

Sphenoid Sinus Pneumatization Patterns in Patients With Rathke's Cleft Cysts: A Retrospective Case–Control Study

✉ Duygu Dolen Burak¹, ✉ Cafer İkbāl Gülsever², ✉ Sefa Öztürk¹, ✉ Yavuz Bahadır Taktak³, ✉ Mehmet Barburoğlu³, ✉ İlyas Dolaş¹, ✉ Altay Sencer¹, ✉ Tuğrul Cem Ünal¹

¹Istanbul University, Istanbul Faculty of Medicine, Department of Neurosurgery, Istanbul, Türkiye

²Hakkari State Hospital, Clinic of Neurosurgery, Hakkari, Türkiye

³Istanbul University, Istanbul Faculty of Medicine, Department of Radiology, Istanbul, Türkiye

ABSTRACT

Introduction: Rathke's cleft cysts (RCCs) are benign lesions of the pituitary region. Variations in sphenoid sinus aeration influence sellar anatomy, but their relationship to RCCs is unknown. This study examined whether specific sphenoid sinus pneumatization patterns are associated with RCCs.

Methods: A retrospective case–control study was conducted, including 126 subjects: 63 patients with magnetic resonance imaging (MRI)-confirmed RCCs and 63 control individuals matched for age and sex, who had no evidence of sellar or parasellar pathology. Computed tomography and MRIs images were evaluated to categorize sphenoid sinus aeration as conchal, presellar, incomplete sellar, or complete sellar. All imaging assessments were performed independently by two neuroradiologists (Y.B.T. and M.B.), blinded to group allocation. Statistical comparisons were made using the chi-square test.

Results: The RCCs and control groups had comparable ages (43.6 ± 12.8 vs. 42.9 ± 13.4 years, $p=0.78$) and sex distribution (61.9% vs. 58.7% female, $p=0.71$). Among patients with RCCs, the incomplete sellar pattern was the most frequent (58.7%), followed by complete sellar (31.7%), presellar (6.3%), and conchal (3.2%) patterns. In contrast, control subjects most commonly demonstrated complete sellar aeration (52.4%). Overall, pneumatization patterns differed significantly between groups (χ^2 : 23.42, df: 3, $p<0.05$).

Conclusion: Individuals with RCCs exhibited a higher prevalence of incomplete sellar sphenoid sinus aeration compared with matched controls. This association may reflect underlying developmental or anatomical factors within the sellar-sphenoid region, potentially contributing to the formation of RCCs or to earlier symptom onset. Awareness of this relationship may support more refined radiologic assessment and improve preoperative planning for patients with cystic sellar lesions.

Keywords: Rathke's cleft cyst, sphenoid sinus, pneumatization, sellar region, pituitary

Introduction

Rathke's cleft cysts (RCCs) are epithelial cysts that develop from persistent embryologic tissue located between the anterior and posterior pituitary lobes. Although many RCCs are asymptomatic and incidentally discovered, symptomatic cases may present with headache, visual disturbances, or endocrine dysfunction from compression of adjacent structures (e.g., pituitary, optic apparatus) (1-3). Recent reviews highlight their variable natural history, noting that most uncompressed RCCs remain stable over time and advocating conservative management for selected cases (4,5). However, growth, recurrence, or symptomatic progression may occur, with recent work proposing risk models to predict which lesions will evolve (5).

The sphenoid sinus, located below the sella turcica, shows substantial interindividual variation in the degree of aeration. Sphenoid sinus pneumatization, which may extend anteriorly, posteriorly, laterally, or inferiorly, can influence both anatomical relationships and radiologic appearance of the sellar region (6). In fact, previous computed tomography (CT) investigations indicate that how the sphenoid sinus pneumatizes can influence multiple aspects of sellar morphology, as well as the protrusion or dehiscence of adjacent neurovascular structures (7). Moreover, the extent of pneumatization is not only surgically relevant (e.g., in planning transsphenoidal corridors) but may also impact biomechanical interactions between sinus cavities and the pituitary gland (8).



