Anatomical Variations in Transsphenoidal Surgery: Septal Deviations, Protrusions, and Dehiscence

Hamza Kasar[1], Murat İnci[2], Mehmet Selçuk[3], Zeliha Fazlıoğulları[4] and Halil Özer[5]

[1] Independent Researcher, Konya, Türkiye;
[2] First and Emergency Aid Program, Department of Medical Services and Techniques, Ermenek Uysal and Hasan Kalan Vocational School of Health Services, Karamanoglu Mehmetbey University, Karaman, Türkiye;
[3] Department of Anatomy, Faculty of Medicine, Nigde Ömer Halisdemir University, Niğde, Türkiye;
[4] Department of Anatomy, Faculty of Medicine, Selcuk University, Konya, Türkiye;
[5] Department of Radiology, Faculty of Medicine, Selcuk University, Konya, Türkiye

CORRESPONDING AUTHOR Mehmet Selcuk, Department of Anatomy, Faculty of Medicine, Niğde Ömer Halisdemir University, 51240, Niğde, Türkiye. fizyomehmetselcuk@gmail.com

RECEIVED March 30, 2026
ACCEPTED June 29, 2026

DOI 10.20471/acc.2026.65.03.09

SUMMARY

This retrospective study aimed to investigate sphenoid sinus (SS) pneumatization types, variations in adjacent structures, and the relationship between nasal septal deviation (NSD) and SS morphology. Computed tomography (CT) images of the paranasal sinuses of 300 patients were examined. Sagittal and coronal SS pneumatization types, the protrusion and dehiscence of the carotid canal (CC), optic canal (OC), foramen rotundum (FR), and Vidian canal (VC), the presence of NSD, and SS septa were evaluated. The most common sagittal pneumatization was the postsellar type (60.3%). As the degree of SS pneumatization increased, the rates of protrusion and dehiscence of the adjacent neurovascular structures increased significantly ($P < 0.05$). Vidian canal protrusion and dehiscence were the most frequently observed variations. A total of 57.2% of all SS were more suitable for surgery due to a wide surgical window and low protrusion/dehiscence ratio. There was no relationship between SS morphology and NSD requiring septoplasty during surgery. As SS pneumatization increased, so did the risk of iatrogenic damage to adjacent structures, despite the increased surgical window. These findings once again highlighted the vital importance of detailed CT evaluation prior to transsphenoidal surgery for patient safety.

KEYWORDS

Computed tomography; Dehiscence; Protrusion; Sphenoid sinus; Septal deviation

Introduction

The sphenoid sinus (SS) is of great surgical importance in the fields of otolaryngology and neurosurgery due to its anatomical location and close relationship with surrounding vital structures[1,2]. It is the least accessible of the paranasal sinuses and exhibits considerable variation in size and shape[3-5]. This variability can pose significant risks in the planning and execution of surgical procedures, such as endoscopic sinus surgery and transsphenoidal approaches[6-8].

As the degree of SS pneumatization increases, structures such as the optic canal (OC), carotid canal (CC), Vidian canal (VC), and foramen rotundum (FR) protrude into the sinus cavity or may show dehiscence (bone lamina thinning or defect)[9-11]. This situation significantly increases the risk of iatrogenic injury to the structures passing through during surgery[12,13].

Nasal septum deviation (NSD) is a common anatomical variation that affects nasal physiology and airway flow, and has been frequently associated with sinus diseases[14,15]. Studies suggest that NSD may affect SS pneumatization patterns and symmetry[7,14,16,17]. Particularly when bony septa within the SS adhere to vital structures such as the CC or OC, septum removal can cause serious damage to these structures[6,18-20].

Although SS pneumatization and septal adhesions have been studied in the literature, there is limited research systematically evaluating the relationship between NSD and SS morphology. The aim of this study was to evaluate the types of pneumatization of SS and its adjacent neurovascular structures, and to investigate the relationship between them and NSD.

Materials and methods

The study was initiated with the approval of the Non-Interventional Clinical Research Ethics Committee of the Faculty of Medicine of Selçuk University, dated 29 July, 2025 (approval number: 2025/457). All procedures involving human participants were conducted in accordance with the ethical standards of the institutional and/or regional research ethics committee(s) and with the principles of the Declaration of Helsinki (1975), as revised in 1983. The CT images of the paranasal sinuses obtained in the first half of 2025 and stored in the PACS (Picture Archiving and Communication Systems) archive of the Department of Radiology at the university were retrospectively examined. This study was retrospective in design and based on the anonymous evaluation of existing imaging data; therefore, a procedure-specific informed consent from patients was not required, as determined by the Ethics Committee.

Sample study

The G*Power (version 3.1.9.2) software was used to calculate the sample size. In a study by Şimşek and İşlek[5], Cohen's h value was reported as 0.282 in the chi-square test comparing the protrusion rate of the right CC in sex-based groups. With an α error of 0.05, a power (1-β) of 0.90, and Df:1, we calculated that 133 images per group and at least 266 CT images for both sexes would be sufficient. Accordingly, images from 300 patients (150 women, 150 men) aged 18 to 80 years without previous trauma, sinus surgery, maxillofacial deformity, intracranial masses, or image artifacts were evaluated. Twenty-four patients with image artifacts and chronic severe sinusitis, who had undergone rhinoplasty and/or septal deviation surgery (septoplasty), and patients with sinonasal tumors that could interfere with the evaluation were excluded from the study. All images were reviewed by an experienced radiologist and anatomist to reach a consensus.

Imaging protocol

All images were acquired using a 256 multislice CT device (Siemens Somatom Flash, Erlangen, Germany) with the following study parameters: kV = 120; mA = 160; rotation time = 0.5 s; collimation = 64 × 0.625; FOV = 220 mm. All CT images were analyzed in the axial, sagittal, and coronal planes using a Syngo Via (Siemens, Germany) workstation. Pneumatization classifications in the coronal plane and variations in OC, FR, VC, and CC were recorded in the right and left halves of each SS (600 sinus halves).

