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ORIGINAL ARTICLE

Predictors of surgical intervention in pediatric orbital complications of acute rhinosinusitis

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ABSTRACT

Objectives: This study aims to evaluate clinical and radiological factors, particularly age, Chandler stage, and sinonasal anatomic variations, associated with surgical intervention in pediatric orbital complications secondary to acute rhinosinusitis.

Patients and Methods: This retrospective cohort study included 100 pediatric patients hospitalized between May 2020 and December 2025. Clinical, ophthalmological, and paranasal sinus computed tomography findings were reviewed. Chandler and Keros classifications, septal deviation, Agger nasi, Haller and Onodi cells, concha bullosa, adenoid hypertrophy, and frontal sinus agenesis were assessed. Factors associated with surgical intervention were analyzed using logistic regression analyses.

Results: The cohort comprised 100 pediatric patients (58 males, 42 females; median age: 7 years; interquartile range [IQR], 4 to 11 years; range, 0 to 17 years) hospitalized for acute rhinosinusitis with orbital complications, with a median hospital stay of eight days (IQR: 4 to 12.25). Surgery was required in 18% of cases, whereas 82% were managed medically. Chandler stage correlated with hospitalization duration (Spearman's rho = 0.583, $p < 0.001$). The surgery rate was 84.2% in Chandler Stage III or higher versus 2.5% in lower stages. In multivariate analysis, Chandler stage showed the strongest association with surgical intervention (adjusted odds ratio [aOR] = 205.0, 95% confidence interval [CI]: 30.99-1355.73, $p < 0.001$). Surgical probability also increased with age (aOR = 1.26 per year, 95% CI: 1.11-1.49, $p < 0.001$). Most anatomical variations were not significantly associated with surgery, although no patient with frontal sinus agenesis required surgical intervention.

Conclusion: Chandler stage and age were the factors most strongly associated with surgical intervention in pediatric orbital complications. These findings should be interpreted in the context of disease-severity-based clinical decision-making. Frontal sinus agenesis was associated with the absence of surgical intervention in this cohort; however, this finding should be interpreted as hypothesis-generating. Treatment planning should primarily rely on clinical staging and age rather than incidental anatomic variations.

Keywords: Orbital cellulitis, paranasal sinuses, rhinosinusitis.

Acute bacterial rhinosinusitis develops in approximately 5.0%-10.0% of cases following viral upper respiratory tract infections, and a small but clinically important proportion of these patients may develop orbital complications.[1-3] Early risk stratification and prompt treatment are essential to prevent rapid progression and permanent visual impairment. In children, the close anatomical relationship between the paranasal sinuses and the orbit facilitates the spread of infection to orbital structures. Management is guided by Chandler's classification, with early stages typically treated

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with intravenous (IV) antibiotics and advanced cases requiring surgery in the presence of abscess formation or visual deterioration.[4] Anatomical variations around the osteomeatal complex may impair sinus drainage and contribute to persistent infection and more severe orbital complications, although their impact on surgical requirement remains unclear.[5,6]

This study aimed to identify independent clinical and radiological factors associated with the need for surgical intervention in pediatric patients hospitalized with orbital complications secondary to acute rhinosinusitis.

PATIENTS AND METHODS

Study design

This single-center retrospective observational cohort study was conducted at University of Health Sciences, Başakşehir Çam and Sakura City Hospital, Department of Otorhinolaryngology. All consecutive pediatric patients aged 0-18 years who were hospitalized for acute rhinosinusitis with orbital complications between May 2020 and December 2025 were retrospectively identified from the electronic medical records and screened for eligibility. Orbital complications were confirmed by combined clinical, ophthalmological, nasal endoscopic, and computed tomography (CT) findings. Patients with complete medical records, documented nasal endoscopy, and paranasal sinus CT were included. Exclusion criteria were adulthood, immunodeficiency, cystic fibrosis, nasal polyposis, chronic rhinosinusitis, sinonasal malignancy, prior maxillofacial or sinus surgery, unrelated orbital pathology, and inadequate imaging or records. Due to the retrospective nature of the study, the requirement for written informed consent was waived by the ethics committee. The study protocol was approved by the Ethics Committee of Başakşehir Çam and Sakura City Hospital Clinical Research Ethics Committee (Date: 13.09.2023, No.: 2023-397). The study was conducted in accordance with the Helsinki Declaration.

