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FRONTAL SINUS DRAINAGE SCORE AS A TOOL FOR ASSESSING OUTFLOW PATHWAYS AND GUIDING TREATMENT IN CHRONIC FRONTAL SINUSITIS

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The frontal sinus is one of the most challenging areas in endoscopic surgery due to significant anatomical variability and the complexity of its drainage pathways, which increases the risk of chronic inflammation and recurrence. The aim of the study was to summarise current data on factors influencing the drainage function of the frontal sinus and to develop an approach to its quantitative assessment. An analysis of international and national publications was conducted, including data from computed tomography, anatomical studies and systematic reviews. It was established that the key factors in drainage impairment are a narrowing of the frontal recess to three millimetres or less, an elongation of the drainage pathway beyond ten millimetres, its more horizontal orientation, and the presence of additional anatomical structures that alter the direction of outflow. Studies have shown that complex and asymmetrical drainage trajectories contribute to mucus stasis and influence the clinical course. On this basis, a scoring system for assessing drainage function has been proposed, which allows patients to be stratified according to the complexity of drainage and enables the rational selection of treatment strategies ranging from conservative management to extensive surgical interventions, thereby improving the accuracy of preoperative planning.

Key words: frontal sinus, international frontal sinus anatomy classification, drainage pathways, frontal sinus outflow tract, morphometry, frontal sinus drainage score.

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ШКАЛА ОЦІНКИ ДРЕНАЖУ ЛОБОВОЇ ПАЗУХИ ЯК ІНСТРУМЕНТ ДЛЯ ОЦІНКИ ШЛЯХІВ ВІДТОКУ ТА ВИБОРУ ЛІКУВАННЯ ПРИ ХРОНІЧНОМУ ФРОНТИТІ

Лобова пазуха є однією з найбільш складних ділянок ендоскопічної хірургії через значну анатомічну варіабельність і складність дренажних шляхів, що обумовлює ризик хронічного запалення та рецидивів. Метою дослідження було узагальнення сучасних даних про чинники, що впливають на дренажну функцію лобової пазухи, та розробка підходу до її кількісної оцінки. Проведено аналіз міжнародних і національних публікацій, що включали дані комп'ютерної томографії, анатомічних досліджень і систематичних оглядів. Встановлено, що ключовими факторами порушення дренажу є звуження лобового заглиблення до трьох міліметрів і менше, подовження дренажного каналу понад десять міліметрів, його більш горизонтальна орієнтація та наявність додаткових анатомічних структур, які змінюють напрямок відтоку. Показано, що складні та асиметричні траєкторії дренажу сприяють застою секрету і визначають перебіг захворювання. На цій основі запропоновано бальну систему оцінки дренажної функції, яка дозволяє стратифікувати пацієнтів за складністю дренажу та обґрунтовано обирати тактику лікування від консервативного ведення до розширених хірургічних втручань, що підвищує точність передопераційного планування.

Ключові слова: лобова пазуха, міжнародна класифікація анатомії лобової пазухи, шляхи дренажу, лобово-носовий канал, морфометрія, шкала дренажу лобової пазухи.

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The frontal sinus represents the most challenging 'frontier' in endoscopic sinus surgery. It is characterised by variable anatomy, multiple drainage pathways, and proximity to the orbit and the anterior cranial fossa. Therefore, even with modern treatment standards, some patients with chronic frontal sinusitis experience recurrent disease or require repeat surgical interventions, and surgical planning must rely not only on the surgeon's experience but also on clear morphometric landmarks. According to international guidelines, the success of treatment for patients with chronic frontal sinusitis depends on the accuracy of preoperative planning of the surgical procedure and the restoration of a physiologically adequate drainage pathway during surgery – from the initial stages of ESS to advanced options for frontal sinus drainage [25, 29].

One of the reasons for the difficulties in diagnosing and treating patients with frontal sinusitis is the variety of drainage pathways of the frontal sinus, which are formed by the bony walls of the frontal-ethmoid region. Clinically, these walls vary in the angle, length and course of the frontal sinus outflow tract (FSOT), creating potential 'bottlenecks' for obstruction and scarring [15].