Pneumatization classification

The location of sagittal sphenoid sinus pneumatization (SSSP) relative to the anterior and posterior walls of the sella turcica in the sagittal plane is classified into four types in the literature[1,3-5,14,21,22] (Figure 1):

- Conchal type: SS is a small cavity in front of the anterior wall of the sella turcica;
- Presellar type: The posterior wall of SS is adjacent to the anterior wall of the sella turcica and does not extend posteriorly;
- Sellar type: The posterior wall of SS is located between the anterior and posterior walls of the sella turcica;
- Postsellar type: The posterior wall of SS is located behind the posterior wall of the sella turcica.

According to Açar et al.[3], who provided a more comprehensive classification in the literature, coronal plane sphenoid sinus pneumatization (CSSP) is divided into six types according to the pneumatization status in the direction of the pterygoid process (PP), anterior clinoid process (ACP) and greater wing of the sphenoid (GWS) (Figure 2):

- Type 1: No abnormal pneumatization in the direction of ACP, PP, and GWS;

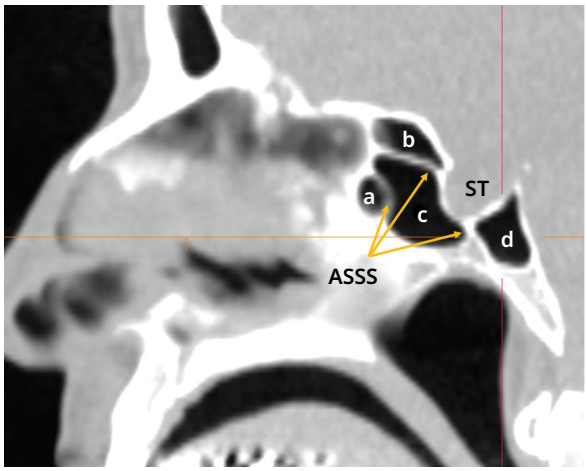


Fig. 1. On a sagittal CT, accessory sphenoid sinus septa (ASSS) divide the sphenoid sinus into four compartments. The conchal (**a**), presellar (**b**), sellar (**b**,**c**), and postsellar (**b**,**c**,**d**) regions are pneumatized. ST = sella turcica

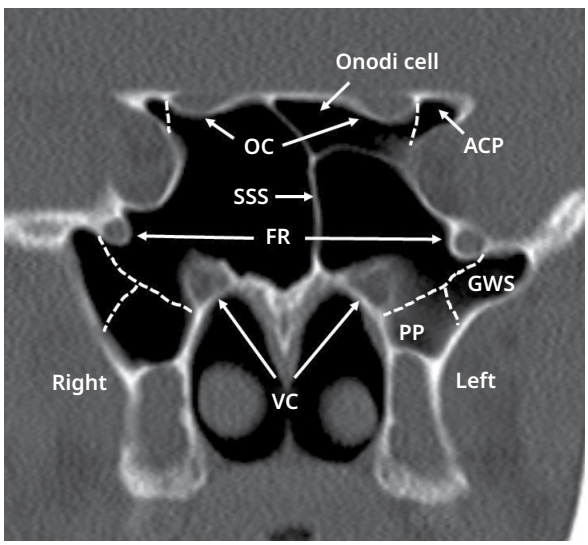


Fig. 2. On a coronal CT, the bilateral anterior clinoid process (ACP), pterygoid process (PP), and greater wing of the sphenoid (GWS) pneumatized (CSSP Type 6). Dashed lines indicate Type 1 borders. Bilateral protrusion of the optic canal (OC), vidian canals (VC), and foramen rotundum (FR). Bilateral VC and right FR dehiscence.

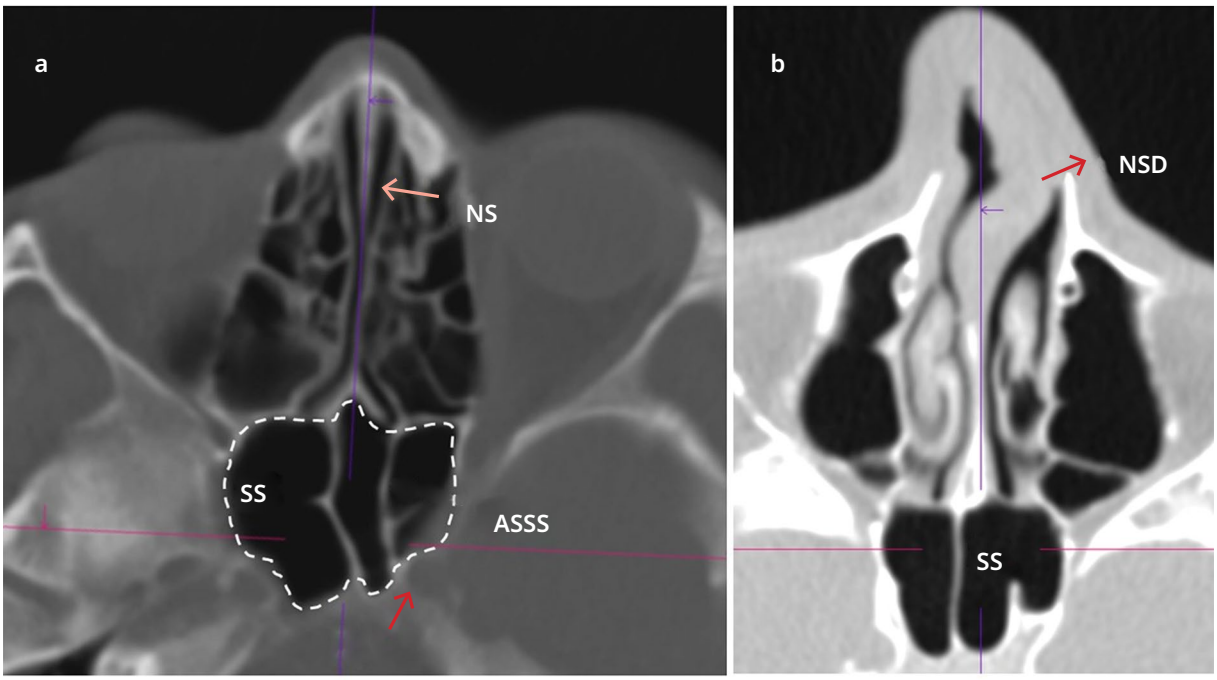


Fig. 3. Axial CT images. a: Accessory sphenoid sinus septum (ASSS) connected to the left carotid canal (CC) (red arrow). b: Left nasal septum deviation (NSD). SS sphenoid sinus, NS nasal septum

