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STUDY OF THE CONFIGURATION OF THE FRONTAL RECESS AND ITS RELATIONSHIP WITH FRONTAL SINUSITIS BASED ON COMPUTED TOMOGRAPHY

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The anatomical complexity of the frontal-ethmoid region is a key factor influencing frontal sinus drainage and increasing the risk of frontal sinusitis. The identification of objective morphometric predictors can improve diagnosis, prognosis and surgical planning in frontal sinus pathology. The aim of the study was to establish the relationship between the complexity of the anatomy of the frontal recess and the presence of frontal sinusitis by analysing the index of surgical complexity and the anterior-posterior distance based on computed tomography in 120 patients (233 anatomical sides). Signs of frontal sinusitis were detected in 26.3% of cases. In the group with frontal sinusitis, the mean of the index of surgical complexity was 2.71±0.89 score, the anterior-posterior distance – 7.98±2.29 mm; in the group without frontal sinusitis – 2.59±0.71 score and 8.38±2.02 mm, respectively. Despite the absence of statistically significant differences ($p>0.05$), a decrease in anterior-posterior distance and an increase in the index of surgical complexity were accompanied by an increase in the frequency of inflammation. The results obtained indicate the potential prognostic value of these parameters and justify their inclusion in a comprehensive preoperative analysis.

Key words: frontal sinusitis, International Classification of the Radiological Complexity, anterior-posterior distance, frontal sinus, computed tomography.

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ДОСЛІДЖЕННЯ КОНФІГУРАЦІЇ ЛОБОВОГО ЗАГЛИБЛЕННЯ ТА ЙОГО ЗВ'ЯЗОК ІЗ ФРОНТИТОМ НА ОСНОВІ КОМП'ЮТЕРНОЇ ТОМОГРАФІЇ

Анатомічна складність лобово-етмоїдальної ділянки залишається ключовим фактором, що впливає на дренаж лобової пазухи та підвищує ризик розвитку фронтиту. Визначення об'єктивних морфометричних предикторів дозволяє покращити діагностику, прогнозування і хірургічне планування при патології лобової пазухи. Метою дослідження було встановлення зв'язку між складністю анатомії лобового заглиблення та наявністю фронтиту шляхом аналізу показника індексу радіологічної складності і передньо-задньої відстані за даними комп'ютерної томографії у 120 пацієнтів (233 анатомічні сторони). Ознаки фронтиту виявлено у 26,3 % випадків. У групі з фронтитом середній показник індексу радіологічної складності становив 2,71±0,89 бали, передньо-задньої відстані – 7,98±2,29 мм; у групі без фронтиту – відповідно 2,59±0,71 та 8,38±2,02 мм. Незважаючи на відсутність статистично значущих відмінностей ($p>0,05$), зменшення передньо-задньої відстані і підвищення показника індексу радіологічної складності супроводжувалися зростанням частоти запалення. Отримані результати свідчать про потенційну прогностичну цінність цих параметрів і обґрунтовують їх включення до комплексного передопераційного аналізу.

Ключові слова: фронтит, Міжнародна класифікація радіологічної складності, лобова пазуха, комп'ютерна томографія.

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Surgical treatment of frontal sinus diseases, particularly chronic rhinosinusitis [2, 9] with inflammation spreading to the frontal sinus, is one of the most difficult problems in endoscopic rhinosurgery. This is caused by the significant variability of the anatomy of the frontal-ethmoid area, which complicates surgical "navigation" and access to the frontal sinus. Patients with chronic frontal sinusitis often have structural features that interfere with normal drainage and require more complex types of surgical procedures.

In 2016, Wormald et al. developed an international classification of frontal sinus anatomy – IFAC (The International Frontal Sinus Anatomy Classification), which describes 7 types of cells that form the frontal-ethmoid area and affect the drainage of the frontal sinus [14]. This classification has made it possible to standardise anatomical variants of the frontal-ethmoid cell structure and improve preoperative planning. Jaremek-Ochniak et al. showed that frontal sinus septal cells (FSC), supraorbital ethmoid cells (SOEC) and supra agger frontal cells (SAFC) are significantly more common in patients requiring extended surgical treatment (Draf IIB) [7]. Al Habsi et al. emphasised the need for routine assessment of IFAC cells when planning frontal sinus surgery [1, 4, 8, 11].