Clinical and radiological evaluation

After admission to the emergency department, all patients were evaluated by pediatricians, otorhinolaryngologists, and ophthalmologists, and demographic, clinical, and hospitalization data were obtained from medical records. Non-contrast paranasal sinus CT images acquired using a 128-slice multidetector CT scanner (Somatom Definition, Siemens Healthcare, Erlangen, Germany) were reviewed in bone and soft-tissue windows by an otorhinolaryngologist and an experienced head and neck radiologist using a predefined framework that included Chandler staging, Keros classification, septal deviation, Agger nasi, Haller and Onodi cells, concha bullosa, adenoid hypertrophy, and frontal sinus development. Both reviewers assessed the scans independently while blinded to the clinical data and surgical outcomes, and discrepancies were resolved by consensus. Formal inter-rater reliability statistics were not calculated since the final dataset was based on consensus readings. Orbital complications were staged using Chandler's system and categorized as mild (Stages I-II) or complicated (Stages III-V). Chandler staging was assigned according to the clinical and radiological orbital findings recorded at presentation and reviewed independently from the final treatment outcome; however, given that surgical decision-making also relied on overlapping severity indicators, a degree of incorporation bias cannot be excluded. Olfactory fossa depth was classified according to Keros, and the presence of sinonasal variations, including Agger nasi, Haller and Onodi cells, concha bullosa, septal deviation, adenoid hypertrophy, and frontal sinus development, was recorded.

Treatment protocol and surgical indications

All patients were monitored during hospitalization and received IV ceftriaxone plus metronidazole, followed by oral antibiotics in those who improved; surgical treatment was adjusted according to culture results when available. Surgical decisions were made by a multidisciplinary team of otorhinolaryngologists and ophthalmologists based on the overall severity of orbital involvement, including ophthalmologic findings, radiologic evidence of abscess, and clinical progression despite IV therapy, rather than the Chandler stage alone. Indications for surgery included decreased visual acuity (Snellen chart), new-onset relative afferent pupillary defect, intraocular pressure > 21.0 mmHg, progressive extraocular movement restriction, or clinical/radiological failure after 24-48 h of IV therapy. To minimize inter-observer variability, all cases were managed and evaluated by the same multidisciplinary team specializing in pediatric rhinology and ophthalmology.

Statistical analysis

Analyses were performed using Jamovi (version 2.6; The Jamovi Project, Sydney, Australia) and R (version 4.4; R Foundation for Statistical Computing, Vienna, Austria).[7,8] Continuous variables were presented as mean ± standard deviation (SD) or median (IQR), and categorical variables as n (%).

Group comparisons used the Mann-Whitney U or Kruskal-Wallis test for continuous variables and the chi-square or Fisher's exact test for categorical variables. Correlations were assessed with Spearman's test. Univariate and multivariate logistic regression identified independent predictors of surgical requirement, reported as odds ratios (ORs) with 95% confidence intervals (CIs). Statistical significance was set at $p < 0.05$.

RESULTS

Demographic characteristics and duration of hospitalization

A total of 100 pediatric patients (58 males, 42 females; median age: 7 years; IQR, 4 to 11 years; range, 0 to 17 years) who were hospitalized for acute rhinosinusitis with orbital complications were included, with a median hospital stay of eight days (IQR: 4-12.25), as shown in Table 1. Surgery was required in 18% of cases, whereas 82% were managed medically. The median age was 10 years (IQR: 2.75) in the surgical group and six years (IQR: 6.0) in the medically managed group. Age showed a significant positive correlation with length of hospitalization (Spearman's rho = 0.351, $p < 0.001$), whereas hospital stay did not differ by sex ($p = 0.742$).