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Address for Correspondence: Cafer İkbāl Gülsever, MD, Hakkari State Hospital, Clinic of Neurosurgery, Hakkari, Türkiye

E-mail: cafer.gulsever@gmail.com **ORCID ID:** orcid.org/0000-0002-9246-1378

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Given the embryological proximity and close spatial relationship between the sphenoid sinus and the pituitary region, it is biologically plausible that variations in pneumatization might correlate with the occurrence, growth, or morphology of RCCs. To our knowledge, no prior work has thoroughly assessed whether particular aeration patterns of the sphenoid sinus are more common among individuals with RCCs.

Therefore, this study aims to evaluate, using CT and magnetic resonance imaging (MRI), whether specific sphenoid sinus pneumatization subtypes are more frequent in patients with RCCs than in matched controls. We hypothesize that less extensive pneumatization (e.g., incomplete sellar) may be more common in RCCs, or that certain pneumatization patterns may predispose to cyst formation or facilitate detection.

Methods

Study Design and Ethical Considerations

This research used a retrospective observational design and followed the ethical standards outlined in the Declaration of Helsinki. This study was approved by the İstanbul University Non-Interventional Clinical Research Ethics Committee (decision number: 23, date: 14.11.2025) neuroradiologists (Y.B.T. and M.B.). Informed consent was waived by the Ethics Committee due to the retrospective nature of the study and the use of anonymized imaging data.

Patient Selection

The study population comprised 126 subjects: 63 with radiologically confirmed RCCs and 63 matched controls without sellar or parasellar pathology. The RCCs group consisted of patients whose diagnoses were established based on MRI findings between January 2018 and December 2023. Controls were selected from individuals who underwent cranial MRI for unrelated, non-sellar reasons (e.g., headache, dizziness) and had no radiological evidence of sellar or parasellar lesions. As this was a retrospective study conducted at a tertiary-care center, the RCC cohort likely reflects a referred, potentially symptomatic population.

Exclusion criteria for both groups included:

1. History of pituitary or sphenoid sinus surgery,
2. Presence of neoplastic or inflammatory sellar lesions,
3. Poor-quality or incomplete imaging data,
4. Congenital craniofacial malformations affecting the sphenoid region.

Imaging Acquisition and Evaluation

MRI and CT images were retrieved from İstanbul University Faculty of Medicine's Picture Archiving and Communication System. MRI scans were performed on 1.5-T or 3-T scanners (GE or Siemens Healthcare systems), using standard sellar protocols that included sagittal and coronal T1-weighted, T2-weighted, and post-contrast T1 sequences. CT images were used to evaluate the bony anatomy of the sphenoid sinus and the extent of pneumatization.

The extent of sphenoid sinus aeration was classified into four subtypes according to the extent of aeration relative to the sella turcica, as described in prior literature (9-12):

1. Conchal type—minimal aeration anterior to the sella;
2. Presellar type—pneumatization extending anteriorly but not reaching the sella;
3. Incomplete sellar type—pneumatization extending partially below the sella;
4. Complete sellar type—pneumatization extending fully below the sella floor (Figure 1).

Two experienced neuroradiologists (Y.B.T. and M.B.), blinded to the patient/control grouping, independently reviewed all scans. In case of disagreement, consensus was reached through joint review. Inter-