One of the key quantitative tools for objectifying the complexity of surgical access is the ICC (The International Classification of the Radiological Complexity, 2016), which assesses anatomically narrow areas of the frontal sinus drainage channel based on computed tomography (CT) [13]. Its combination with the anterior-posterior (AP) distance of the frontal recess allows predicting both the complexity of access

and the risk of developing frontal sinusitis [11]. For example, Wormald et al. showed that an AP distance of less than 5 mm significantly increases the risk of chronic frontal sinusitis [13], and Johari et al. described a correlation between the density of frontal ethmoid cells and the need for extended surgical access in chronic frontal sinusitis [8].

Anatomical studies using 3D reconstruction [12], morphometric analysis, and multiplanar CT have made it possible to detail the dimensions of the frontal recess, determine the direction of drainage, and assess the impact of individual cells on the extent of surgical intervention (Choby et al.) [3, 5, 10]. It has been confirmed that FSC and SOEC are associated with a high level of access complexity and are more common in patients with ineffective standard conservative treatment [5, 6].

From a clinical point of view, it is important not only to identify the configuration of the cells, but also to quantitatively assess its impact on surgical complexity. The introduction of ICC, IFAC and morphometric parameters into routine clinical practice can significantly improve treatment outcomes. The work of Al Habsi et al. demonstrated that accurate preoperative planning based on anatomy reduces the risk of complications and recurrence [1]. Thus, the integration of these parameters into a multidisciplinary approach is clinically significant in modern otorhinolaryngology.

The purpose of the study was to identify the relationship between the complexity of the frontal recess anatomy and the presence of frontal sinus inflammation by analysing computed tomography data.

Materials and methods. An analysis of computed tomography data of the paranasal sinuses in 120 patients treated at the Poltava Regional Clinical Hospital named after M.V. Sklifosovsky between 2024 and 2025 was performed. The task was to identify morphological factors that influence the development of inflammatory processes in the frontal sinus, in particular the possible connection between the configuration of the frontal-ethmoid cells and the anterior-posterior length of the frontal-nasal canal (AP) with the development of frontal sinusitis. The structure of the frontal-nasal canal was assessed based on the cone-beam CT data of the paranasal sinuses. The assessment included the identification of cells according to IFAC and the measurement of the AP length of the frontal recess. Based on a previous study, the frontal ethmoid cells were determined according to IFAC in these groups of patients, and the results were used to determine the ICC [9]. AP distance (anteroposterior distance) is a linear dimension in the anterior-posterior direction that characterises the depth of the anatomical structures of the frontal-ethmoid region, in particular the cells bordering the frontal sinus. It is measured from the frontal beak to the base of the skull at the narrowest point on a parasagittal CT scan. A smaller AP distance of the frontal recess is associated with a higher risk of developing frontal sinusitis due to limited ventilation and drainage of the frontal sinus. Both indicators were integrated into the ICC scale (Table 1), which allows for a quantitative assessment of the anatomical complexity of access to the frontal sinus.

Table 1

International Frontal Sinus Anatomy Classification [12]

	Wide AP diameter (≥10 mm)	Narrow AP diameter (9–6 mm)	Very narrow AP diameter (≤5 mm)
Cells below ostium (agger nasi, SAC, SBC)	Less complex (Grade 1)	Moderate complexity (Grade 2)	High complexity (Grade 3)
Cells encroaching into the ostium (SAFC, SBFC, SOEC, FSC)	Moderate complexity (Grade 2)	High complexity (Grade 3)	Highest complexity (Grade 4)
Cells extending significantly into frontal sinus (SAFC, SBFC, SOEC, FSC)	High complexity (Grade 3)	Highest complexity (Grade 4)	Highest complexity (Grade 4)

Notes: AP refers to the frontal ostium anterior-posterior diameter as measured from the frontal beak to the skull base at its narrowest distance on the parasagittal CT scan.

Classification of the cells is from the recent IFAC [14]. AP = anterior-posterior; CT = computed tomography; FSC = frontal septal cell; IFAC = International Frontal Sinus Classification; SAC = supra agger cell; SAFC = supra agger frontal cell; SBC = supra bulla cell; SBFC = supra bulla frontal cell; SOEC = supra orbital ethmoid cell.

The study included 120 patients, representing a total of 240 anatomical sides (right and left frontal sinuses). Computed tomography was performed in three projections: coronal, axial, and sagittal. In 7 cases, frontal sinus aplasia (complete absence of the sinus on one side) was detected, so these 7 sides were excluded from the analysis. As a result, 233 sides were evaluated in detail. The analysis was performed by two independent experts in endoscopic rhinology; in case of discrepancies, a third specialist was involved to reach a consensus.

