Bulletin of the *Transilvania* University of Braşov
Series VI: Medical Sciences • Vol. 19 (68) No. 1 – 2026
https://doi.org/10.31926/but.ms.2026.68.19.1.4

STRUCTURAL COMPLEXITY AND ANATOMICAL VARIATIONS OF THE SPHENOID SINUS: AN IMAGING STUDY

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Abstract: *Due to its anatomical relationships with adjacent vascular and neural structures, the sphenoid sinus is of major importance in transsphenoidal surgical approaches. The extensive anatomical variations of the sphenoid sinus make its imaging evaluation highly valuable for selecting the surgical technique, as well as for preventing intra- and postoperative complications. This study aims to evaluate the anatomical complexity of the sphenoid sinus using Computed Tomography (CT), achieving objectives such as: assessing the dimensions of the sphenoid sinus in relation to age-related characteristics, identifying morphological variations and the presence of intrasinus septa on CT slices, and analyzing the sinus extensions (recesses) and their degree of extension.*

Key words: *sphenoid sinus, anatomical variations, computer tomography*

1. Introduction

The central position of the sphenoid sinus and its anatomical relationships with the pituitary gland, cavernous sinuses, nasal cavities, and the pharyngeal vault confer upon it significant anatomical and clinical importance [10].

The sphenoid sinus exhibits the highest rate of anatomical variations compared to other sinuses in the human body. This increased anatomical variability is due to the different patterns of sphenoid sinus pneumatization [9].

The development of the sphenoid sinus begins concurrently with that of the nasal cavity, between weeks (W) 4 and 8 of intrauterine life. During W4-5, the nasal placodes appear, and in W5-6, the nasal pits, nasal sacs, and primitive choanae develop. In W12, the sphenoid sinus emerges as mucosal evaginations from the posterior ethmoidal cells invade the body of the sphenoid bone. At birth, the sinus is a rudiment of approximately 2 mm filled with connective tissue, making it radiologically invisible [5].

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The pneumatization process of the sphenoid sinus begins postnatally. At birth, the body of the sphenoid bone contains red bone marrow, which subsequently converts to yellow marrow between the ages of seven months and two years. These changes mark the onset of the pneumatization process. Pneumatization can commence before the age of two, and sphenoid sinus maturation may be reached around 14 years of age [4]. In 1961, Hammer and Radberg classified sphenoid sinus variations into three patterns: conchal, presellar, and sellar [2]. The study by [7] presents four types of sphenoid sinuses: A, B, C, and D. Type A - conchal, Type B - presellar, Type C - incomplete sellar, Type D - complete sellar. The presence of various septation patterns and their high variability pose a risk during endoscopic sinus surgery [3].

Computed tomography (CT) is one of the optimal methods for documenting and analyzing anatomical variations due to its accurate representation of bone structures [6].

Preoperative evaluation of the sphenoid sinus to identify the pneumatization pattern is necessary in endoscopic approaches to skull base structures, in order to facilitate surgical access and avoid complications such as injury to adjacent structures [1].

Patients may present with various clinical manifestations, such as headaches, nasal discharge, or non-specific symptoms. Potential complications of sphenoid sinusitis can range from mucoceles to skull base or cavernous sinus involvement, or cranial neuropathy, although these are rare. Additionally, primary or adjacent tumors invading the sphenoid sinus are uncommon [8].

2. Research Aim and Objectives

Despite major advancements in the field of medical imaging, the anatomical variability of the sphenoid sinus remains a challenge for both radiologists and surgeons. This study aims to evaluate and analyze the sphenoid sinus on CT scans, focusing on its dimensions in relation to age, its morphological features, and its internal structure concerning the presence of septa and sinus extensions (recesses).

3. Materials and Methods

A prospective observational study was conducted over a one-month period in 2025, comprising a total of 31 cases.

Inclusion criteria:

- Patients selected by the attending specialist for a CT examination, following a specialized consultation for symptoms suggestive of sphenoid sinus pathology.

Non-contrast CT examinations, performed using General Electric and Siemens Somatom Emotion 16 CT scanners, were analyzed using a bone window setting for the visualization of the paranasal sinuses.