The precision and minimally invasive nature of the surgeon's procedures are enhanced by both technological solutions (high-resolution computed tomography (CT), intraoperative navigation) and the quality of preoperative planning allows for the simulation of personalised FSOT obstruction scenarios and the local correction of problematic areas [20].

An additional level of complexity is posed by the proximity of the frontal sinus to vital structures. The anterior ethmoidal artery exhibits significant anatomical variability (including extracanal location), which increases the risk of intraoperative bleeding and complicates manoeuvring within the frontal recess (FR). The variability of its course and distances to landmarks has been demonstrated by a number of studies [21, 30]. Combined with the thin

lamina papyracea and proximity to the anterior cranial fossa, this underscores the importance of clear visualisation of the surgical field and intraoperative orientation within the structures of the FR [6].

Finally, the clinical consequences of errors or delayed restoration of drainage in frontal sinus surgery remains high. Although severe complications are rare, frontal sinusitis is associated with the most dangerous complications – ranging from orbital to intracranial – and requires multidisciplinary collaboration and timely surgical intervention [16]. In this context, interest in extended interventions (Draf IIb/III) is naturally growing: meta-analyses and clinical series demonstrate improved outcomes and a reduced incidence of restenosis, emphasising the need for thorough preoperative preparation [1, 4, 8, 10].

In particular, simple CT metrics, such as the anteroposterior (A-P) diameter of the ostium, are already demonstrating clinical utility during surgical procedures. These data highlight the need to develop integrated predictive tools that combine anatomical, topographical and morphometric variables, taking into account technological capabilities and CT planning.

The purpose of the study was to analyse current literature data on the anatomical, topographical and morphometric factors influencing frontal sinus drainage, as well as to develop a conceptual model, the Frontal Sinus Drainage Score, for the standardised assessment of frontal sinus outflow tract complexity and to justify the choice of surgical approach carried out in the context of treatment for patients with chronic frontal sinusitis.

Materials and methods. A literature search was conducted in PubMed, Scopus, Web of Science, and Google Scholar to identify studies on frontal sinus drainage pathways, frontal recess anatomy, FSOT morphology, IFAC-classified frontal cells, and their association with chronic frontal sinusitis. The review was performed in accordance with PRISMA recommendations. Years included: 2021-2026. Years excluded: publications before 2021 (Table 1).

Database 1 – PubMed/MEDLINE. Search query: ("frontal sinus" OR "chronic frontal sinusitis") AND ("frontal recess" OR "frontal sinus outflow tract" OR "drainage pathway" OR "frontal drainage pathway").

Database 2 – Scopus. Search query: TITLE-ABS-KEY (("frontal sinus" OR "chronic frontal sinusitis") AND ("frontal recess" OR "frontal sinus outflow tract" OR "drainage pathway" OR "frontal drainage pathway")).

Database 3 - Web of Science. Search query: TS = (("frontal sinus" OR "chronic frontal sinusitis") AND ("frontal recess" OR "frontal sinus outflow tract" OR "drainage pathway" OR "frontal drainage pathway")).

Database 4 - Google Scholar. Search query: ("frontal sinusitis" OR "chronic frontal sinusitis") AND ("frontal recess" OR "frontal sinus outflow tract" OR "IFAC") AND ("computed tomography" OR "morphometry").

Table 1

Simplified PRISMA Flow

Stage	Description	Number of Records/Studies
1. Identified	Total number of records identified through database searching and other sources	684
2. Duplicates Removed	Number of records removed before screening (e.g., duplicates)	120
3. Screened (Title/Abstract)	Number of records screened after duplicates were removed	564
4. Assessed for Eligibility (Full-text)	Number of full-text articles assessed for eligibility against the inclusion/exclusion criteria	78
5. Included in Review	Total number of primary studies finally included in the systematic review	30

Records retrieved from all databases were imported into a reference database and screened for eligibility. Duplicate records were removed before title and abstract screening. Full-text articles were assessed according to predefined inclusion and exclusion criteria. Original clinical studies, anatomical and radiological investigations, systematic reviews, and meta-analyses related to frontal sinus drainage pathways, IFAC anatomy, and FSOT morphometry were included.

