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CT-BASED STUDY OF ANATOMICAL VARIATIONS IN CHRONIC RHINOSINUSITIS PATIENTS

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Abstract.

Introduction: Chronic rhinosinusitis (CRS) is frequently associated with anatomical variations that may predispose individuals to impaired sinus drainage and mucosal inflammation. Computed tomography (CT) of the paranasal sinuses provides an essential diagnostic tool for evaluating these variations.

Objective: To assess the prevalence and types of anatomical variations in patients with CRS using CT Data.

Material and Methods: A retrospective cross-sectional study was conducted on 75 patients diagnosed with CRS. CT scans were evaluated for anatomical variations including concha bullosa, deviated nasal septum, agger nasi cells, Haller cells, Onodi cells, uncinate process variations, and paradoxical middle turbinate.

Results: The most frequent variation observed was concha bullosa (64%), followed by deviated nasal septum (61.3%), agger nasi cells (49.3%), and Haller cells (32%). Onodi cells were observed in 21.3% of patients, uncinate process variations in 17.3%, and paradoxical middle turbinate in 12%.

Conclusion: Anatomical variations are common in CRS patients and can play a critical role in the pathophysiology of the disease. CT imaging is vital in identifying these variations, which can guide appropriate surgical planning.

Key words. Chronic rhinosinusitis, computer tomography, anatomical variations, maxillofacial system, odontogenic pathology, paranasal sinuses, ostiomeatal complex.

Introduction.

Chronic rhinosinusitis (CRS) is a prevalent inflammatory condition of the paranasal sinuses that persists for over 12 weeks, affecting a significant portion of the global population. Patients often experience nasal obstruction, facial pressure, nasal discharge, and reduced sense of smell. CRS is classified into CRS with nasal polyps (CRSwNP) and CRS without nasal polyps (CRSsNP) [1].

Chronic rhinosinusitis (CRS) is a common and often debilitating condition characterized by inflammation of the nasal and paranasal sinus mucosa lasting more than 12 weeks. It significantly impacts the quality of life, productivity, and healthcare costs. The etiology of CRS is multifactorial, involving infectious, allergic, environmental, and anatomical components.

Among the various contributory factors, anatomical variations of the sinonasal region have gained increasing attention due to their potential role in disrupting normal mucociliary clearance and sinus ventilation [2]. Variations such as concha bullosa, deviated nasal septum, Haller cells, and Onodi cells can narrow the ostiomeatal complex, impeding sinus drainage and predisposing to infection and chronic inflammation [3,4]. According to everything was mentioned above, the aim of our work was to assess the prevalence and types of anatomical variations in patients with CRS using CT imaging.

Materials and Methods.

The material for the study was collected at the Kharkiv Research Institute of General and Emergency Surgery and the Meref'yanska Central District Hospital (based on the concluded cooperation agreement No. 173/10 18 dated October 18, 2018, on scientific and practical collaboration).

The study was conducted using a Toshiba Aquilion Computed Tomography Scanner (Japan), a multislice CT scanner capable of simultaneously acquiring data from four slices, each 0.5 mm thick. It is known for its high-performance capabilities, including a full rotation time of up to 0.4 seconds. The device enables high-resolution multislice scanning with high throughput. For the evaluation of the paranasal sinuses, a slice thickness of 2 mm was used. The high image quality of this device is combined with a low radiation dose due to the highly efficient use of X-ray exposure.

Medical images were viewed using the Radiant DICOM VIEWER, a tool for viewing DICOM-format medical images (version PACS 4.6.9, 64-bit), which features a user-friendly interface and high performance.

The study complied with the requirements of the Declaration of Helsinki of the World Medical Association on ethical principles for medical research involving human subjects. All participants were informed about their involvement in the study and provided written informed consent. The research was approved by the Bioethics Committee of Kharkiv National Medical University (Minutes of the committee meeting No. 5, dated November 11, 2018).

High-resolution computed tomography (CT) of the paranasal sinuses is considered the gold standard imaging modality for the evaluation of CRS [5, 6]. CT imaging allows for precise identification of sinonasal anatomical structures and their variations, which is crucial for both diagnosis and surgical planning. Understanding these variations is vital, particularly in functional endoscopic sinus surgery (FESS), where detailed anatomical knowledge can help avoid complications and ensure complete disease clearance.