Database creation and statistical data processing were performed using Microsoft Excel.

4. Results and Discussion

Following the statistical analysis of the study cohort (Figure 1), we observed a higher proportion of female patients (58%) presenting to the specialist with sphenoid sinus-specific symptoms and subsequently undergoing CT evaluation, compared to male patients (42%).

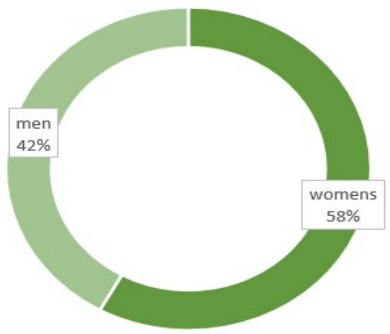

Fig. 1. *Distribution of the study cohort by patient sex*

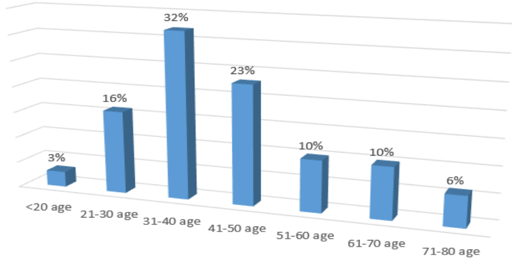

Fig. 2. *Distribution of subjects by age group*

Analyzing the age distribution of the subjects (Figure 2), we observed the highest incidence (32%) in the 31-40 age group, followed by the 41-50 age group (23%) and the 21-30 age group (16%), in contrast to a significantly lower incidence in the 71-80 (6%) and under 20 (3%) age groups.

In the study cohort, we observed a female predominance (58%) and a peak incidence in the fourth decade of life (31-40 years), accounting for 32%.

Following the analysis of the measured anteroposterior (AP), craniocaudal (CC), and transverse (T) diameters of the sphenoid sinus and their stratification into size ranges, we observed that most AP diameters (36%, Figure 3) range between 31 and 35 mm, the majority of CC diameters (45%, Figure 4) are between 21 and 25 mm, and most T diameters (45%, Figure 5) measure under 40 mm.