The analysis included original clinical studies, radiological and anatomical studies, as well as systematic reviews and meta-analyses that examined the structural features of the frontal-ethmoid region, variants of the frontal sinus drainage pathways (FSDP), and morphometric parameters of the FSOT. A mandatory criterion for inclusion was the availability of data on anatomical variants according to the IFAC classification, types of drainage pathways, or quantitative FSOT indices and their association with the development of chronic frontal sinusitis or treatment outcomes. Isolated clinical cases without sufficient analysis and publication, which did not contain the necessary morphometric or anatomical data, were excluded.

During the literature review, all data were grouped into three categories: anatomical features (frontal-ethmoid cells according to the IFAC), topography of drainage pathways (FSDP types) and morphometric characteristics of the FSOT (minimum anteroposterior diameter, length and inclination angle). For each of these parameters, values associated in the literature with impaired drainage and the development of inflammation were taken into account.

Based on a synthesis of the data obtained, the concept of the integrated FSDS scale was developed. The scale includes anatomical, topographical and

morphometric indicators. Each unfavourable factor was assigned 1 point. Threshold values for the indicators were determined based on the literature and their clinical significance.

The study was conducted without involving patients or using personal data, as it is based exclusively on the analysis of published scientific sources.

Results of the study and their discussion. In cases of chronic rhinosinusitis, interpreting IFAC anatomy becomes more difficult: mucosal oedema and thickening of the soft tissue contours 'blur' the boundaries of the cells and make them harder to identify on standard reconstructions. In most cases, it is advisable to use 3D reconstructions and standardised CT assessment protocols, which, according to Jaremek–Ochniak et al. (2022), improve the accuracy of interpretation [12]. The authors point out that, due to the large number of variations in the cells and the complex topography of the frontal-ethmoid region, even experienced radiologists find it difficult to identify all the cells of the FR. Using 3D reconstruction, the researchers assessed the feasibility of identifying the cells and emphasised that accurately determining their location is a prerequisite for an adequate assessment of FSDP patency.

The reliability of IFAC has been confirmed in an international multicentre study demonstrating high inter- and intrarater agreement among experienced rhinologists, supporting its use as a standardised tool for frontal recess assessment (Villarreal et al. (2019)).

Similar reproducibility was demonstrated among senior otolaryngology residents, indicating that IFAC can be applied reliably even outside highly specialised rhinology centres (Assiri et al. (2020)).

Hemmi T et al. (2024) proposed a computed tomography technique involving a 30° forward tilt of the scanning plane, which enables better visualisation of the drainage pathway of the frontal sinus. This angle allows for images that run parallel to the natural direction of the frontal sinus ostium, thereby clearly defining the cells of the FR, the attachment site of the uncinate process, and the relationship between the ostium and the recess. The authors demonstrated that conventional axial or coronal projections often "smooth out" these structures, and clinicians may underestimate the degree of their narrowing. Such a morphometric error in imaging may lead to incorrect preoperative planning and, consequently, to incomplete restoration of drainage after surgery, which increases the risk of frontal sinusitis recurrence. These findings highlight the importance of topographically oriented CT imaging for the accurate assessment of the anatomy of the frontal sinus ostium and the prevention of inflammatory complications [9].

Recent anatomical investigations have challenged traditional concepts regarding the agger nasi cell, suggesting that its morphology and relationship to the frontal recess may be more complex than previously assumed [3].

The combined clinical and radiological data suggest that isolated frontal-ethmoid cells, as defined by the IFAC classification, may increase the risk of frontal sinus inflammation due to their close proximity to the frontal ostium and their impact on the direction and continuity of drainage [24]. Nofal et al. (2022) applied the IFAC to assess the anatomy of the FR in patients with chronic rhinosinusitis to establish possible links between cell types and the development of frontal sinusitis. Analysis of computed tomography scans showed that the presence of anterior cells (agger nasi cell (ANC) and supra agger cell (SAC)) often causes narrowing of the frontal sinus ostium and impaired drainage. Combinations of several cells further reduce the lumen of the FSOT, creating conditions for secretion stasis and the development of inflammation. The study confirmed that it is the anatomical configuration of the FR, as determined by IFAC, that is a key factor in the pathogenesis of frontal sinusitis and, consequently, must be taken into account during the preoperative assessment of the complexity of the procedure.