- Type 2: Only pneumatization of GWS, with SS passing laterally to FR;
- Type 3: Only pneumatization of PP, with SS descending below VC;
- Type 4: Only pneumatization of ACP;
- Type 5: Both GWS and PP are pneumatized;
- Type 6: Pneumatization of GWS, PP, and ACP.

Adjacent and septal structures

The protrusion and dehiscence of the vital structures adjacent to SS, namely CC, OC, FR, and VC, were recorded as present/absent (Figure 2).

The symmetry of the septum within SS and the presence of an accessory sphenoid sinus septum (ASSS) were examined. In particular, the adhesion of the septa to the CC (dangerous sphenoid septum) within SS was noted. For septa that are completely separated from a line drawn through the mid-sagittal plane using imaging tools, a diagnosis of septal deviation was made. The midsagittal plane was defined using the crista galli and the internal occipital protuberance as landmarks (Figure 3). The presence of Onodi cells (sphenoid-ethmoidal cells) was examined and recorded (Figure 2).

Statistical analysis

The data were analyzed using SPSS software version 22 (IBM SPSS Inc., Chicago, IL, USA). Categorical variables such as sex, age groups, and side were presented as numbers and percentages.

Age was the only continuous variable and was considered to have a normal distribution based on the Shapiro–Wilk test results, and because the skewness and kurtosis values were between –1.5

and +1.5. The mean ± standard deviation (SD) and minimum-maximum values were reported, and comparisons between sexes were performed using the independent samples t-test. In the analysis of categorical variables, Pearson's chi-square test was used to examine relationships between groups, the Friedman test for right-left comparisons of CSSP types, and the McNemar test for right-left comparisons of protrusion and dehiscence. The correlation of structures was evaluated using the Spearman correlation coefficient. A statistical significance level of $P < 0.05$ was accepted in all tests.

Results

The mean age of individuals was 36.88 ± 14.64 (min. 18, max. 80), and the age of the female patients (38.81 ± 15.53) was significantly higher than that of the male patients (34.96 ± 13.49) ($P < 0.05$). Findings regarding pneumatization, protrusion, dehiscence, septum, and age groups in individuals are presented below under the appropriate headings.

Sagittal and coronal sphenoid sinus pneumatization

The most common type of SSSP was the postsellar type, seen in 181 individuals (60.3%), while the least common was the conchal type, detected in only 1 female patient (0.3%). Among CSSP types, the most common on both the left and right side was Type 1, in which there was no pneumatization between adjacent structures. The least common was Type 2, in which the greater sphenoid wings were pneumatized. The prevalence of SSSP and CSSP types did not show a significant difference between sexes ($P > 0.05$) (Table 1). The prevalence of CSSP types did not show a significant difference between the right and left side ($P = 0.180$) either.

Protrusion and dehiscence of adjacent structures

Protrusion of CC, the most important of the adjacent vital structures, was quite common — found in at least one side in 66.3% of the patients. Dehiscence, on the other hand, was relatively lower: found in at least one side in 31% of the patients. Similarly, OC protrusion was present in 54.7% of the sinuses and OC dehiscence in 31.7%, FR protrusion in 53% and FR dehiscence in 29.7%, and finally, VC protrusion in 76.7% and VC dehiscence in 56.3%, making VC the structure that extended most into the SS. The protrusion and dehiscence rates of the structures did not show significant differences between sexes ($P > 0.05$) (Table 1).

In the comparison of prevalence between sides; CC protrusion ($P = 0.710$), OC protrusion ($P = 0.870$) and OC dehiscence ($P = 0.470$), FR dehiscence ($P = 0.401$), and VC protrusion ($P = 0.136$) and VC dehiscence ($P = 0.665$) showed no significant differences. However, CC dehiscence ($P = 0.006$) and FR protrusion ($P = 0.003$) were significantly more prevalent on the left side than on the right side.

The relationship between sagittal and coronal sphenoid sinus pneumatization types and adjacent structures

We determined that SSSP types have a significant effect on GWS, PP, and ACP pneumatization, and that the rates of protrusion and dehiscence in all structures adjacent to SS showed significant differences in SSSP types ($P < 0.05$) (Table 2).

There was a strong relationship between SSSP and CSSP types ($P < 0.05$) (Table 2). Individuals with the postsellar type showed the highest prevalence of CSSP Types 5 and 6 on both sides compared to the presellar and sellar types.

