus, which might explain the differences between ethnic groups [11]. Furthermore, Johari et al. also compared Malaysian subjects with more than one population using the same classification and they also reported some differences between Southeast Asian and other East Asian populations in some cells [19]. These discrepancies were similarly attributed to their ethnic background. Previous studies show no correlation between the different anatomical variations and the increased incidence of signs of opacification. These variations only alter the surgical approach based on radiological signs and patient symptoms [10].

3. Frontal Recess Cells and Their Association with Sinusitis

In regard to the anatomical terminology, authors have used different names for naming the cells surrounding the frontal drainage pathway that include frontal cells [14][18], frontal sinus cells [17], and frontal recess cells [15][19][20][21]. To avoid confusion to the readers, in this research, the researchers describe these cells as frontal recess cells throughout the manuscript. The association between frontal recess cell variations and sinusitis has been examined in various studies. Brunner et al. was one of the early studies to examine if agger nasi cells contribute to sinusitis [25]. Although they had a relatively small sample size, they found a significant link between a narrowed nasofrontal duct due to agger nasi cell pneumatization and chronic frontal sinusitis. In addition, Meyer et al. reported that some pneumatization variants significantly affect the presence of frontal cells. In hyperpneumatization, for example, there was a positive association with the appearance of frontal cells and vice versa [26]. It is essential to address the classifications used when discussing what was reported in previous articles. That is because cell identification or labelling might vary according to each model. Thus, to ensure accuracy, the researchers grouped them accordingly. For instance, in 2003, Meyer et al. [26] indicated that individuals with type III and type IV had a significant relationship with frontal mucosal thickening using the Bent et al. classification [27]. Nevertheless, their presence does not always lead to sinusitis [26]. In contrast, three more recent articles following the same classification have yet to find significance [18][28][29]. Several authors have attributed these insignificant findings to sinusitis as a mucosal inflammation rather than an anatomical obstruction [20][21][29].

The following articles used the Kuhn classification [30]. It was challenging to differentiate whether they used the original Kuhn classification [30] or the modified Kuhn classification [31], as the authors did not clarify in most articles. Lien et al. reported that SBCs, FBCs, and SOECs were significantly related to frontal sinusitis, probably due to a narrowed drainage pathway as shortening happens on the anteroposterior parameters of the frontal recess or frontal ostium [21]. They have also reported a significant association with recessus terminalis (RT) due to the absence of a physical barrier along the drainage tract against allergens, irritants, or ascending infections [32]. In the study of Langille et al., although type VI frontal cells were not identified in any subjects, a significance was found with type I, II, and III [33]. It has also been noted that ethnic diversity, seasonality, and the classical presentation of sinusitis are all factors that might explain the variability between different authors [33]. Both Kubota et al. [20] and Johari et al. [19] reported a *p*-value less than 0.05 for only frontal bulla cells (FBCs) with sinusitis. Type III and IV frontal cells were significant in studies by both House et al. and Meyer et al. [26][34]. Interestingly, they also reported a significant *p*-value on the interfrontal sinus septal cell with an odds ratio of 0.51 (0.26, 0.99). This suggests a

lesser chance of developing a sinus disease if this cell is present. Lai's and Hashimoto's findings indicate no significance when it comes to the presence of these cells [35][36]. On the other hand, they reported a significant association between some opacified areas or opacified frontal cells and sinusitis, respectively. These were the frontal recess and sinus lateralis for the former, and agger nasi, type I frontal cell (FC1), and SBC for the latter.

Since IFAC is a relatively new classification, a few studies only used it to look for its association with sinusitis. In 2019, Sommer et al., using IFAC, attempted to investigate any relationship between the cells and radiological signs of opacification, but the study ended up with no significant findings [10]. However, it is important to keep in mind the way in which frontal cell incidence was reported in this study. It did not differentiate whether a patient had these cells unilaterally or bilaterally, unlike most previous studies, which reported each side separately. One patient can have two cells (one on each side), which might affect the total incidence and the explanation of the results. One year later, Seth et al. failed to draw a significant association. Furthermore, the inconsistency between various studies can be attributed to different ethnicities, classifications, or even a small sample size [15]. Among the IFAC-based articles, only Fawzi et al. found a significant association between developing sinusitis and two types of frontal cells: SOECs and FSCs [14]. It is worth mentioning that both were the least prevalent group of cells in their sample. However, given the position of FSCs, for example, the possibility of frontal sinus blockage can be explained. Thus, their role in sinusitis should be considered, especially during endoscopic sinus surgery. As part of post-surgical management, recurrence is sometimes attributed to an incomplete resection of cells situated within the sinus drainage pathway or a blockage of the drainage pathway [14]. There is an attempt to correlate the IFAC and Kuhn classifications for comparison purposes. Types I and II were assumed to be SACs, and types III and IV were assumed to be SAFCs [16]. Such an assumption must be examined in further studies to reach a clearer conclusion regarding sinusitis and frontal recess cells.

Given all the discrepancies between different classifications and, therefore, different findings, it has been found that having sinusitis can make it even more challenging to identify the cells [37]. On the other hand, the IFAC classification made it easier to assess frontal cells in healthy individuals or those who have a less severe degree of sinusitis [37]. Therefore, concluding an association between frontal cells and sinusitis is limited when severe sinusitis cases are usually excluded due to visualization difficulty [11]. Similarly, Sommer et al. reported the simplicity of using such classification, especially with those with prior anatomical backgrounds [10].

4. Surgical Approaches with Anatomical Variations in Frontal Sinus Anatomy

Considering the complexity of the frontal sinus and the overall knowledge of the direct pathway, multiple explanations have been added to address this point. For example, in the presence of a supra agger cell (SAC) with a small bulla cell, the technique is to divert the drainage through the agger nasi window to drain the frontal sinus, while in comparison to the supra- aggar nasi cell with a small bulla cell, the technique is to go with an intact bulla to drain the frontal sinus through an intact bulla with the use of an angled scope and instrument. In contrast, if a large supra agger frontal cell (SAFC) is present, the removal of the bulla and any cells above it is required in order to expose the frontal recess and sinus drainage safely without damaging the orbits, skull base, or anterior ethmoid

artery. However, if the nasion is short and low, with a small agger nasi cell, and the drainage is blocked, then entry to the frontal sinus is achieved laterally by drilling the frontal beak in order to face the frontal sinus posterior table using a straight-degree scope and equipment without the need for a curved-degree scope [38]. Further drilling of the frontal beak to the orbital superior medial wall and the medial part of the crisa galli or middle turbinate attachment may be necessary for large supra agger frontal cells and medially supra orbital ethmoid cells, making the procedure Draf 2a/2b or Draf III [7].

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