Chandler's classification and clinical progression

Patient distribution by Chandler stage is shown in Table 2. Most cases were classified as Stage I (74%), whereas complicated orbital infections (Stage III or higher) accounted for 19% of the cohort. Chandler stage showed a moderate positive correlation with hospital stay (Spearman's rho = 0.583, $p < 0.001$), and hospitalization duration increased significantly with advancing stage (Kruskal-Wallis H = 33.96, $p < 0.001$). Surgical intervention was required in 84.2% (16/19) of patients with Chandler Stage III or higher, compared with 2.5% (2/81) of those with Stage I-II.

Radiological findings and anatomical variations

The relationship between sinonasal anatomical variations and the requirement for surgical intervention is presented in Table 3. The presence of Onodi, Haller, and Agger nasi cells, as well as concha

Table 1. Demographic and clinical characteristics of the study population (n = 100)

Variables	n	%	Median	IQR
Age (year)			7	4-11
0-5			41	
6-9			26	
10-14			27	
15-17			6	
Sex				
Male	58	58		
Female	42	42		
Length of stay (days)			8	4-12.25
Treatment modality				
Surgical	18	18		
Medical	82	82		

IQR, interquartile range.

Table 2. Patient distribution and length of stay according to Chandler's classification

Chandler's classification	Clinical description	n	Median	IQR
Stage I	Preseptal cellulitis	74	5.5	2.25-10
Stage II	Orbital cellulitis	7	11	9-19
Stage III	Subperiosteal abscess	11	14	12.5-18
Stage IV	Orbital abscess	7	31	13.5-35
Stage V	Cavernous sinus thrombosis	1	51	

IQR, interquartile range.

Table 3. Univariate logistic regression analysis of factors associated with surgical intervention

Variables	Surgical (n)	Medical (n)	Total (n)	OR	95% CI	p
Chandler Stage ≥ III	16	3	19	210.67	32.53-1364.31	< 0.001*
Keros type 2-3	10	62	72	0.40	0.14-1.16	0.092
Septal deviation	10	27	37	1.90	0.97-3.72	0.061
Onodi cell	2	7	9	1.34	0.25-7.06	0.730
Haller cell	7	15	22	2.84	0.95-8.55	0.063
Agger nasi cell	6	20	26	1.55	0.52-4.67	0.436
Concha bullosa	2	17	19	0.48	0.10-2.28	0.355
Adenoid hypertrophy	9	47	56	0.75	0.27-2.07	0.572
Frontal sinus agenesis	0	35	35	-	-	< 0.001**

OR, odds ratio; CI, confidence interval; * Statistical significance was set at $p < 0.05$; ** Frontal sinus agenesis was excluded from the logistic regression model due to zero frequency in the surgical group and was instead analyzed using Fisher's exact test ($p < 0.001$).

Table 4. Multivariate logistic regression analysis of factors predicting surgical requirement

Variables	aOR	%95 CI	p
Chandler Stage ≥ III	205.00	30.99-1355.73	< 0.001*
Keros type 2-3	0.46	0.06-3.32	0.443

aOR: adjusted odds ratio; CI, confidence interval; * Statistical significance was defined as $p < 0.05$.

bullosa and adenoid hypertrophy, had no statistically significant effect on surgical requirements (all p-values > 0.05). None of the 35 patients with frontal sinus agenesis required surgical intervention. Among the anatomical variations, septal deviation (OR = 1.90, $p = 0.061$), Keros types 2-3 (OR = 0.40, $p = 0.092$), and Haller cells (OR = 2.84, $p = 0.063$) demonstrated a trend toward association with surgical requirement; however, these relationships did not reach the level of statistical significance.