Among the CSSP types determined according to the pneumaticity status of GWS, PP, and ACP, the

Table 1. Comparison of sagittal and coronal sphenoid sinus pneumatization types, protrusion, and dehiscence of adjacent structures between female and male patients

		All cases		Female		Male		*P*
		n=300	%	n=150	%	n=150	%	
Nasal septum deviation	Absent	235	**78.33**	129	**86.00**	106	**70.67**	0.002*
	Right	34	**11.33**	14	**9.33**	20	**13.33**	
	Left	31	**10.33**	7	**4.67**	24	**16.00**	
Sphenoid sinus septum deviation	Absent	170	**56.67**	87	**58.00**	83	**55.33**	0.354
	Right	76	**25.33**	33	**22.00**	43	**28.67**	
	Left	54	**18.00**	30	**20.00**	24	**16.00**	
Accessory sphenoid sinus septum	Absent	222	**74.00**	109	**72.67**	113	**75.33**	0.743
	Only right	31	**10.33**	18	**12.00**	13	**8.67**	
	Only left	35	**11.67**	18	**12.00**	17	**11.33**	
	Bilateral	12	**4.00**	5	**3.33**	7	**4.67**	
Sphenoid sinus septum carotid canal connection	Absent	200	**66.67**	105	**70.00**	95	**63.33**	0.187
	Right	52	**17.33**	20	**13.33**	32	**21.33**	
	Left	48	**16.00**	25	**16.67**	23	**15.33**	
Sagittal sphenoid sinus pneumatization	Conchal	1	**0.33**	1	**0.67**	NA	**NA**	0.287
	Presellar	37	**12.33**	20	**13.33**	17	**11.33**	
	Sellar	81	**27.00**	34	**22.67**	47	**31.33**	
	Postsellar	181	**60.33**	95	**63.33**	86	**57.33**	
Onodi cell	Absent	166	**55.33**	81	**54.00**	85	**56.67**	0.657
	Only right	41	**13.67**	20	**13.33**	21	**14.00**	
	Only left	50	**16.67**	29	**19.33**	21	**14.00**	
	Bilateral	43	**14.33**	20	**13.33**	23	**15.33**	
Right coronal sphenoid sinus pneumatization	Type 1	142	**47.33**	67	**44.67**	75	**50.00**	0.735
	Type 2	10	**3.33**	5	**3.33**	5	**3.33**	
	Type 3	32	**10.67**	17	**11.33**	15	**10.00**	
	Type 4	21	**7.00**	10	**6.67**	11	**7.33**	
	Type 5	39	**13.00**	24	**16.00**	15	**10.00**	
	Type 6	56	**18.67**	27	**18.00**	29	**19.33**	

Table 1. [continued]

		All cases		Female		Male		*P*
		n=300	%	n=150	%	n=150	%	
Left coronal sphenoid sinus pneumatization	Type 1	136	**45.33**	62	**41.33**	74	**49.33**	0.236
	Type 2	11	**3.67**	6	**4.00**	5	**3.33**	
	Type 3	48	**16.00**	25	**16.67**	23	**15.33**	
	Type 4	14	**4.67**	4	**2.67**	10	**6.67**	
	Type 5	52	**17.33**	32	**21.33**	20	**13.33**	
	Type 6	39	**13.00**	21	**14.00**	18	**12.00**	
Carotid canal protrusion	Absent	101	**33.67**	51	**34.00**	50	**33.33**	0.978
	Only right	13	**4.33**	4	**2.67**	9	**6.00**	
	Only left	16	**5.33**	10	**6.67**	6	**4.00**	
	Bilateral	170	**56.67**	85	**56.67**	85	**56.67**	
Carotid canal dehiscence	Absent	207	**69.00**	97	**64.67**	110	**73.33**	0,121
	Only right	18	**6.00**	12	**8.00**	6	**4.00**	
	Only left	40	**13.33**	24	**16.00**	16	**10.67**	
	Bilateral	35	**11.67**	17	**11.33**	18	**12.00**	
Optic canal protrusion	Absent	136	**45.33**	71	**47.33**	65	**43.33**	0.123
	Only right	10	**3.33**	8	**5.33**	2	**1.33**	
	Only left	8	**2.67**	6	**4.00**	2	**1.33**	
	Bilateral	146	**48.67**	65	**43.33**	81	**54.00**	
Optic canal dehiscence	Absent	205	**68.33**	104	**69.33**	101	**67.33**	0.049
	Only right	27	**9.00**	15	**10.00**	12	**8.00**	
	Only left	21	**7.00**	11	**7.33**	5	**3.33**	
	Bilateral	47	**15.67**	20	**13.33**	27	**18.00**	
Foramen rotundum protrusion	Absent	141	**47.00**	66	**44.00**	75	**50.00**	0.531
	Only right	11	**3.67**	5	**3.33**	6	**4.00**	
	Only left	31	**10.33**	16	**10.67**	15	**10.00**	
	Bilateral	117	**39.00**	63	**42.00**	54	**36.00**	

Table 1. [continued]

		All cases		Female		Male		*P*
		n=300	%	n=150	%	n=150	%	
Foramen rotundum dehiscence	Absent	211	**70.33**	104	**69.33**	107	**71.33**	0.785
	Only right	29	**9.67**	13	**8.67**	16	**10.67**	
	Only left	22	**7.33**	12	**8.00**	10	**6.67**	
	Bilateral	38	**12.67**	21	**14.00**	17	**11.33**	
Vidian canal protrusion	Absent	70	**23.33**	37	**24.67**	33	**22.00**	0.861
	Only right	17	**5.67**	9	**6.00**	8	**5.33**	
	Only left	28	**9.33**	13	**8.67**	15	**10.00**	
	Bilateral	185	**61.67**	91	**60.67**	94	**62.67**	
Vidian canal dehiscence	Absent	131	**43.67**	63	**42.00**	68	**45.33**	0.712
	Only right	22	**7.33**	8	**5.33**	14	**9.33**	
	Only left	26	**8.67**	15	**10.00**	11	**7.33**	
	Bilateral	121	**40.33**	64	**42.67**	57	**38.00**	

*Statistically significant, chi-square test (significance level $P < 0.05$)

protrusion and dehiscence rates of all structures adjacent to the SS differed ($P<0.05$). When different regions of the sphenoid bone became pneumatized, representing an expansion in the extent of sinus pneumatization, the protrusion and dehiscence of adjacent structures into the sinus also increased.

Nasal septum, sphenoid septa, and Onodi cells

Nasal septal deviation was present in 21.7% of all samples and was significantly less common in women (14%) than in men (29.3%) ($P = 0.002$) (Table 1). However, there was no significant difference based on the side of septal deviation ($P = 0.710$). Deviations were in one direction only; no S-shaped deviations were observed.