Anatomical variations such as concha bullosa, deviated nasal septum, and Haller cells may narrow the sinus drainage pathways, contributing to the development and chronicity of the disease. Identification of such variations through CT imaging can provide crucial insights into the etiology of CRS and help guide surgical planning. This study investigates the prevalence and types of anatomical variations in CRS patients using CT imaging. This study was conducted to analyse the prevalence of common anatomical variations in patients diagnosed with CRS using CT imaging and to explore their potential association with chronic sinus disease. By identifying the anatomical patterns contributing to CRS, the findings aim to assist clinicians in improving both diagnostic accuracy and therapeutic strategies.

The study population (n=75) demonstrated a male predominance with 54.7% males and 45.3% females. The majority of patients were between the ages of 30 and 50 years, with a mean age of 38.6 ± 9.4 years. All patients included in the study presented with clinical features suggestive of CRS, such as nasal obstruction, nasal discharge, postnasal drip, facial pain or pressure, and anosmia or hyposmia. Patient evaluation involved a comprehensive history, nasal endoscopy, and CT imaging. Inclusion Criteria:

1. Patients aged 18-60 years with symptoms of CRS lasting more than 12 weeks.
2. Availability of diagnostic CT imaging of the paranasal sinuses.

Exclusion Criteria:

1. History of sinonasal surgery.
2. Facial trauma or congenital craniofacial anomalies.
3. Fungal sinusitis or neoplasms.

The CT scans were independently reviewed by two senior radiologists and an ENT specialist. Anatomical variants were classified based on well-defined radiological criteria [7]. CT images were assessed for anatomical variations by experienced radiologists. The anatomical variations evaluated included:

1. Concha bullosa
2. Deviated nasal septum
3. Agger nasi cells
4. Haller cells
5. Onodi cells
6. Uncinate process variations
7. Paradoxical middle turbinate

To ensure objectivity, each scan was scored using the Lund-Mackay scoring system for disease severity and the presence or absence of each anatomical variation was marked bilaterally [8]. Interobserver reliability was calculated using the kappa statistic.

Statistical Analysis.

Statistical processing was performed using methods of variational statistics. The normality of distribution was assessed using the Shapiro-Wilk test. The prevalence of anatomical variants of the paranasal sinuses (PNS) and the osteomeatal complex (OMC) was calculated as the percentage ratio of the number of objects with a specific variant to the total number of examined cases [9].

The range of individual variability in the anatomical structure of the PNS and OMC was evaluated using the following statistical indicators:

1. M – arithmetic mean.
2. M(M) – standard error of the mean.
3. σ – standard deviation.
4. Cv – coefficient of variation.
5. M(Cv) – standard error of the coefficient of variation.
6. min – minimum observed value.
7. max – maximum observed value.

The sizes of those indicators were measured in millimeters using multiplanar reconstruction in coronal sections. Measurements were performed independently by two radiologists, and mean values were used for analysis to minimize interobserver variability.

To evaluate the relationship between the size of the concha bullosa and the size of the hiatus semilunaris, Pearson's correlation coefficient (r) was calculated. This method was chosen due to the continuous and approximately normally distributed nature of both variables. A two-tailed p-value < 0.05 was considered statistically significant. The statistical analysis was performed using SPSS.

Results and Discussion.

CT scan analysis revealed the presence of multiple anatomical variations in most patients. Notably, 84% of patients had more than one variation. The most common variation, concha bullosa, was seen in 48 patients (64%). Of these, 28 had unilateral concha bullosa and 20 had bilateral involvement.

Deviated nasal septum was present in 46 patients (61.3%), with 70% of the deviations causing significant narrowing of the nasal airway on one side. Agger nasi cells were observed in 49.3% of patients and were frequently associated with obstruction of the frontal recess.

The yellow arrow in the Figure 1 (left) appears to indicate a Haller cell (infraorbital ethmoid air cell). Haller cells are ethmoidal air cells that extend into the floor of the orbit and can narrow the infundibulum, potentially contributing to maxillary sinusitis. Haller cells were found in 24 patients (32%), predominantly on the right side. Onodi cells were less common (21.3%) but are clinically significant due to their proximity to the optic nerve and sphenoid sinus. Uncinate process variations and paradoxical middle turbinates were observed in 17.3% and 12% of patients respectively