Similar conclusions were reached by Al Habsi T. et al (2024). This review summarises current evidence regarding the influence of variations in the cells of the FR on the development of the frontal sinusitis. The authors analysed existing studies conducted using various classifications (Kuhn, IFAC) and imaging techniques, and concluded that despite some inconsistency in the results, the majority of studies confirm an association between narrow anatomical variants of the FR and an increased risk of frontal sinusitis. Structures located in the medial or anterior part of the FR that reduce its lumen, particularly the ANC, SAC and frontal septal cell (FSC), create a mechanical barrier to drainage, leading to mucus stasis. Thus, anatomical variability of the FR has direct clinical significance, and taking this into account may improve the preoperative assessment of the risk of frontal sinusitis [2].

Prospective data demonstrate a link between specific variants of the frontal sinus (marked pneumatisation, medialisation of the cells) and CT signs of inflammation, reinforcing the notion of a direct link between topography and the risk of developing inflammation [22]. This CT study examines the prevalence of various IFAC cells and their association with frontal sinus opacification. The authors found that certain cell types, notably SAC, SBC and supra agger frontal cell (SAFC), significantly reduce the lumen of the FR, disrupting physiological drainage. Such morphometric narrowing creates conditions for sinus hypoventilation, chronic inflammation and mucus stasis.

The study by Nguyen et al. (2025) is devoted to a comprehensive analysis of the morphology and morphometry of the frontal sinus in a Vietnamese population, taking into account the structures that influence the size of the drainage tract (FSOT). Based on CT scans of 280 frontal sinuses, the authors determined the mean values for the A-P diameter of the frontal sinus ostium (≈6.4 mm) and the FR (≈3.2 mm). It was found that the presence of ANC and SAC cells significantly reduces the width of the FSOT, whilst SAFC narrows the ostium. Such morphometric

changes directly impair sinus aeration and contribute to the development or recurrence of frontal sinusitis. The authors emphasise the importance of quantitative assessment of the FSOT prior to surgery for predicting the complexity of access and the risk of inflammation [23].

In this study, the authors investigated the different types of anatomical variations in the frontal-ethmoid cells and their association with radiological signs of sinusitis. A detailed CT analysis revealed that a narrow FR, particularly when it contains several clusters of IFAC cells, significantly increases the likelihood of frontal sinus inflammation. Patients with a minimum FR diameter of less than 3 mm had an almost twofold higher incidence of frontal sinusitis than those with a wider FSOT. This confirms that the topographical complexity and morphometric narrowing of the FR play a key role in impaired drainage and, consequently, in the aetiopathogenesis of chronic frontal sinusitis [8].

In this study, the authors examine in detail how preoperative assessment of the expected diameter of the formed frontal sinus ostium during Draf III surgery influences surgical outcomes. The aim of the study was to assess whether the minimum and maximum A-P diameters of the FSOT are associated with the risk of recurrence and, consequently, with the need for surgical revision. Insufficient FSOT dilation in patients with a narrow topography leads to mucus stasis, loss of ventilation and recurrent frontal sinus inflammation, whereas achieving an adequate diameter significantly reduces the incidence of restenosis. Thus, these findings demonstrate a direct link between preoperative morphometric parameters and the risk of recurrent frontal sinusitis, emphasising the need for an individualised approach to planning the type of drainage according to Draf [18].

The high prevalence of ANC (>91.7%, according to the global literature) and SBC among various population groups has not been shown to have a direct impact on the development of frontal sinusitis [26]. Age-related analysis has demonstrated that ANC and SBC remain the predominant frontal cells across all age groups, although some frontal cell variants show significant differences between paediatric and adult populations [17]. Recent evidence also suggests that the prevalence of selected IFAC cells varies according to sex and ethnicity, further emphasising the importance of population-specific anatomical assessment [11]. Only isolated cases of atypical anatomy could be considered a risk factor for the development of frontal sinusitis in a patient.