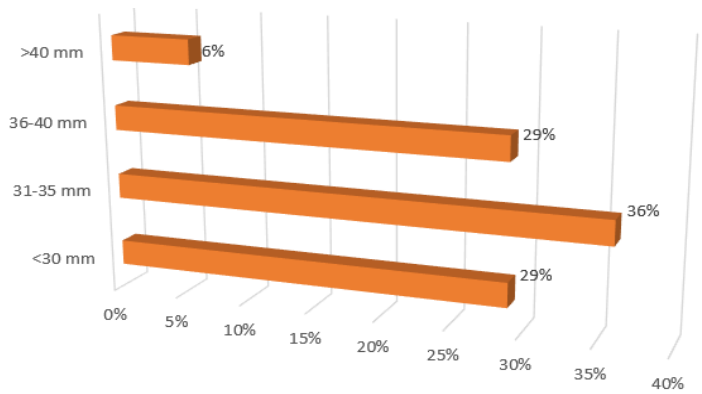

Fig. 3. *Distribution of cases by AP diameter size*

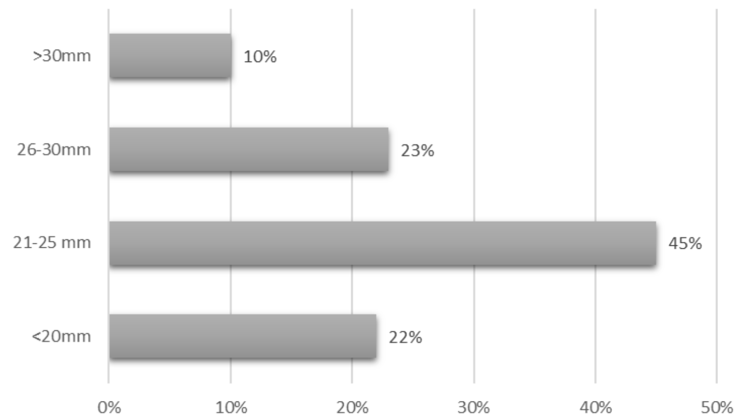

Fig. 4. *Distribution of cases by CC diameter size*

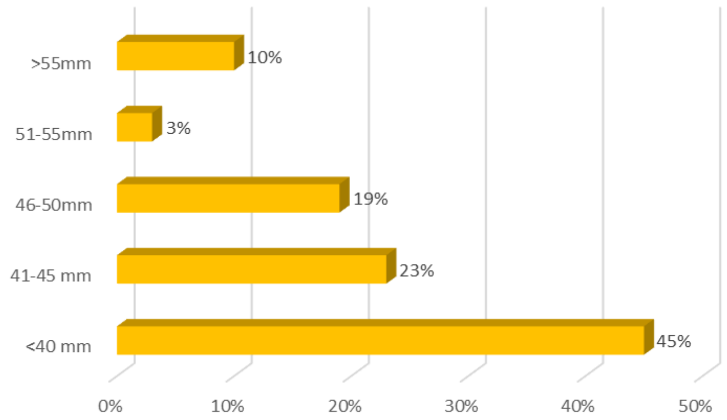

Fig. 5. *Distribution of cases by T diameter size*

The majority of the analyzed sinuses exhibit optimal pneumatization, with average dimensions of 31-35 mm (AP), <40 mm (T), and 21-25 mm (CC). The T diameter exhibits the greatest variation compared to the other diameters.

Evaluating the presence, number, orientation, and morphology of the septa, we found a single septum in the majority of cases (52%), and an absent septum in 6% of cases (Figure 6). When septa are present, the complete septum is the most frequently encountered (64%, Figure 7), and over 50% of the existing septa are deviated to the right (Figure 8). Regarding septal symmetry, 60% are asymmetrically distributed (Figure 9).

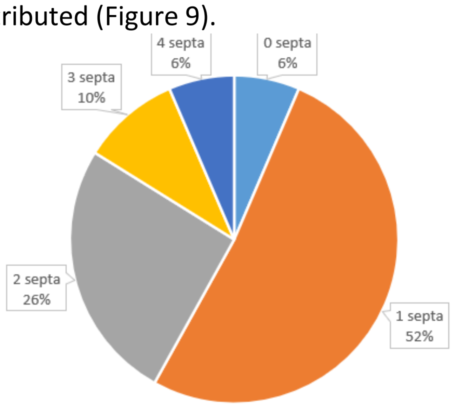

Fig. 6. *Distribution of cases by number of septa*

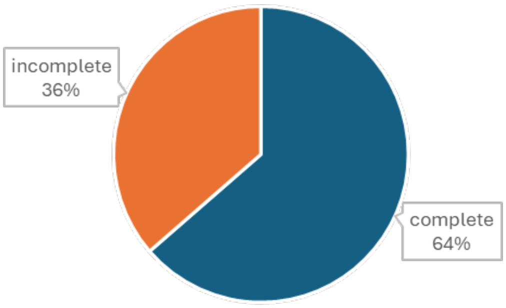

Fig. 7. *Distribution of cases by septal morphology*

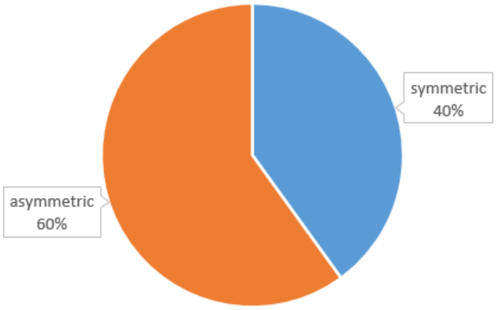

Fig. 8. *Distribution of cases by septal symmetry*

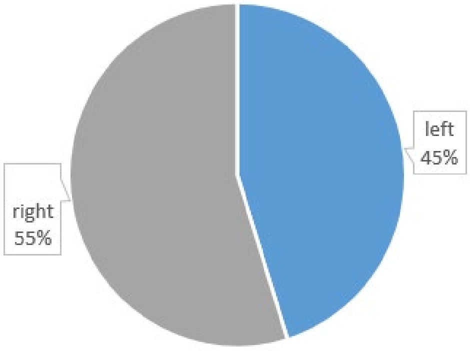

Fig. 9. *Distribution of cases by septal orientation*

Fig. 10. *Axial CT slice of the sphenoid sinus, bone window, demonstrating two septa (one complete and one incomplete), asymmetric – a representative image for the majority of the evaluated cases*