In total, SS septal deviation was found in 43.3% of the patients, ASSS presence in 26%, the connection of SS internal septa with CC in 30.3%, and Onodi cells in 44.7%, with no significant difference in prevalence between sexes ($P > 0.05$) (Table 1). Although SS septal deviation was more common on the right side (25.3%) than on the left side (18%), this difference was not statistically significant ($P = 0.054$). No significant differences were observed between the sides in terms of ASSS prevalence ($P = 0.622$), the rates of septal connections with the CC within the SS ($P = 0.689$), nor the presence of Onodi cells ($P = 0.345$).

The presence and direction of NSD were not found to be associated with SS septal deviation and CC connection, the presence of an accessory SS septum, nor SSSP and CSSP types ($P < 0.05$).

Table 2. Relationship between sagittal sphenoid sinus pneumatization types, coronal pneumatization, and adjacent structures

		Presellar		Sellar		Postsellar		*P*
		n	%	n	%	n	%	
CC protrusion	Absent	33	89.19	40	49.38	27	14.92	<0.001
	Unilateral	2	5.41	13	16.05	14	7.73	
	Bilateral	2	5.41	28	34.57	140	77.35	
CC dehiscence	Absent	37	100	70	86.42	99	54.70	<0.001
	Unilateral	NA	NA	8	9.88	20	27.62	
	Bilateral	NA	NA	3	3.70	32	17.68	
OC protrusion	Absent	30	81.08	41	50.62	64	35.36	<0.001
	Unilateral	3	8.11	5	6.17	10	5.52	
	Bilateral	4	10.81	35	43.21	107	59.12	
OC dehiscence	Absent	35	94.59	61	75.31	108	59.67	<0.001
	Unilateral	1	2.70	12	14.81	35	19.34	
	Bilateral	1	2.70	8	9.88	38	20.99	
FR protrusion	Absent	36	97.30	51	62.96	53	29.28	<0.001
	Unilateral	1	2.70	9	11.11	32	17.68	
	Bilateral	NA	NA	21	25.93	96	53.04	
FR dehiscence	Absent	37	100	66	81.48	107	59.12	<0.001
	Unilateral	NA	NA	11	13.58	40	22.10	
	Bilateral	NA	NA	4	4.94	34	18.78	
VC protrusion	Absent	28	75.68	25	30.86	16	8.84	<0.001
	Unilateral	7	18.92	14	17.28	24	13.26	
	Bilateral	2	5.41	42	51.85	141	77.90	
VC dehiscence	Absent	36	97.30	49	60.49	45	24.86	<0.001
	Unilateral	1	2.70	14	17.28	33	18.23	
	Bilateral	NA	NA	18	22.22	103	56.91	
Right CSSP types and SSSP types relationship								<0.001
Left CSSP types and SSSP types relationship								<0.001

*Statistically significant, chi-square test (significance level $P < 0.05$). CC = carotid canal, OC = optic canal, FR = foramen rotundum, VC = Vidian canal, SSSP = sagittal sphenoid sinus pneumatization, CSSP = coronal sphenoid sinus pneumatization

Table 3. Comparison of pneumatization types, protrusion and dehiscence rates across age groups

		18–32 years		33–47 years		48–80 years		*P*
		n=137	%	n=88	%	n=75	%	
SSSP	Conchal	NA	**NA**	1	**1.1**	NA	**NA**	0.026*
	Presellar	12	**8.8**	9	**10.2**	16	**21.3**	
	Sellar	34	**24.8**	22	**23.8**	25	**33.3**	
	Postsellar	91	**66.4**	56	**63.6**	34	**45.3**	
Right CSSP	Type 1	51	**37.2**	45	**51.1**	46	**61.3**	0.024*
	Type 2	5	**3.6**	2	**2.3**	3	**4**	
	Type 3	15	**10.9**	11	**12.5**	6	**8**	
	Type 4	10	**7.3**	7	**8**	4	**5.3**	
	Type 5	23	**16.8**	9	**10.2**	7	**9.3**	
	Type 6	33	**24.1**	14	**15.9**	9	**12**	
Left CSSP	Type 1	50	**36.5**	42	**47.7**	44	**58.7**	0.022*
	Type 2	8	**5.8**	2	**2.3**	1	**1.3**	
	Type 3	17	**12.4**	19	**21.6**	12	**16**	
	Type 4	9	**6.6**	2	**2.3**	3	**4**	
	Type 5	29	**21.2**	15	**17**	8	**10.7**	
	Type 6	24	**17.5**	8	**9.1**	7	**9.3**	
Onodi cell	Absent	81	**59.1**	43	**48.9**	42	**56**	0.424
	Unilateral	35	**25.6**	32	**26.7**	24	**32**	
	Bilateral	21	**15.3**	13	**14.8**	9	**12**	
CC protrusion	Absent	36	**26.3**	29	**29**	36	**48**	0.031*
	Unilateral	14	**10.2**	8	**9.1**	7	**9.3**	
	Bilateral	87	**63.5**	51	**58**	32	**42.7**	
CC dehiscence	Absent	90	**65.7**	58	**65.9**	59	**78.7**	0.162
	Unilateral	31	**22.6**	20	**22.7**	7	**9.3**	
	Bilateral	16	**11.7**	10	**11.4**	9	**12**	
OC protrusion	Absent	53	**38.7**	43	**48.9**	40	**53.3**	0.008*
	Unilateral	6	**4.4**	3	**3.4**	9	**12**	
	Bilateral	78	**56.9**	42	**47.7**	26	**34.7**	

Table 3. [Continued]