In our own study of the anatomy of the frontal-ethmoid cells using the IFAC classification system, 120 computed tomography scans (233 sides) were analysed. The most common structures were ANC (97%) and SBC (82%), whilst supraorbital ethmoid cell was found in only 18% of cases. In two-thirds of cases (67%), the cells communicated with the frontal sinus lumen; however, no statistically significant association was found between cell type and the presence of frontal sinusitis. This indicates that the configuration of the cells alone is not an independent predictor of inflammation, but forms the anatomical basis for assessing the complexity of drainage and surgical access [29].

Thus, analysis of IFAC cells indicates that the anterior frontal-ethmoid cells are of greatest clinical interest, as they are capable of significantly altering the drainage pathway and creating mechanical barriers in the region of the frontal sinus ostium. At the same time, no single type of cell can be regarded as an absolute predictor of frontal sinusitis: their number, size and topographical relationships are of decisive importance.

Three-dimensional volumetric studies further suggest that the volume of frontal cells may be more clinically relevant than their mere presence, as larger cells exert a greater influence on frontal recess configuration and drainage dynamics [28].

Fawzi et al. reported that selected frontal cells were significantly associated with frontal sinusitis, particularly when they contributed to narrowing of the frontal recess [5]. In contrast, Seth et al. found no consistent association between most IFAC cell types and frontal sinusitis, suggesting that additional anatomical and functional factors influence disease development (Seth N et al. (2020)).

Analysis of the anterior ethmoid genu has demonstrated that frontal recess anatomy is determined by the overall configuration of surrounding structures rather than by isolated frontal cells alone [27].

Jiang et al. demonstrated that frontal recess anatomy can be analysed according to drainage pathways using bony connecting plates as landmarks, highlighting the importance of pathway-oriented rather than cell-oriented assessment [13].

Taken together, these findings suggest a hierarchical relationship between anatomical structures and disease development. Frontal cells defined by IFAC do not directly cause frontal sinusitis; rather, they influence the configuration of the FSDP, which in turn determines the morphometric characteristics of the FSOT. It is this combined effect of anatomy, drainage trajectory and morphometry that ultimately influences the risk of impaired drainage and chronic frontal sinusitis.

The course of chronic rhinosinusitis accompanied by involvement of the frontal sinus is largely determined by the individual topography of the drainage pathway. Complex drainage pathways are more commonly observed in patients with recurrent forms of frontal sinusitis. This indicates that a personalised FSDP analysis is required prior to surgery. The theoretical parameters of this assessment are provided by the classification of five bone-determined FSDP types proposed by Kikawada et al. (2022). It is these types that define the basic direction of natural drainage and typical areas of narrowing [19]. In a follow-up to this work, Kikawada et al. (2025) transformed the classification into a practical algorithm for selecting the approach. Tailoring the surgical approach to the specific patient's drainage pattern reduces the risk of complications and

restenosis and improve the quality of postoperative outcomes [14].

In this study, the authors conducted a computed tomography analysis of variations in the FSDP and assessed their association with the development of frontal sinusitis. CT scans of the paranasal sinuses of patients with chronic sinusitis were analysed. The researchers determined the type and position of the uncinate process (UP), the shape and direction of the frontal sinus ostium, and the presence of associated frontal-ethmoid cells. The results showed that the type of superior attachment of the UP is a key anatomical factor determining the course and shape of the drainage tract. In cases where the frontal sinus opened medially to the superior attachment of the UP, the incidence of frontal sinusitis was significantly higher than with a lateral location of the drainage pathway. This medial drainage pattern was associated with a higher risk of mucus stasis due to direct contact between the FR and the middle nasal meatus, which facilitates retrograde spread of infection. Conversely, the lateral position of the tract, where the frontal sinus is drained via the frontal infundibulum (infundibulum frontale), was associated with a lower incidence of inflammatory changes. The study laid the groundwork for further morphometric studies of FSOT and for the development of preoperative risk prediction schemes for frontal sinusitis (Mahmutoğlu et al. (2015)).