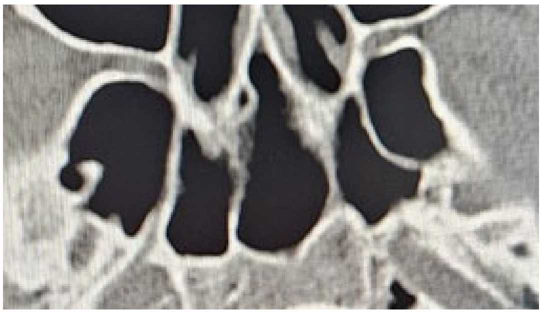

Fig. 11. *Axial CT slice of the sphenoid sinus, bone window, demonstrating a multiseptate sinus with four complete septa and one incomplete septum*

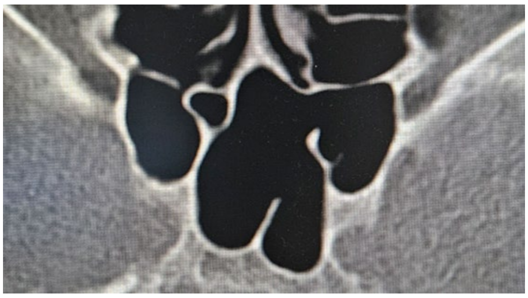

Fig. 12. *Axial CT slice of the sphenoid sinus, bone window, demonstrating multiple septa: one complete septum deviated to the right and two incomplete, asymmetric septa deviated to the left*

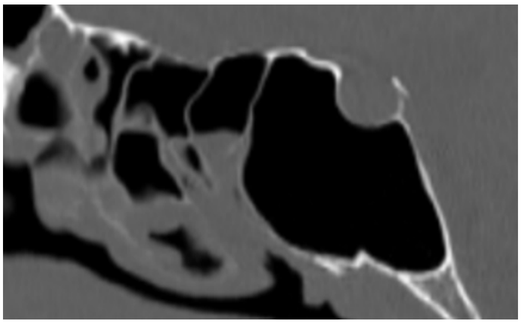

Fig. 13. *Sagittal CT slice of the sphenoid sinus, bone window, demonstrating the absence of septa*

Following the analysis of the presence and number of sinus recesses (Figure 13), we observed that they are most frequently absent (39% of cases). In 22% of cases, the sphenoid sinus exhibits a single recess, 16% exhibit two recesses, 13% present three recesses, and 10% present four recesses.

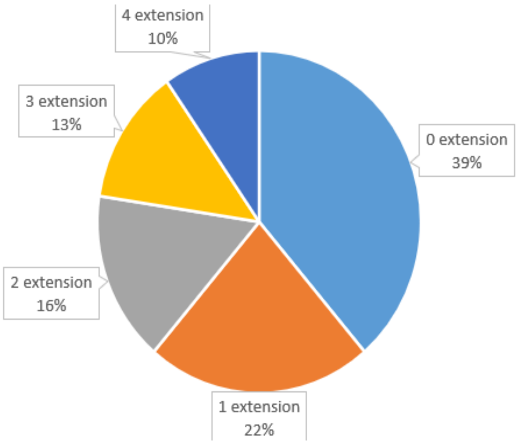

Fig. 14. *Distribution of cases by the presence and number of recesses*

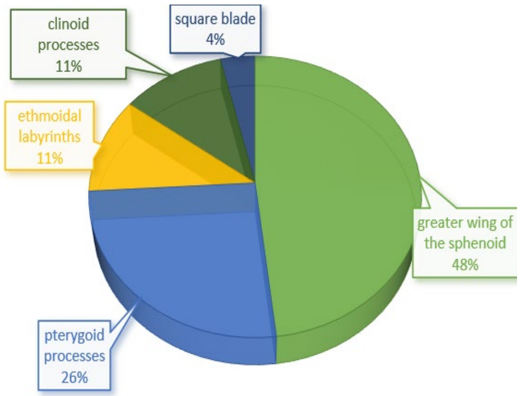

Fig. 15. *Distribution of cases by recess topography*

Following the evaluation of recess topography (Figure 14), we observed a higher incidence for the greater wing of the sphenoid (48%), followed by the pterygoid processes (26%), while the lowest incidence was recorded for the dorsum sellae (4%).