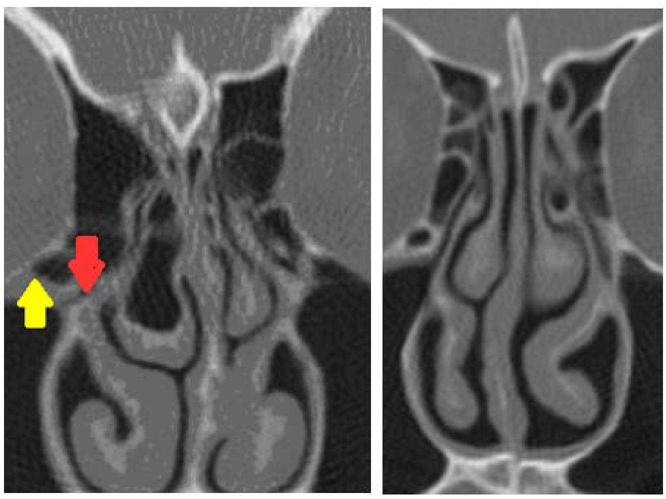

Figure 1. *Left - The yellow arrow indicates a Haller cell, while the red arrow marks the area of the ethmoidal infundibulum (uncinate process region), right - Pneumatization of the middle turbinate.*

The red arrow points to the uncinate process or a related structure near the ostiomeatal complex.

Statistical analysis revealed a strong correlation (see Figure 2) between the presence of concha bullosa and ipsilateral maxillary sinusitis ($p = 0.03$). Similarly, septal deviation showed significant association with sinus disease laterality ($p = 0.04$). Other variations showed trends toward association but did not reach statistical significance.

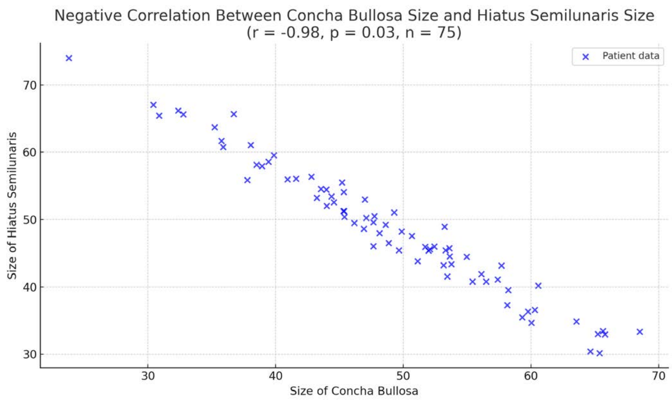

Figure 2. *Correlation between the sizes of Concha Bullosa (mm) and Hiatus Semilunaris (mm).*

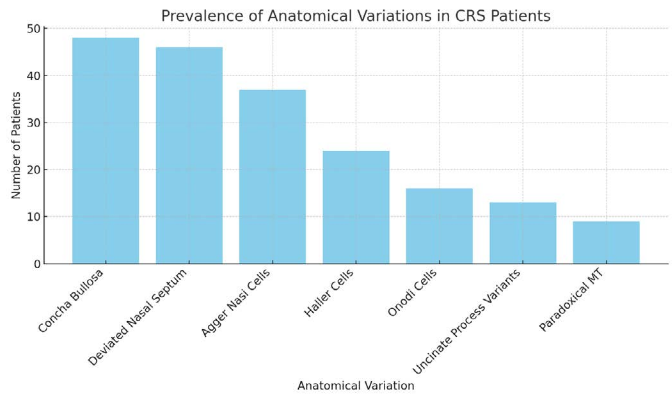

Figure 3. *Diagram representing the number of patients with various anatomical variations observed on CT imaging among CRS cases (n=75).*

Table 1. *The frequency of anatomical variations.*

Anatomical Variation	Frequency	Percentage
Concha bullosa	48	64.0%
Deviated nasal septum	46	61.3%
Agger nasi cells	37	49.3%
Haller cells	24	32.0%
Onodi cells	16	21.3%
Uncinate process variation	13	17.3%
Paradoxical middle turbinate	9	12.0%

Our findings corroborate previous research that suggests a significant role of anatomical variations in the pathogenesis of CRS. The presence of structural anomalies such as concha bullosa, septal deviation, and Haller cells can impair normal mucociliary clearance and ventilation, predisposing to chronic inflammation.

Concha bullosa, by pneumatizing the middle turbinate, may encroach upon the ostiomeatal complex, leading to impaired drainage of the maxillary, anterior ethmoid, and frontal sinuses [10]. In our study, a significant association was found between concha bullosa and ipsilateral maxillary sinusitis, underlining the functional impact of this variation.