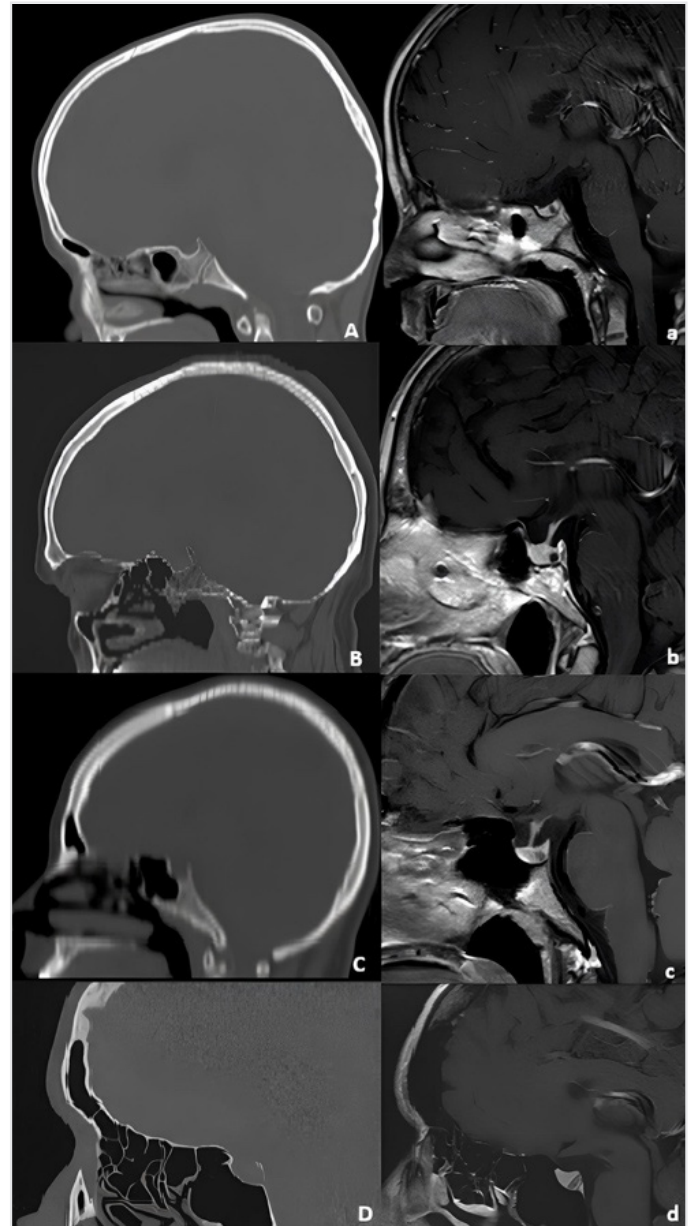


Figure 1. Representative sagittal computed tomography (left column) and corresponding magnetic resonance imaging (right column) images demonstrating the four primary sphenoid sinus pneumatization subtypes in patients with Rathke's cleft cyst. (A, a) Conchal type: minimal aeration anterior to the sella; (B, b) presellar type: aeration extending anteriorly but not reaching the sella; (C, c) incomplete sellar type: partial pneumatization beneath the sella turcica; (D, d) complete sellar type: extensive pneumatization extending fully below the sellar floor

observer consistency was assessed qualitatively. All images selected for inclusion in figures were reviewed for clarity and anatomical representativeness.

Data Collection and Statistical Analysis

Demographic data (age and sex) and radiological classifications were recorded for each subject. Descriptive statistics were expressed as mean $\pm$ standard deviation for continuous variables and as frequency (percentage) for categorical variables. The chi-square (χ^2) test was used to assess the association between groups (RCCs vs. controls) and sphenoid sinus pneumatization types. Due to the relatively limited sample size and the categorical nature of the primary variables, multivariate regression analysis was not performed. A p value of <0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA).

Results

Demographic Characteristics

This study included 126 participants, consisting of 63 individuals with RCCs and an equal number of age- and sex-matched controls.

The RCCs group had a mean age of 43.6 ± 12.8 years (21-68 years), whereas the control group averaged 42.9 ± 13.4 years (20-70 years). This difference was not statistically significant ($p=0.78$). The RCCs group included 39 females (61.9%) and 24 males (38.1%), whereas the control group included 37 females (58.7%) and 26 males (41.3%). The gender distribution between groups was comparable ($p=0.71$).

Distribution of Sphenoid Sinus Pneumatization Types

The pattern of sphenoid sinus aeration differed markedly between the RCCs and the control groups (χ^2 : 23.42, df: 3, $p<0.05$). In patients with RCCs, incomplete sellar pneumatization was the most frequent pattern (58.73%, $n=37$), while complete sellar aeration accounted for 31.75% ($n=20$). Presellar types (6.35%, $n=4$) and conchal types (3.17%, $n=2$) were observed much less frequently.

In contrast, the control group demonstrated a higher prevalence of the complete sellar type (52.38%, $n=33$), with lower prevalences of the incomplete sellar type (28.57%, $n=18$), presellar type (17.46%, $n=11$), and conchal type (1.59%, $n=1$).

This difference indicates that incomplete sellar pneumatization is more frequently associated with RCCs, whereas complete sellar pneumatization is more common in individuals without sellar pathology (Table 1).

Discussion

In this study, we identified a significant difference in sphenoid sinus pneumatization patterns between patients with RCCs and matched controls. Incomplete sellar pneumatization was markedly more frequent among individuals with RCCs, whereas complete sellar pneumatization predominated in the control population. This finding suggests a potential anatomical or developmental relationship between sphenoid sinus aeration and the presence of RCCs, which has not been previously emphasized in the literature.