		18–32 years		33–47 years		48–80 years		*P*
		n=137	%	n=88	%	n=75	%	
OC dehiscence	Absent	93	**67.9**	58	**65.9**	54	**72**	0.880
	Unilateral	21	**15.3**	15	**17**	12	**16**	
	Bilateral	23	**16.8**	15	**17**	9	**12**	
FR protrusion	Absent	51	**37.2**	43	**48.9**	47	**62.7**	0.011*
	Unilateral	22	**16.1**	13	**14.8**	7	**9.3**	
	Bilateral	64	**46.7**	32	**36.4**	21	**28**	
FR dehiscence	Absent	87	**63.5**	64	**72.7**	60	**80**	0.039*
	Unilateral	30	**21.9**	10	**11.4**	11	**14.7**	
	Bilateral	20	**14.6**	14	**15.9**	4	**5.3**	
VC protrusion	Absent	23	**16.8**	20	**22.7**	27	**36**	0.014*
	Unilateral	18	**13.1**	17	**19.3**	10	**13.3**	
	Bilateral	96	**70.1**	51	**58**	38	**50.7**	
VC dehiscence	Absent	50	**36.5**	37	**42**	44	**58.7**	0.028*
	Unilateral	22	**16.1**	17	**19.3**	9	**12**	
	Bilateral	65	**47.4**	34	**38.6**	22	**29.3**	

*Statistically significant, chi-square test, (significance level $P < 0.05$). SSSP = sagittal sphenoid sinus pneumatization, CSSP = coronal sphenoid sinus pneumatization, CC = carotid canal, OC = optic canal, FR = foramen rotundum, VC = Vidian canal

Table 4. Comparison of protrusion and dehiscence rates of structures adjacent to the sphenoid sinus with other studies

(%)	Year	n	CCP	CCD	OCP	OCD	FRP	FRD	VCP	VCD
Şimşek and İşlek	2024	262 (CT)	24.4		39.4				53	
Lopes et al.	2024	75 (CT)	31	0	21	4	23	5	39	6
Kuriakose et al.	2024	400 (CT)	43	27.8	37.5	47.8	37	64	44.5	35.8
Açar et al.	2024	300 (CT)	50	19.7	46.7	45.6	44	23	57.7	46.3
Our study	2025	300 (CT)	66.3	31	54.7	31.7	53	29.7	76.7	56.3

CCP = carotid canal protrusion, CCD = carotid canal dehiscence, OCP = optic canal protrusion, OCD = optic canal dehiscence, FRP = foramen rotundum protrusion, FRD = foramen rotundum dehiscence, VCP = Vidian canal protrusion, VCD = Vidian canal dehiscence

Differences in age groups

To detail age-related changes and evaluate the potential impact of skeletal maturation and aging on SS morphology, participants were categorized into age groups using 15-year intervals: 18–32 years (n = 137) and 33–47 years (n = 88). A third combined group of 48–80 years (n = 75) was created because the individual older cohorts (48–63 and 64–80 years) did not contain a sufficient sample size for independent, robust statistical comparisons. The analysis revealed that SSSP and CSSP, the protrusion of adjacent structures, and FR and VC dehiscence rates were statistically significantly different between the age groups ($P < 0.05$) (Table 3). We determined that the 18–32 age group had more pneumatized SS than the 48–80 age group ($P < 0.05$). For this reason, the protrusion of all adjacent structures and the dehiscence rates of those other than CC and OC were higher in the younger group ($P < 0.05$). No significant difference was observed between the age groups in terms of the prevalence of Onodi cells, and CC and OC dehiscence ($P > 0.05$).

Discussion

The degree and pattern of SS pneumatization are critically important, especially in planning transsphenoidal surgical procedures and reducing the risk of potential complications[15,21,22].

Sagittal and coronal sphenoid sinus pneumatization types

Literature studies on SS morphology have revealed several similarities and differences regarding pneumatization. In CT studies, the postsellar type was reported to be the most common type, with a prevalence of 56% in a study by Lopes et al.[2], 62.7% in a study by Açar et al.[3], 79.4–80.2% in a study by Şimşek and İşlek[5], and 60.0% in a study by Mendonça et al.[7] However, Pirinc et al.[21] reported that the sellar type was the most common at 41.5%, while Kuriakose et al.[9] reported it at 90%. In the present study, the postsellar type of pneumatization was the most common type (60.3%). These differences may be due to sample size, ethnicity, and especially age range.

Considering that transsphenoidal surgery is the most commonly preferred approach for accessing the pituitary gland and lesions at the base of the skull, it is well-known that the SSSP type is quite important in determining the surgical technique and the size of the surgical window[12,23,24]. Well-aerated sellar and postsellar sinuses provide a wider surgical field, while the presellar type, which has thicker walls, and the conchal type, which has minimal aeration, may require longer operating times[2,9,25]. In light of this information, it can be said that 87.3% of SS (sellar and postsellar types) in our study were more suitable for transsphenoidal surgery.

Different classification systems exist for CSSP types. Şimşek and İşlek[5] reported that the pre-Vidian type (44.3–47.3%) was the most common in the coronal plane. Açar et al.[3] observed Type 5 (23.6%) and Type 6 (21.7%) as the most common CSSP types. These results emphasize the prevalence of types with more extensive pneumatization. In the present study, Type 1 (46.3%) was the most common type, while high iatrogenic risk Types 5 (14.2%) and 6 (15.9%) were less common at 30.1%.

The relationship between sagittal and coronal sphenoid sinus pneumatization types and adjacent structures

Although direct volumetric measurements were not performed in the present study, the progression from the presellar to postsellar type and the involvement of lateral recesses (Types 5 and 6) are well-established anatomical indicators of increased

sinus volume and expansion, which is known to strongly correlate with neurovascular protrusions[3,12]. Gibelli et al.[12] stated that CC protrusion is positively correlated with SS volume, but OC protrusion can occur independently of sinus volume. Štoković et al.[22], Şimşek and İşlek[5], and Açar et al.[3] stated that the postsellar type was most strongly associated with the likelihood of OC, FR, VC, and CC protrusion/dehiscence. The present study, which is consistent with the literature, found that 87.3% of SS were of the sellar and postsellar types. Assuming that the highest protrusion and dehiscence rates (30.1%) were associated with Type 5 and Type 6 pneumatization, the remaining 57.2% of sellar and postsellar SS could be considered low-risk for transsphenoidal surgery.