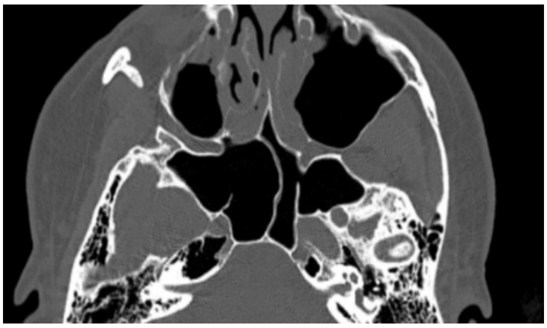

Fig. 16. *Axial CT slice of the sphenoid sinus, bone window, demonstrating a recess extending into the greater wing of the sphenoid*

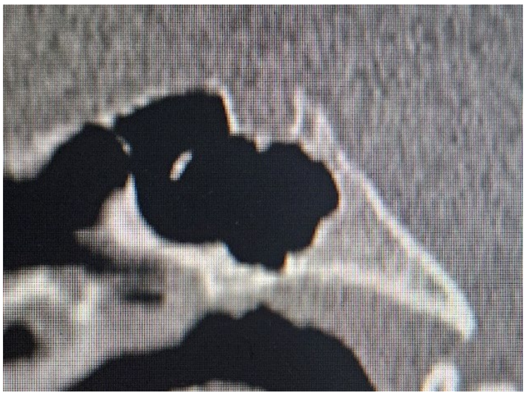

Fig. 17. *Sagittal CT slice of the sphenoid sinus, bone window, demonstrating a recess extending into the dorsum sellae*

Following the statistical analysis of the correlation between the dimensions of the AP, CC, and T diameters and the sex of the subjects in the study cohort, the following results were obtained:

–**AP diameter – sex correlation:** *p*-value = 0.03, $p < 0.05$ => statistically significant

–**CC diameter – sex correlation:** *p*-value = 0.02, $p < 0.05$ => statistically significant

–**T diameter – sex correlation:** *p*-value = 0.22, $p > 0.05$ => not statistically significant

Although the transverse diameter recorded higher mean values in males, the difference did not reach the threshold of statistical significance ($p = 0.223$). However, a significant sexual dimorphism is evident in the anteroposterior and craniocaudal diameters, both being larger in males.

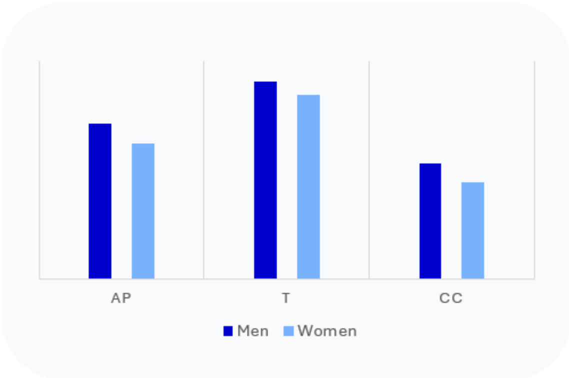

Fig. 18. *Sexual dimorphism of sphenoid sinus dimensions*

Table 1

Correlation of AP, CC, and T diameters with subject age

ANALYZED PARAMETER	PEARSON CORRELATION COEFFICIENT (r)
age- AP diameter	-0,23
age- T diameter	-0,21
age- CC diameter	0,06

Following the statistical evaluation and the correlation of the AP, CC, and T diameters with the age of the subjects, the following results were obtained:

- **Age - AP (-0.23) and Age - T (-0.21)**: an extremely weak negative correlation (non-significant)
- **Age - CC (0.06)**: a value of practically zero – there is absolutely no relationship

Table 2

Correlation of the AP, CC, and T diameters with sphenoid sinus recesses between age and sinus height

ANALYZED PARAMETER	Value p
extensions - diameter AP	**0,71**
extensions - diameter T	**0,51**
extensions - diameter CC	**2,04**

Regarding the correlation of the AP, CC, and T diameters with the sphenoid sinus recesses, the obtained statistical *p*-values were > 0.05 => not statistically significant.