Although no prior studies have directly examined the association between RCCs and sphenoid sinus pneumatization, previous radiological investigations have clarified how the degree of sinus aeration influences the configuration of the sella turcica and surrounding structures (12). Recent CT-based analyses have demonstrated that extensive pneumatization correlates with a thinner sellar floor and altered relationships with the internal carotid artery, optic nerve, and other parasellar elements (5,12). Dogan et al. (5) showed that sellar and postsellar pneumatization are the dominant patterns in the general adult population, while incomplete aeration represents a smaller minority. Similarly, Tavakoli et al. (11), using cone-beam CT, reported that sellar and postsellar configurations together accounted for over 70% of cases. In contrast, our cohort of patients with RCCs exhibited a striking predominance of the incomplete sellar pattern, suggesting that patients with RCCs may differ systematically from the general population in the anatomical development of the sphenoid sinus. However, differences in classification systems may influence this apparent discrepancy. Previous studies, such as those by Dogan et al. (5) and Tavakoli et al. (11), often grouped sellar and postsellar pneumatization patterns together, whereas the present study subdivided these into incomplete and complete sellar types. When these two categories are considered jointly in our control group, the overall distribution is broadly consistent with prior reports in the general adult population. Therefore, the observed differences should be interpreted in the context of classification methodology rather than as a direct contradiction with existing literature.

Table 1. Distribution of sphenoid sinus pneumatization subtypes in RCC and control groups

Sphenoid sinus pneumatization type	RCC group (n=63)		Control group (n=63)		p value
	n	%	n	%	
Conchal type	2	3.17	1	1.59	
Presellar type	4	6.35	11	17.46	
Incomplete sellar type	37	58.73	18	28.57	
Complete sellar type	20	31.75	33	52.38	
Total	63	100	63	100	<0.05

Data are presented as the number of cases (n) and the percentage (%). A significant difference was observed between groups (χ^2 : 23.42, df: 3, $p<0.05$). The incomplete sellar type was the most frequent pattern among RCC patients, whereas the complete sellar type predominated in controls. RCC: Rathke's cleft cyst

This observation may be interpreted within the context of the shared embryologic and anatomical evolution of the sellar region. The sphenoid sinus begins to pneumatize during early childhood and usually reaches the sella turcica by the age of seven, continuing to expand through puberty (13). Variability in the extent of this pneumatization influences the thickness of the sellar floor and the position of the pituitary fossa relative to the sinus cavity (14). In individuals with limited or incomplete sellar pneumatization, the bony sellar floor remains thicker, providing a denser barrier between the pituitary gland and the sinus. Because RCCs arise from epithelial remnants of Rathke's pouch at the junction of the anterior and posterior pituitary, such structural differences may influence the persistence, expansion, or presentation of these cystic remnants. The thicker bony confines and smaller sellar volume associated with incomplete pneumatization could restrict inferior expansion toward the sinus, causing RCCs to enlarge superiorly or remain intrasellar. As a result, these cysts may produce symptoms such as headache, visual field deficits, or endocrine dysfunction at smaller sizes, leading to earlier detection on imaging and thus overrepresentation in symptomatic cohorts such as ours (15,16).

Beyond mechanical constraint, developmental coupling between the processes of sinus pneumatization and sellar ossification may also contribute. Both occur in close temporal and spatial proximity during embryogenesis and depend on local osteogenic and epithelial-mesenchymal interactions. Subtle alterations in local signaling pathways (e.g., bone morphogenetic protein activity) or in vascular remodeling might delay or limit pneumatization and simultaneously influence the microenvironment of Rathke's pouch remnants. A less pneumatized sphenoid may also yield different local pressure gradients, venous drainage characteristics, or mucosal-osseous interactions, creating a milieu more favorable for cyst persistence or enlargement. Conversely, in a fully pneumatized sinus, increased aeration and mucosal exposure might facilitate micro-drainage or resorption of cystic fluid, potentially reducing cyst visibility or size on imaging. This interplay of developmental timing, regional mechanics, and tissue microenvironment offers a plausible embryologic framework linking incomplete pneumatization with RCCs formation or manifestation (17).