Factors predicting the requirement for surgical intervention

In the univariate analysis, Chandler Stage ≥ III was strongly associated with surgical requirement (OR: 210.67, 95% CI: 32.53-1364.31, $p < 0.001$) (Table 3). No sinonasal anatomical variation was significantly associated with surgery, although septal deviation, Haller cells, and Keros types 2-3 showed borderline associations (all $p > 0.05$). Multivariate logistic regression including variables with clinical relevance or borderline univariate associations, as presented in Table 4, showed that Chandler Stage ≥ III remained strongly associated with surgical intervention (adjusted odds ratio [aOR]: 205.0, 95% CI: 30.99-1355.73, $p < 0.001$). Although Keros classification showed a borderline univariate association ($p = 0.092$), it was not confirmed as an independent predictor after adjustment for Chandler Stage (aOR: 0.46, 95% CI: 0.06-3.32, $p = 0.443$).

Surgical intervention and the factor of age

Age was found to have a significant linear effect on the requirement for surgical intervention. For every one-year increase in age, the probability of requiring surgery increased by 26% (aOR: 1.26/year; 95% CI: 1.11-1.49; $p < 0.001$). In addition to this linear increase, categorical analyses based on age groups revealed that the risk of surgery increased markedly beyond certain age thresholds. Compared to the 0-5 age group, the requirement for surgery was 13.33 times higher in the 10-14 age group (95% CI: 2.61-68.05, $p = 0.002$) and 20 times higher in the 15-17 age group (95% CI: 2.75-145.47, $p = 0.003$); these differences were statistically significant. The results of the multiple comparison analysis regarding the risk of surgical intervention across different age categories are summarized in Table 5.

DISCUSSION

Pediatric orbital complications secondary to rhinosinusitis require urgent care to prevent vision loss and intracranial spread. Since identifying surgical

Table 5. Odds ratios for surgical requirement among pediatric age categories: Inter-group comparisons

Age groups	0-5 years	6-9 years	10-14 years	15-17 years
0-5 years				
OR	-	1.739	13.33	20.00
95% CI	-	0.22-13.1	2.61-68.0	2.75-145.4
p	-	0.592	0.002*	0.003*
6-9 years				
OR	0.57	-	7.67	11.50
95% CI	0.07-4.36	-	1.47-39.9	1.55-85.1
p	0.592	-	0.016*	0.017*
10-14 years				
OR	0.07	0.13	-	1.50
95% CI	0.01-0.38	0.02-0.68	-	0.30-7.43
p	0.002*	0.016*	-	0.619
15-17 years				
OR	0.05	0.08	0.66	-
95% CI	0.01-0.36	0.01-0.64	0.13-3.30	-
p	0.003*	0.017*	0.619	-

OR, odds ratio; CI, confidence interval; * Statistical significance was defined as $p < 0.05$.

candidates remains difficult, this study evaluates the prognostic impact of age and sinonasal anatomy on surgical requirements.

Chandler's classification showed the strongest association with hospital stay and surgical intervention in our cohort. Most cases were successfully managed medically, consistent with the literature supporting conservative treatment as the primary approach for many orbital infections.[9] However, surgical rates increased markedly in patients with Chandler Stage III or higher, in line with previous studies highlighting the importance of advanced Chandler stages in surgical decision-making.[10,11] Higher stages were also associated with longer hospital stays, reflecting greater disease severity. Nevertheless, this finding should be interpreted with caution, as Chandler staging overlaps with the clinical and radiological severity markers used in surgical decision-making. Therefore, its strong association with surgical intervention may partly reflect incorporation bias, and the Chandler stage should be regarded primarily as a marker of disease severity rather than a fully independent predictor.

The role of sinonasal anatomical variations in the development and clinical course of orbital complications remains uncertain. Although variations such as concha bullosa and septal deviation may impair osteomeatal drainage, evidence that they independently predict clinical severity or surgical requirement is limited.[6,12] Similarly, Shpilberg et al.,[6] Crosbie et al.,[12] and Çelik et al.[13] found no significant association between these radiological variations and clinical outcomes or the need for surgery. As emphasized by Wong and Levi,[11] surgical intervention in pediatric orbital complications is primarily driven by clinical and radiological severity rather than anatomical variations. Our findings support this view, as no statistically significant association was detected between sinonasal anatomical variations and surgical requirement. However, septal deviation, Haller cells, and higher Keros types showed borderline associations, and these findings may have failed to reach statistical significance due to the limited sample size and the relatively small number of surgical events. Therefore, these variables should not be interpreted as definitively uninfluential, but rather as factors whose role requires confirmation in larger cohorts.