Table 3

Correlation of the AP, CC, and T diameters with sphenoid sinus septa

ANALYZED PARAMETER	PEARSON CORRELATION COEFFICIENT (r)
septa- AP diameter	**0,18**
septa- diameter T	**-0,06**
septa- diameter CC	**0,15**

5. Particular Case

A case in which the sphenoid sinus can only be visualized on the right side, presenting a recess extending into the greater wing of the sphenoid, and being septated. The left side is occupied by a very large ethmoid cell communicating with the left nasal fossa, separated from the sphenoid sinus by a thick bony wall. Figures 18, 19, and 20 demonstrate the craniocaudal progression on axial CT slices, bone window.

Fig. 19. *Axial CT slice, bone window, demonstrating a particular case in which the left sphenoid sinus is occupied by a very large ethmoid cell*

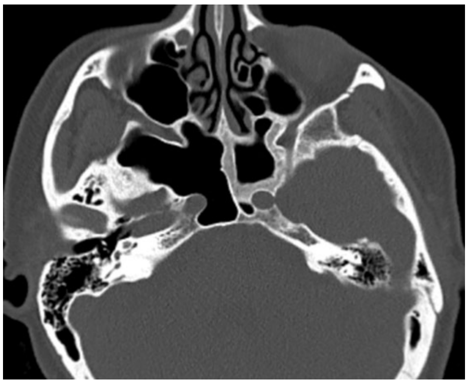

Fig. 20. *Axial CT slice, bone window, demonstrating a particular case in which the left sphenoid sinus is occupied by a very large ethmoid cell*

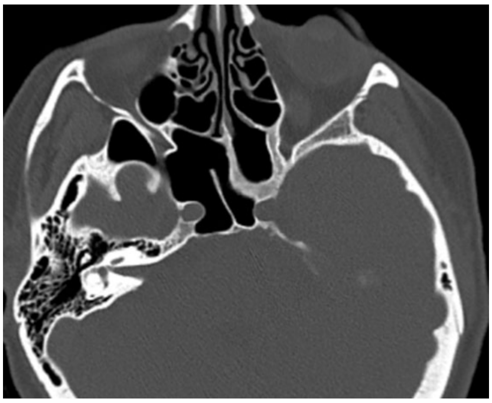

Fig. 21. *Axial CT slice, bone window, demonstrating a particular case in which the left sphenoid sinus is occupied by a very large ethmoid cell*

6. Conclusions

Females comprised the majority of the study cohort.

The highest incidence of suggestive sphenoid sinus pathology was found in the 31–40 age group.

In most cases, a complete, asymmetric septum deviated to the right is encountered.

The majority of cases present recesses; most frequently, a single recess is exhibited, with the most common localization being the greater wing of the sphenoid bilaterally.

Significant sexual dimorphism is present in the anteroposterior and craniocaudal diameters, both being larger in males.

Sphenoid sinus dimensions do not change significantly with advancing age.

The size of the sphenoid sinus (on any of its three axes: AP, T, or CC) has no influence on the formation of recesses.

There is no linear correlation between sphenoid sinus size and the complexity of its septation.

The developmental process of the recesses and septa is completely independent of the baseline volume of the sinus cavity itself.

Particular cases also exist, such as the replacement of the sphenoid sinus by an ethmoid cell.

CT examination remains the preferred method for the imaging assessment of the sphenoid sinus.

Author Contributions:

Conceptualization: GS, MAT; data collection: GS, MAT; data analysis and/or interpretation: GS, MAT; writing – original draft preparation: GS, MAT; writing – review and editing: GS, MAT.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest regarding the publication of this paper.

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