For each side, the following were recorded:

1) presence/absence of frontal sinusitis (based on radiological data);
2) AP distance (in millimetres);
3) ICC score (from 1 to 4);
4) anatomical variants according to IFAC;
5) additional data on the age and gender of patients.

To describe the distribution of the sides, two groups were formed: with frontal sinusitis (n=63) and without frontal sinusitis (n=170). Microsoft Excel 365 was used for statistical data processing. Quantitative indicators are presented as mean values and standard deviations (M±SD). The comparison of mean values in two independent groups (with and without frontal sinusitis) was performed using Student's t-test. The level of statistical significance was taken as $p<0.05$. To assess the frequency of phenomena and the ratio of qualitative characteristics, a comparison of percentage indicators was used.

Results of the study and their discussion. The study provided a number of clinical and anatomical observations that deepen our understanding of the role of morphological factors in the formation of susceptibility to inflammatory changes in the frontal sinus. A total of 233 frontal sinuses were analysed, of which 63 sides (26.3 % of the total) showed signs of frontal sinusitis, while 177 sides (73.7 %) were free of inflammation. This distribution demonstrates the real clinical picture, in which cases without acute or chronic pathology predominate, which is to be expected when assessing a contingent of patients undergoing CT not only for diagnostic but also for preventive purposes.

The distribution of patients by gender showed that in the group with frontal sinusitis there were 25 men and 19 women, while in the group without frontal sinusitis there were 39 men and 37 women. The assessment of age characteristics showed that the average age of patients with frontal sinusitis was 42.03±12.28 years, while in the group without frontal sinusitis, this indicator was practically the same and amounted to 41.74±13.18 years. This indicates the homogeneity of the age composition of the groups and allows avoiding potential age bias. All patients belonged to the young to middle age category. Age was not a predictor of changes in anatomy or the development of inflammation in the frontal sinus within this sample.

The gender of the patients also had no statistically significant effect on the formation of the frontal sinusitis group. In the group with inflammation, there were 33 male (52.4 %) and 30 female (47.6 %) sides, and in the group without inflammation, there were 95 male (53.7 %) and 82 female (46.3 %) sides. Overall, men accounted for 53.3 % and women for 46.7% of all 233 cases. This allows us to conclude that the gender distribution in the study cohort was relatively even, which increases the reliability of the results obtained.

The analysis of the morphological characteristics of the frontal recess included two main parameters: AP distance and ICC complexity score. In patients with frontal sinusitis, the mean AP distance was 7.98±2.29 mm, while in patients without frontal sinusitis, it was 8.38±2.02 mm. From a clinical point of view, a larger AP distance does not always mean better drainage capacity, since drainage efficiency is influenced by both the configuration and the presence of cells that can restrict patency.

The ICC index, which is integral and takes into account both the AP distance and the presence of complex cells according to the IFAC classification, averaged 2.71±0.89 points in the group with frontal sinusitis and 2.59±0.71 points in the group without frontal sinusitis. A higher ICC in patients with frontal sinusitis may indicate that the inflammatory process occurs more often in cases where the anatomy appears more complex according to CT criteria.

The results indicate the importance not only of the formal calculation of parameters, but also their clinical interpretation. For example, two patients may have the same AP distance, but the presence of a frontal septal cell or large supraorbital cells can radically change the functional patency of the frontal-nasal canal. In further studies, it is advisable to conduct a separate analysis by IFAC cell type, which will allow detailing the role of each morphotype in the formation of the risk of frontal sinusitis. The summary results of the study are presented in Table 2.

Table 2

Quantitative characteristics of the studied groups (M±SD)

Predictors	With frontal sinusitis (n=63)	Without frontal sinusitis (n=170)	Total (n=233)
Age, years	42.03±12.28	41.74±13.18	41.81±12.91
Men, n	25	39	64
Women, n	19	37	56
ICC	2.71±0.89	2.59±0.71	2.65±081
AP, mm	7.98±2.29	8.38±2.02	8.09±2.23

The results of our study demonstrated that the mean ICC and AP values of the frontal recess length in patients with and without frontal sinusitis did not differ significantly. Despite slightly higher mean values in the group with frontal sinusitis, the p-value did not exceed the critical level of 0.05, which does not allow conclusions to be drawn about a reliable difference between the samples.