Turgut et al. (2005) conducted a study into the relationship between the location of the frontal sinus outflow tract (FSOT) and the development of frontal sinusitis. The authors analysed 486 sides of the frontal sinuses in 243 patients with chronic sinusitis, determining the type of attachment of the UP and the direction of drainage relative to its upper margin. According to the results, in 66% of cases the drainage pathway ran medially to the superior attachment of the UP, and in 34% – laterally. The data obtained demonstrated that the medial location of the FSOT creates a more direct connection between the FR and the middle nasal meatus, facilitating retrograde spread of infection and reducing the effectiveness of drainage. Furthermore, the authors noted that the most common type of UP attachment was to the lamina papyracea (63%), whilst attachments to the cranial base or the middle turbinate were less common [7].

Our study examined FSOT parameters – length, inclination angle and A–P diameter – as well as drainage pathway types according to Kikawada et al. (2022). It was found that FSOT length had virtually no effect on the risk of frontal sinusitis (18.4±4.2 mm vs 19.1±4.9 mm), whereas the A–P diameter was significantly smaller in the group with chronic inflammation (2.9 mm vs 3.8 mm; $p = 0.026$). Furthermore, the angle of the FSOT in patients with frontal sinusitis was more horizontal (59.2° vs 62.1°; $p = 0.017$), indicating poorer gravitational drainage of secretions.

In terms of structure, the UP–BLEB (uncinate process–basal lamella of ethmoidal bulla) drainage pathway predominated among patients with frontal sinusitis (45% vs 19%), whereas the UP–MT (uncinate–middle turbinate) pathway was more common in the control group (55% vs 31%).

Summarising the data on anatomical variations of the frontal drainage pathways, it can be concluded that these variations determine the natural drainage pathway and define the critical areas of increased risk of obstruction. The presence of complex or asymmetrical variants is associated with recurrent frontal sinusitis, and personalised analysis of the trajectory using modern imaging methods allows not only for a more accurate prediction of the disease course, but also for the selection of the optimal surgical approach. This lays the foundation for personalised surgery aimed at restoring the natural drainage pathway.

The morphometric parameters of the FSOT directly determine its drainage capacity and, together with anatomical and topographical factors, contribute to the overall risk of inflammation in the frontal sinus. In clinical samples, narrowing of the lumen and increased tortuosity of the passage are associated with recurrent disease and persistent inflammation, necessitating the inclusion of morphometry in the standard preoperative assessment protocol. Morphometric parameters depend on the variant of FSDP: different configurations result in different angles and lengths of the FSOT, and consequently, different hydrodynamic resistance; it is logical to include these quantitative parameters in the risk assessment model. In this prospective study, the authors investigated the types of anatomical variations in the FR and their association with radiological signs of sinusitis. A thorough CT analysis showed that a narrow FR, particularly when it contains multiple IFAC cells, significantly increases the likelihood of frontal sinus inflammation. Patients with a minimum recess diameter of less than 3 mm had an almost twofold higher incidence of frontal sinusitis than those with a wider FSOT. This confirms that the topographical complexity and morphometric narrowing of the FR play a key role in impaired drainage and, consequently, in the aetiopathogenesis of chronic frontal sinusitis [8].

Thus, the morphometric parameters of the FSOT play a key role in determining the risk of chronic sinusitis. Narrow, long and horizontally oriented passages create conditions conducive to secretion stagnation and recurrence, whereas wider and more vertical variants ensure effective drainage. When combined with anatomical and topographical features, morphometry allows for a more accurate assessment of risk and the identification of “critical segments” for surgical correction. It is precisely the inclusion of these parameters in an integrated risk assessment model that can improve treatment efficacy and reduce the likelihood of restenosis.

Frontal Sinus Drainage Score (FSDS). Concept and scientific justification. The FSDS system we propose is a conceptual model designed to assess the anatomical, topographical and morphometric factors that determine the complexity of the frontal sinus drainage pathway, and, on this basis, to assist in selecting a treatment method for patients with chronic frontal sinusitis. The FSDS is not yet a ready-to-use clinical protocol and requires further validation; however, it can be used as a tool for the standardised assessment of CT changes and to support clinical decision-making prior to the selection of a treatment strategy (Table 2).