Deviated nasal septum is another frequently encountered anomaly that can create asymmetry in nasal airflow and affect sinus drainage patterns. Our results showed a strong association with unilateral sinus disease, consistent with the current literature [11,12].

The identification of agger nasi and Haller cells is critical in preoperative planning. These cells, when prominent, may narrow the frontal recess and the infundibulum, respectively, leading to frontal or maxillary sinus involvement. Their accurate identification through CT imaging is essential to avoid intraoperative complications [13].

Onodi cells, though less common, are significant due to their anatomical proximity to the optic nerve. Misidentification or failure to recognize this variant during endoscopic surgery can result in catastrophic complications including optic nerve injury [14,15].

The study highlights the role of CT imaging not only as a diagnostic modality but also as a surgical guide [16]. A thorough understanding of sinonasal anatomy and its variations can assist in accurate diagnosis, prevent complications, and improve surgical outcomes [17].

Further research with larger patient populations and multi-center participation may help validate and generalize these findings. Correlating these variations with intraoperative and postoperative outcomes would also add value to the field [18].

CT imaging is indispensable in evaluating patients with chronic rhinosinusitis. Our study demonstrated a high prevalence of anatomical variations that may contribute to the development and chronicity of sinusitis [19-21]. The most common variations identified were concha bullosa and nasal septal deviation, both significantly associated with sinus disease.

One more aspect is connected with teeth affect the composition and distribution of the oral microbiome, and their anatomical position can have broader implications for health [22,23]. The maxillary molars and premolars, in particular, are located in close proximity to the floor of the maxillary sinus - often separated by only a thin layer of bone or, in some individuals, by the sinus membrane alone. This anatomical relationship means that infections originating in the roots of these upper teeth can easily extend into the maxillary sinus, leading to odontogenic sinusitis [24,25]. Such conditions can contribute to chronic sinus inflammation and shift the local microbial environment in both the oral cavity and the sinus itself. Additionally, tooth extraction in this region may cause sinus perforation, creating a direct pathway for microbial exchange between the oral and sinus cavities. These anatomical connections highlight how oral infections, particularly periodontitis or periapical abscesses, can transcend local boundaries and trigger broader systemic effects. Furthermore, misaligned or crowded teeth can influence salivary flow, food retention, and oxygen gradients, which in turn shape microbial habitats. Dental interventions such as orthodontics, restorations, or extractions alter these microenvironments and can shift the balance of microbial species. Understanding these relationships emphasizes the importance of comprehensive dental and periodontal care as part of systemic disease prevention [26].

Recent work has also highlighted the utility of CT-based data for not only diagnosing sinus pathologies but also for biometric recognition and evaluating of medical images [27,28]. Such approaches expand the diagnostic potential of radiologic imaging beyond classical assessment, providing novel clinical and forensic applications [29,30].

Preoperative identification of these anatomical factors using CT allows for better surgical planning and can reduce intraoperative and postoperative complications [31-33]. This study reinforces the need for personalized anatomical assessment in all patients undergoing endoscopic sinus surgery.

This study is limited by its retrospective and cross-sectional design, which restricts the ability to establish causal relationships. Additionally, the relatively small sample size may affect the generalizability of the findings. These limitations were primarily due to practical constraints. The retrospective and cross-sectional design was chosen based on the availability of existing clinical data, which allowed for an initial exploration of the research question. Additionally, resource and time limitations, as well as the study being conducted at a single center, restricted the achievable sample size. Future studies with prospective, longitudinal designs and larger, multi-center cohorts are recommended to validate and extend these findings. To address these limitations in future research, a prospective and longitudinal study design should be implemented to allow for better control of variables and to establish temporal relationships. Expanding the study across multiple centers would enhance the generalizability of the findings and help recruit a larger, more diverse sample. Conducting a power analysis in advance can ensure an adequate sample size is achieved, strengthening the statistical validity of the results. These steps would provide a more robust foundation for evaluating the studied associations and improving the reliability of conclusions.

Conclusion.

Computed tomography is an essential tool for evaluating anatomical variations in patients with chronic rhinosinusitis. This study confirms a high prevalence of structural variants — such as concha bullosa and nasal septal deviation — that may contribute to sinus obstruction and inflammation. Recognizing these variations is crucial for accurate diagnosis and effective surgical planning. Moreover, advanced imaging analysis may support broader applications, including assessing systemic influences like smoking and enabling biometric identification.

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