This indicates that the isolated use of ICC and AP distances cannot serve as independent prognostic predictors of the presence of frontal sinusitis without taking into account other anatomical or functional factors. Therefore, the role of these morphometric parameters is auxiliary and should be considered in conjunction with other characteristics of the frontal recess, in particular the types of cells according to the IFAC classification.

Despite the absence of statistically significant differences, the observed trends confirm the feasibility of further studying the morphology of the frontal sinus drainage pathway using multivariate analysis, including cell types, 3D reconstructions, and clinical data.

ICC is a combined indicator of the complexity of surgical access to the frontal sinus and takes into account both the number and type of anatomical cell variants (according to IFAC) and the linear AP distance of the drainage channel. Thus, an increase in ICC in patients with frontal sinusitis can be considered a clinical sign of complex morphology, which potentially complicates physiological drainage and may contribute to the development of inflammation in the frontal sinus.

The results obtained are consistent with publications in recent years. In particular, the works of Fawzi et al. (2022) and Jaremek-Ochniak et al. (2022) show that the presence of septal cells of the frontal sinus, supraorbital cells and other variants significantly complicates access to the frontal sinus and is associated with a higher probability of inflammation [4, 7]. Similar conclusions are also presented by Al Habsi et al. (2024), pointing to the clinical value of preliminary assessment of cell configuration by CT [1].

Particular attention should be paid to the AP parameter. A reduction in this distance was associated with higher ICC scores and, accordingly, with an increased risk of frontal sinusitis. This confirms the observation that a short frontal sinus length may cause narrowing of the drainage pathway, creating conditions for ventilation disorders.

The results are consistent with our previous observations (Loburets A. et al., 2024), which demonstrated a difference in the prevalence of SOEC and FSC among frontal ethmoid cells in patients with chronic frontal sinusitis compared to individuals without inflammatory changes, although this difference was not statistically significant [9].

Although previous studies demonstrate the importance of the morphology of individual cells, our study is one of the first to quantitatively compare ICC scores with clinical manifestations of frontal sinusitis. This approach may have important practical significance for determining the indications for surgical intervention and justifying the extent of endoscopic revision in the frontal recess.

From a practical point of view, the results obtained can be used as a basis for development of a structured approach of preoperative CT analysis of the paranasal sinuses. Elevated ICC and reduced AP distance can be considered as prognostic factors in the development of inflammation and complications after standard frontotomy.

Thus, the results of our study confirm the importance of careful anatomical assessment of the frontal recess when planning surgical intervention. Further studies involving 3D modelling, large multicentre samples and multivariate analysis will improve the accuracy of prediction and individualise the approach to the treatment of patients with chronic frontal sinusitis.

Conclusions

1. As a result of analysing 233 frontal sinus images obtained using cone beam computed tomography, signs of frontal sinusitis were observed in 26.3 % of cases, demonstrating the significant prevalence of this pathology in the sample.

2. The average ICC score was slightly higher and the AP distance was shorter in the group of patients with frontal sinusitis, but these differences were not statistically significant ($p>0.05$).

3. The results obtained do not allow us to consider ICC or AP distance as independent reliable markers of the risk of frontal sinusitis, but indicate the potential role of morphological features in the formation of the drainage capacity of the frontal recess.

4. The data obtained confirm the possibility of using ICC and AP distance as prognostic criteria when planning the extent of endoscopic surgery of the frontal sinus, which is important for reducing the risk of complications and recurrences.

5. The results of the study open up the prospect of creating a standardised approach to the analysis of frontal recess anatomy using the IFAC classification, which will contribute to more accurate prediction of the complexity of the intervention.

Prospects for further research. In the future, it would be advisable to expand the study by means of multivariate analysis, taking into account IFAC cell types and using 3D reconstructions to improve the accuracy of preoperative visualization.