Notably, patients with frontal sinus agenesis in our cohort required no surgical intervention and had a shorter length of stay. Pediatric paranasal sinus studies indicate that frontal sinus maturation is strongly age-dependent and may influence patterns of infectious spread.[1,15] As noted by Palabıyık,[16] frontal sinus development continues throughout childhood and adolescence. D'Anza et al.[17] reported that the frontal sinus infundibulum is structurally more complex in adults and more susceptible to developmental variation in children. In addition, Taubenslag et al.[18] suggested that the onset of frontal sinus pneumatization may promote sequestration of infection and increase surgical requirement through impaired drainage. Thus, an aerated frontal sinus may provide an anatomical substrate that facilitates infectious spread; however, since frontal sinus development is closely related to age, any association between frontal sinus anatomy and clinical outcome should be interpreted cautiously. In our cohort, no patient with frontal sinus agenesis required surgical intervention, suggesting a potentially more favorable course in this subgroup. Nevertheless, frontal sinus pneumatization is inherently age-dependent, and agenesis is more common in younger children, who also tend to respond better to conservative treatment.[17] Therefore, the observed association between frontal sinus agenesis and the absence of surgical intervention may partly reflect age-related clinical differences rather than a purely independent anatomical effect. Previous studies have likewise shown that age is associated with patterns of infectious spread, microbiological profile, and overall treatment outcomes in pediatric orbital complications.[9,17,19] Accordingly, age and frontal sinus development should be considered interrelated variables, and this observation should be regarded as hypothesis-generating rather than evidence of a causal protective effect.

Our analyses identified age as an important determinant of surgical requirement, with the sharpest increase observed in children aged ≥ 10 years. This is consistent with studies identifying age > 9 years as a clinically relevant threshold for increased surgical risk.[9,20,21] Similarly, Zhao et al.[22] reported a positive correlation between advanced age and surgical need, while Smith et al.[20] emphasized a lower threshold for intervention in children older than nine years. Younger children generally show better response to conservative treatment and fewer postoperative complications, whereas older children are more likely to require surgery, particularly in the presence of visual impairment or extensive subperiosteal abscesses.[11,18,20,23] This difference may reflect incomplete frontal sinus development, earlier diagnosis, and more localized abscesses in younger children versus increasing sinus volume, more organized infection, and polymicrobial processes in older children.[9,24]

This study has several limitations. Its retrospective, single-center design may limit generalizability. The limited number of surgical events and the skewed distribution of Chandler stages may have reduced the power to detect modest associations for some sinonasal anatomical variables and to robustly analyze advanced complications. Lamina papyracea defects were excluded, as congenital dehiscence and inflammatory erosion are difficult to distinguish on retrospective imaging. Formal inter-rater reliability statistics were not calculated, although image assessments were performed independently using predefined criteria and finalized by consensus. In addition, given that frontal sinus maturation is strongly age-dependent, the apparent association between frontal sinus agenesis and a more favorable clinical course could not be fully separated from the effect of age. Finally, since the Chandler stage overlaps with the severity criteria used in surgical decision-making, a degree of incorporation bias cannot be excluded.

In conclusion, age and clinical stage were the variables most strongly associated with management decisions in pediatric orbital complications. Given that Chandler staging overlaps with the severity criteria used in surgical decision-making, its prognostic value should be interpreted cautiously. Sinonasal anatomical variations were not statistically significant predictors, although some showed borderline associations. Frontal sinus agenesis was associated with a more favorable course, but this finding should be interpreted cautiously and regarded as hypothesis-generating. Overall, treatment decisions should be based primarily on disease severity and orbital involvement.

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Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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