Factors taken into account in the FSDS system:

1. Anatomical variations of IFAC cells. Frontal-ethmoid cells, classified according to IFAC (2016), influence the formation of the FSDP and may alter its configuration. In particular, SAC and SAFC cells extending into the ostium lumen may create mechanical obstructions and impede drainage. On the FSDS scale, such variants are scored as 1 point. In cases of multiple or massive pneumatisation, the scores are added together.

2. Topographical factors of FSDP. According to the classification by Kikawada et al. (2022, 2025), there are at least five variants of FSDP. Simple and straight variants provide better patency, whereas complex configurations (UP–BLEB, BLEB–BLMT) complicate both natural drainage and surgical access. On the FSDS scale, such unfavourable variants are scored as 1 point.

3. Morphometric parameters of FSOT. The quantitative characteristics of the FSOT directly determine its functional capacity:

– A minimum diameter of ≤ 3 mm indicates a narrow channel and impedes outflow.

– A channel length of > 10 mm increases drainage resistance.

– An inclination angle≤ 60° (horizontal FSOT) reduces the efficiency of outflow, whereas a more vertical orientation promotes better drainage.

In the current version of the FSDS, each adverse scenario is assigned a score of 1; the final weighting factors are to be determined following a multivariate analysis in future studies.

Table 2

Structure of the FSDS

Risk factors	Criterion	Point
Anatomical (IFAC)	Hyperpneumatised SACs, SAFCs or other cells enter the frontal sinus and constrict the ostium.	+1
	Multiple large (hyperpneumatic) cells in the FR	+1
Topographic (FSDP)	Posterior drainage pathways of the frontal sinus (UP–BLEB, BLEB–BLMT)	+1
Morphometric (FSOT)	Minimum diameter ≤ 3 mm	+1
	FSOT length > 10 mm	+1
	FSOT inclination angle ≤ 60° (horizontal orientation)	+1

Interpretation of results

– 0–1 points: simple drainage pathway; conservative treatment is appropriate.

– 2–3 points: moderately complex drainage pathway; conservative treatment is possible, but with an increased risk of failure; in the event of surgical intervention, Draf I/IIa is recommended.

– 4–6 points: complex drainage pathway; conservative treatment is ineffective; surgical treatment is advisable, and extensive procedures (Draf IIb/III) are recommended.

The proposed scale has been developed to improve the accuracy of preoperative assessment in patients with chronic frontal sinusitis. It enables the standardisation of the interpretation of CT findings, thereby reducing the subjectivity of assessments between different clinicians. The system is designed to assess the complexity of the frontal sinus drainage pathway, guiding the surgeon towards potentially complex anatomical areas and allowing the optimal treatment strategy to be selected in advance – ranging from conservative management to standard endoscopic procedures (ESS, Draf I/IIa) or extended approaches (Draf IIb/III).

From a clinical perspective, the FSDS facilitates clinical decision-making, helping to avoid both underestimating the complexity of the drainage pathway (which may lead to insufficient treatment efficacy) and overly aggressive interventions that may cause unnecessary trauma. Furthermore, the scale provides a standardised basis for comparing study results and can be used for the objective analysis of clinical series and systematic reviews. Thus, the FSDS is a tool that combines anatomical assessment with the practical choice of treatment method in patients with chronic frontal sinusitis.

At this stage, the FSDS is a conceptual model developed on the basis of a review of the literature. It does not replace the surgeon's clinical experience and should be applied taking into account the individual characteristics of the patient. The next step is to conduct a retrospective analysis of CT images using a large sample to refine the scale's parameters. Prospective validation is also required to assess its clinical effectiveness. A promising avenue is to compare the total FSDS score with the complexity of the surgical procedure and treatment outcomes across different patient groups.

Thus, the FSDS can be regarded as a scale designed to assess the complexity of the drainage pathway and to justify the choice of treatment method in patients with chronic frontal sinusitis.

Conclusion

Anatomical variability of the frontal-ethmoid cells (IFAC), particularly the SAFC and SBFC, influences the formation and complexity of the frontal sinus drainage pathway, creating potential mechanical barriers to outflow.