References

1. Al Habsi T, Al-Ajmi E, Washahi MA, Lawati MA, Maawali SA, Mahajan A, et al. Does Frontal Recess Cell Variation Associate with the Development of Frontal Sinusitis? A Narrative Review. Diagnostics (Basel). 2024 Jan 3;14(1):103. doi: 10.3390/diagnostics14010103.
2. Bousquet J, Toumi M, Sousa-Pinto B, Anto JM, Bedbrook A, Kaidashev I, et al. The Allergic Rhinitis and Its Impact on Asthma (ARIA) Approach of Value-Added Medicines: As-Needed Treatment in Allergic Rhinitis. J Allergy Clin Immunol Pract. 2022 Nov;10(11):2878-2888. doi: 10.1016/j.jaip.2022.07.020.
3. Choby G, Thamboo A, Won TB, Kim J, Shih LC, Hwang PH. Computed tomography analysis of frontal cell prevalence according to the International Frontal Sinus Anatomy Classification. Int Forum Allergy Rhinol. 2018 Jul;8(7):825-830. doi: 10.1002/alr.22105.
4. Fawzi NEA, Lazim NM, Aziz ME, Mohammad ZW, Abdullah B. The prevalence of frontal cell variants according to the International Frontal Sinus Anatomy Classification and their associations with frontal sinusitis. Eur Arch Otorhinolaryngol. 2022 Feb;279(2):765-771. doi: 10.1007/s00405-021-06843-0.
5. Feng Y, Yan S, Wang J, Liu Y, Li X. [The role of supraorbital ethmoid cell and the significance of a proposed classification of the anterior ethmoid artery in endoscopic sinus surgery]. Lin Chuang Er Bi Yan Hou Tou Jing Wai Ke Za Zhi. 2021 Jun;35(6):495-500. doi: 10.13201/j.issn.2096-7993.2021.06.003. [in Chinese].
6. Jang DW, Lachanas VA, White LC, Kountakis SE. Supraorbital ethmoid cell: a consistent landmark for endoscopic identification of the anterior ethmoidal artery. Otolaryngol Head Neck Surg. 2014 Dec;151(6):1073-1077. doi: 10.1177/0194599814551124.
7. Jaremek-Ochniak W, Sierdziński J, Popko-Zagor M. Three-dimensional computed tomography analysis of frontal recess cells according to the International Frontal Sinus Anatomy Classification (IFAC) - difficulties in identification of frontal recess cells in patients with diffuse primary chronic rhinosinusitis? Otolaryngol Pol. 2022 Jan 14;76(2):7-14. doi: 10.5604/01.3001.0015.6959.
8. Johari HH, Mohamad I, Sachlin IS, Aziz ME, Mey TY, Ramli RR. A computed tomographic analysis of frontal recess cells in association with the development of frontal sinusitis. Auris Nasus Larynx. 2018 Dec;45(6):1183-1190. doi: 10.1016/j.anl.2018.04.010.
9. Loburets A, Loburets V, Bezega M, Gasiuk I. The study of frontal recess configurations based on computed tomography data and their association with frontal sinusitis. Pol Otorhino Rev. 2024;13(4):7-12. doi: 10.5604/01.3001.0054.8393.
10. Nair PP, Varghese A, Kumar N, Varghese SS. Computed Tomographic Study of Frontal Sinus Cells and Opacification as Per the International Frontal Sinus Anatomy Classification. Indian J Otolaryngol Head Neck Surg. 2024;76(4):3451-3457. doi: 10.1007/s12070-024-04724-6.
11. Nofal AAB, El-Anwar MW. Frontal Recess Cells in International Frontal Sinus Anatomy Classification (IFAC); Prevalence, Infection Incidence, and Relation to Frontal Sinus Infection in Chronic Sinusitis Patients. Indian J Otolaryngol Head Neck Surg. 2022 Dec;74(Suppl 3):4748-4755. doi: 10.1007/s12070-021-03069-8.
12. Voloshan OO, Grigorov SM, Demyanyk DS, Ruzin GP, Lokes KP. Prospects of an automated computer software implementation for prediction of course and treatment in patients with different forms of odontogenic maxillary sinusitis. World of Medicine and Biology. 2019;4(70):39–45. doi:10.26724/2079-8334-2019-4-70-39-45.
13. Wormald PJ, Bassiouni A, Callejas CA, Kennedy DW, Citardi MJ, Smith TL, et al. The International Classification of the Radiological Complexity (ICC) of Frontal Recess and Frontal Sinus. Int Forum Allergy Rhinol. 2017 Apr;7(4):332-337. doi: 10.1002/alr.21893.
14. Wormald PJ, Hoseman W, Callejas C, Weber RK, Kennedy DW, Citardi MJ, et al. The International Frontal Sinus Anatomy Classification (IFAC) and Classification of the Extent of Endoscopic Frontal Sinus Surgery (EFSS). Int Forum Allergy Rhinol. 2016;6(7):677-696.

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