The current findings are consistent with the broader literature on RCCs' morphology and behavior. Recent reviews have underscored that RCCs are benign, epithelial cysts of variable clinical course, often stable but sometimes enlarging due to intermittent fluid accumulation or inflammation (2,3). Imaging studies have documented considerable heterogeneity in cyst size, location, and wall characteristics, supporting the idea that local anatomic context influences disease expression (18). Case reports of intrasphenoidal or ectopic RCCs further illustrate how developmental variations in sinus and sellar anatomy can modify cyst location. Therefore, the higher frequency of incomplete sellar pneumatization observed in our RCC cohort may represent a developmental variation similar to that proposed for ectopic cyst locations (19,20).

From a clinical perspective, the recognition of this anatomical relationship carries several implications. For surgical planning,

incomplete sellar pneumatization is associated with a thicker bony barrier and altered landmarks, which require careful preoperative assessment to optimize transsphenoidal access. Awareness of this pattern may help anticipate technical difficulty and tailor drilling strategies. For radiologists, identifying an incomplete sellar sinus in the presence of a sellar cyst should raise awareness of possible RCCs and guide the differential diagnosis, distinguishing RCCs from other cystic lesions such as cystic adenomas or arachnoid cysts. In the context of conservative management, the possibility that incomplete pneumatization predisposes to earlier symptom onset could explain why some RCCs become clinically apparent despite small size, while others in fully pneumatized sinuses remain quiescent (21-23).

Study Limitations

This study has several limitations that should be acknowledged. First, its retrospective design limits causal inference between sphenoid sinus pneumatization patterns and the presence of RCCs. Second, the sample was drawn from a single İstanbul University Faculty of Medicine, which may have introduced selection bias toward symptomatic, referred, or more clinically apparent cases. Therefore, the RCC cohort may not fully represent the general population or incidentally detected lesions. Third, we did not include quantitative morphometric measurements (e.g., sellar depth, volume, or floor thickness), and this omission limits our ability to directly support the proposed developmental and anatomical interpretations. These parameters may act as important intermediate variables linking sphenoid pneumatization to the development of RCCs. Additionally, the four-type classification of sphenoid sinus pneumatization did not account for lateral or clival extension variants, which may also influence sellar anatomy. Another limitation is that the statistical analysis was limited to univariate comparisons. Multivariate methods, such as logistic regression, were not applied to control for potential confounding variables. Therefore, the observed association between pneumatization patterns and the presence of RCCs should be interpreted with caution, as it may be influenced by unmeasured or residual confounders. Although two neuroradiologists (Y.B.T. and M.B.) reviewed the imaging studies, interobserver agreement was assessed qualitatively rather than using quantitative reliability metrics. Future research incorporating prospective designs, larger and more diverse populations, and comprehensive morphometric and volumetric analyses would strengthen understanding of the developmental and anatomical relationships suggested by this study.

Conclusion

Our results indicate that individuals with RCCs more frequently exhibit incomplete sellar-type aeration of the sphenoid sinus. This relationship likely reflects a combination of developmental coupling and mechanical constraint within the sellar-sphenoid complex. By providing new evidence on anatomical factors that may influence the occurrence and presentation of RCCs, this study enhances understanding of the development of the pituitary region and underscores the importance of detailed radiological evaluation of sphenoid pneumatization patterns when assessing sellar lesions.

Ethics

Ethics Committee Approval: This study was approved by the İstanbul University Non-Interventional Clinical Research Ethics Committee (decision number: 23, date: 14.11.2025).

Informed Consent: Informed consent was waived by the Ethics Committee due to the retrospective nature of the study and the use of anonymized imaging data.

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Footnotes

Authorship Contributions: Surgical and Medical Practices - D.D.B., C.İ.G.; Concept - D.D.B., C.İ.G., S.Ö., M.B., İ.D., A.S., T.C.Ü.; Design - D.D.B., C.İ.G., S.Ö., Y.B.T., M.B., İ.D., A.S., T.C.Ü.; Data Collection or Processing - D.D.B., S.Ö., Y.B.T., M.B.; Analysis or Interpretation - M.B., İ.D., A.S., T.C.Ü.; Literature Search - C.İ.G., S.Ö., Y.B.T.; Writing - C.İ.G., S.Ö.

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