Topographical variations of FSDP, particularly complex and asymmetrical ones, complicate the configuration of the drainage pathway and require detailed analysis prior to selecting a treatment method.

The morphometric parameters of the FSOT (minimum diameter ≤3 mm, length >10 mm, horizontal orientation) determine the degree of drainage pathway complexity and are of key importance for treatment planning.

The FSDS is a scale for assessing the complexity of the drainage pathway, which combines anatomical, topographical and morphometric factors and allows the choice of treatment method to be justified – ranging from conservative management to various options for surgical intervention (ESS, Draf I/IIa, Draf IIb/III).

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IMPACT OF ELECTRONIC CIGARETTES ON ENDOTHELIAL FUNCTION AND CARDIOPULMONARY HEALTH IN YOUNG ADULTS

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The global use of electronic cigarettes has increased rapidly, particularly among adolescents and young adults, driven by aggressive marketing, flavored products and misconceptions about relative safety. Electronic cigarette aerosols contain nicotine, propylene glycol, glycerol, flavoring chemicals, carbonyl compounds, volatile organic compounds, heavy metals and other toxicants. Current evidence indicates that vaping induces oxidative stress, endothelial dysfunction, immune dysregulation and structural injury of the respiratory tract. Clinically, electronic cigarette use is associated with electronic cigarette or vaping product use-associated lung injury, worsening of asthma, decreased lung function and adverse cardiovascular effects, including acute blood pressure and heart rate elevation, impaired flow-mediated dilation and activation of pro-thrombotic pathways. In adolescents, additional concerns relate to neurocognitive development and nicotine dependence. This narrative review summarizes contemporary data on the pulmonary, cardiovascular and immunological effects of electronic cigarettes, compares them with combustible tobacco, highlights gaps in long-term evidence and identifies the need for prospective studies of endothelial and lung injury biomarkers in young users.

Key words: electronic cigarettes, vaping, endothelial dysfunction, cardiovascular disease, lung injury, adolescents.

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ВПЛИВ ЕЛЕКТРОННИХ СИГАРЕТ НА ЕНДОТЕЛІАЛЬНУ ФУНКЦІЮ ТА КАРДІОПУЛЬМОНАЛЬНЕ ЗДОРОВ'Я У МОЛОДИХ ДОРОСЛИХ

Поширеність використання електронних сигарет швидко зростає, особливо серед підлітків та молодих дорослих, що зумовлено активним маркетингом, ароматизованими продуктами та уявленням про їхню відносну безпеку. Аерозолі електронних сигарет містять нікотин, пропіленгліколь, гліцерин, ароматизатори, карбонільні сполуки, леткі органічні речовини, важкі метали та інші токсичні речовини. Сучасні дані свідчать, що вейпінг викликає окислювальний стрес, ендотеліальну дисфункцію, імунну дисрегуляцію та ураження дихальних шляхів. Клінічно застосування електронних сигарет пов'язане з ураженням легенів, асоційованим із використанням електронних сигарет або продуктів для вейпінгу, погіршенням перебігу астми, зниженням функції легенів та несприятливими серцево-судинними ефектами. Особливе значення для підлітків мають ризики для нейрокогнітивного розвитку та формування нікотинової залежності. У огляді узагальнено сучасні дані щодо легеневих, серцево-судинних та імунологічних ефектів електронних сигарет, а також зазначено необхідність подальших проспективних досліджень.

Ключові слова: електронні сигарети, вейпінг, ендотеліальна дисфункція, серцево-судинні захворювання, ураження легенів, підлітки.

The global prevalence of electronic cigarette use has risen sharply over the past decade. The increase is especially evident among adolescents and young adults, and in several countries the prevalence of vaping among school-aged individuals exceeds that among adults [4, 12, 15].

Several factors have contributed to this expansion. Electronic cigarettes are available in disposable and refillable formats, are promoted through social media and influencer marketing, and are offered in a wide range of flavor varieties that increase their appeal to younger users [4, 12, 34]. Although these products were initially introduced as potential harm-reduction tools for adult smokers, accumulating evidence raises substantial concerns regarding their independent health effects [3, 6, 22].