In the literature on SS morphology, it is understood that the protrusion and dehiscence ratios indicate a very wide range (Table 4)[2,3,5,9]. These differences may stem from methodological diversity, sample size, ethnic origin, or age range. However, studies agree that the highest rates of protrusion and opening are found in VC, and the lowest in OC and FR.

There are discrepancies in the literature regarding the effect of sex on pneumatization types. In the present study, the lack of significant differences ($P > 0.05$) in SSSP and CSSP prevalence between sexes is consistent with the findings of Pirinc et al.[21] and de Mendonça et al.[7] However, Açar et al.[3] reported that the prevalence of right CSSP showed a significant difference between women and men. This demonstrates the complexity of sex-related variations in SS anatomy, the subjectivity of assessment, and therefore the possibility of different researchers obtaining different results.

Nasal septum, sphenoid septa, and Onodi cells

Previous studies have suggested that NSD may influence SS development and septation. Akgül et al.[14] reported significantly higher rates of asymmetric SS septation in individuals with NSD, while Orhan et al.[17] demonstrated reduced SS volume on the deviated side. Tang et al.[16] further showed that severe NSD was associated with increased SS pneumatization and involvement of adjacent neurovascular structures. In contrast, Yazıcı[20] found higher incidences of concha bullosa, Onodi cells, and ACP pneumatization in NSD patients, but reported no effect on CC, OC, FR, or VC protrusion or dehiscence — findings partially supported by the present study. Although Kumar et al.[8] reported a markedly higher NSD prevalence in revision endoscopic sinus surgery patients than observed in our cohort (21.7%), our results indicated that NSD does not significantly affect SS pneumatization type or related protrusion and dehiscence rates ($P > 0.05$); discrepancies that may be explained by methodological and sample differences. Nevertheless, NSD remains clinically relevant due to its potential to restrict the surgical field, complicate endoscope placement, and necessitate septoplasty during transsphenoidal approaches, particularly with binasal techniques.

Differences in age groups

There are discrepancies in the literature regarding the effect of age on pneumatization types. Şimşek and İşlek[5], and Açar et al.[3] found that mean age was significantly lower in patients with the postsellar type SS. This study is consistent with the literature in terms of pneumatization being more common in younger age groups (18–32 years) ($P < 0.05$).

Limitations

Our inability to support our study examining structures at risk for endoscopic sinus surgery and transsphenoidal surgery with clinical results was this study's greatest limitation. A prospective study in which researchers investigate complications arising after endoscopic sinus surgery or transsphenoidal

surgery together with SS morphology could overcome this limitation.

Conclusions

The type of SS pneumatization significantly affects the protrusion and dehiscence of adjacent neurovascular structures, with younger individuals exhibiting higher rates compared to older patients. These findings underscore the importance of preoperative CT evaluation in transsphenoidal surgery to anticipate surgical window dimensions and minimize the risk of complications. Further studies with larger NSD cohorts are needed to clarify the potential role of NSD in SS morphology.

DISCLOSURE OF CONFLICT OF INTEREST The authors declare that they have no conflicts of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. ■

References

1. Hamid O, El Fiky L, Hassan O, Kotb A, El Fiky S. Anatomic variations of the sphenoid sinus and their impact on transsphenoid pituitary surgery. Skull Base. 2008;18:9-15. https://doi.org/10.1055/s-2007-992764
2. Lopes PF, Carvalho T, Furtado M. Anatomical variations of sphenoid sinus on cone beam computed tomography. Acta Otorrinolaringol Engl Ed (in press). 2025. https://doi.org/10.1016/j.otorri.2025.512229
3. Açar G, Gökşan AS, Aydoğdu D. Computed tomography based evaluation of the association between sphenoid sinus pneumatization patterns and variations of adjacent bony structures in relation to age and gender. Neurosurg Rev. 2025;47:349. https://doi.org/10.1007/s10143-024-02594-8
4. Cellina M, Gibelli D, Floridi C, et al. Sphenoid sinuses: pneumatisation and anatomical variants-what the radiologist needs to know and report to avoid intraoperative complications. Surg Radiol Anat. 2020;42:1013–1024. https://doi.org/10.1007/s00276-020-02490-y
5. Şimşek S, İşlek A. Pneumatization of the sphenoid sinus is the major factor determining the variations of adjacent vital structures. Egypt J Otolaryngol. 2024;40:2. https://doi.org/10.1186/s43163-023-00560-7
6. Fadda GL, Petrelli A, Urbanelli A, et al. Risky anatomical variations of sphenoid sinus and surrounding structures in endoscopic sinus surgery. Head Face Med. 2022;18:29. https://doi.org/10.1186/s13005-022-00336-z
7. Mendonça DS, Newman NI, Leite JER, et al. Surgical-related morphological characteristics of sphenoid sinuses: a comprehensive CT-based analysis. J Clin Exp Dent. 2024;16:e1445. https://doi.org/10.4317/jced.62099
8. Kumar N, Lanca Gomes P, Marino MJ, Miglani A, Lal D. Technical quality of contemporary endoscopic sinus surgery: an assessment by study of anatomical features needing attention at revision surgery. Sinusitis. 2024;8:28–36. https://doi.org/10.3390/sinusitis8020005
9. Kuriakose S, Nuvven A, Revankar S, Shetty B, Shetty S. Morphology, pneumatization, septation, and protrusion of nearby structures into the sphenoid sinus: a retrospective radiological study. Bull Med Biol Res. 2024;3:25–31. https://doi.org/10.61751/bmbr/3.2024.25
10. Wang J, Bidari S, Inoue K, Yang H, Rhoton A Jr. Extensions of the sphenoid sinus: a new classification. Neurosurgery. 2010;66:797–816.
11. Zada G, Agarwalla PK, Mukundan S, Dunn I, Golby AJ, Laws ER. The neurosurgical anatomy of the sphenoid sinus and sellar floor in endoscopic transsphenoidal surgery. J Neurosurg. 2011;114:1319–1330. https://doi.org/10.3171/2010.11.JNS10768

12. Gibelli D, Cellina M, Gibelli S, et al. Relationship between sphenoid sinus volume and protrusion of internal carotid artery and optic nerve: a 3D segmentation study on maxillofacial CT scans. Surg Radiol Anat 2019;41:507–512. https://doi.org/10.1007/s00276-019-02207-w
13. Güldner C, Pistorius SM, Diogo I, Bien S, Sesterhenn A, Werner JA. Analysis of pneumatization and neurovascular structures of the sphenoid sinus using cone-beam tomography (CBT). Acta Radiol. 2012;53:214–219. https://doi.org/10.1258/ar.2011.110381
14. Akgül MH, Muluk NB, Burulday V, Kaya A. Is there a relationship between sphenoid sinus types, septation and symmetry; and septal deviation? Eur Arch Otorhinolaryngol. 2016;273:4321–4328. https://doi.org/10.1007/s00405-016-4138-7
15. Atsal G, Demir E, Yildirim O, Edizer DT, Olgun L. The relationship between degree of nasal septum deviation with sinonasal structures and variations. J Craniofac Surg. 2022;33:e447–e449. https://doi.org/10.1097/SCS.0000000000008274
16. Tang J, Hou J, Zhang Y, et al. Impact of nasal septum deviation on the sphenoid bone pneumatization: a retrospective computed tomography study. Acta Otolaryngol. 2025;145:234–240. https://doi.org/10.1080/00016489.2025.2455761
17. Orhan I, Ormeci T, Bilal N, Sagiroglu S, Doganer A. Morphometric analysis of sphenoid sinus in patients with nasal septum deviation. J Craniofac Surg 2019;30:1605–1608. https://doi.org/10.1097/SCS.0000000000005443
18. Adibelli ZH, Songu M, Adibelli H. Paranasal sinus development in children: a magnetic resonance imaging analysis. Am J Rhinol Allergy. 2011;25:30–35. https://doi.org/10.2500/ajra.2011.25.3552
19. Nobre ML, Sarmento ACA, Bedaque HdP, et al. Image guidance for endoscopic sinus surgery: systematic review and meta-analysis. Rev Assoc Med Bras. 2023;69:e20230633. https://doi.org/10.1590/1806-9282.20230633
20. Yazici D. The analysis of computed tomography of paranasal sinuses in nasal septal deviation. J Craniofac Surg 2019;30:e143–e147. https://doi.org/10.1097/SCS.0000000000005077
21. Pirinc B, Fazliogullari Z, Guler I, Unver Dogan N, Uysal II, Karabulut AK. Classification and volumetric study of the sphenoid sinus on MDCT images. Eur Arch Otorhinolaryngol. 2019;276:2887–2894. https://doi.org/10.1007/s00405-019-05549-8
22. Štoković N, Trkulja V, Dumić-Čule I, et al. Sphenoid sinus types, dimensions and relationship with surrounding structures. Ann Anat. 2016;203:69–76. https://doi.org/10.1016/j.aanat.2015.02.013
23. Keleş H, Yakar H, Kaya İ, et al. The relationship between sphenoidal sinus and sella turcica morphometry in the Turkish population: a retrospective study. Surg Radiol Anat. 2024;46:977–984. https://doi.org/10.1007/s00276-024-03392-z
24. Perondi GE, Isolan GR, de Aguiar PHP, Stefani MA, Falcetta EF. Endoscopic anatomy of sellar region. Pituitary. 2013;16:251–259. https://doi.org/10.1007/s11102-012-0413-9
25. Kayalioglu G, Erturk M, Varol T. Variations in sphenoid sinus anatomy with special emphasis on pneumatization and endoscopic anatomic distances. Neurosciences (Riyadh) 2005;10:79–84.

SAŽETAK

Anatomske poteškoće u transsfenoidalnoj kirurgiji: septe, protruzije i dehiscencije

Hamza Kasar, Murat İnci, Mehmet Selçuk, Zeliha Fazlıoğulları i Halil Özer

Cilj ove studije bio je istražiti tipove pneumatizacije sfenoidnog sinusa (SS), varijacije susjednih struktura te odnos između devijacije nosne pregrade (NSD) i morfologije SS-a. U ovoj retrospektivnoj studiji analizirane su slike kompjutorizirane tomografije (CT) paranazalnih sinusa 300 bolesnika. Procijenjeni su sagitalni i koronalni tipovi pneumatizacije SS-a, protruzija i dehiscencija karotičnog kanala (CC), optičkog kanala (OC), okruglog otvora (FR) i pterigoidnog kanala (VC), prisutnost NSD-a te septumi SS-a. Najčešći sagitalni tip pneumatizacije bio je postselarni tip (60,3 %). S porastom stupnja pneumatizacije SS-a, učestalost protruzije i dehiscencije susjednih neurovaskularnih struktura značajno se povećavala ($P < 0,05$). Protruzija i dehiscencija VC-a bile su najčešće zabilježene varijacije. Ukupno 57,2 % svih SS-a bilo je pogodnije za kirurški zahvat zbog širokog kirurškog pristupa i niskog omjera protruzije/dehiscencije. Nije utvrđena povezanost između morfologije SS-a i NSD-a koji zahtijeva septoplastiku tijekom operacije. Iako povećana pneumatizacija SS-a omogućuje širi kirurški pristup, ona istodobno povećava rizik od ijatrogenog oštećenja susjednih struktura. Ovi rezultati još jednom naglašavaju ključnu važnost detaljne prijeoperativne CT procjene u transsfenoidalnoj kirurgiji radi sigurnosti bolesnika.

KLJUČNE RIJEČI

Dehiscencija; Protruzija; Devijacija nosne pregrade; Kompjutorizirana tomografija; Sfenoidni sinus