Original Article

DOI: 10.4274/haseki.galenos.2026.44127
Med Bull Haseki 2026;64(1):35-41

Magnetic Resonance Imaging in the Evaluation of Sinusitis Related Complications in Children

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Abstract

Aim: Acute sinusitis in children can occasionally lead to orbital or intracranial complications as a result of contiguous spread of infection. We aimed to evaluate the magnetic resonance imaging (MRI) features and distribution patterns of these complications in pediatric patients with acute paranasal sinusitis.

Methods: This retrospective analytical study included 32 pediatric patients (aged 0-18 years) who underwent contrast-enhanced brain and diffusion-weighted MRI between May 2017 and April 2024 for suspected sinusitis-related complications. Demographic data (age, sex), sinus involvement, and MRI findings were evaluated. Statistical analyses were performed using chi-square tests and Student's t-tests; a p-value of <0.05 was considered significant. All MR images were reviewed by a pediatric neuroradiologist with ten years of experience.

Results: Among the 32 pediatric patients, the most frequent complication was subperiosteal abscess (n=15, 46.9%), followed by preseptal cellulitis (n=13, 40.6%). Less common findings included epidural empyema (n=2, 6.3%), venous sinus thrombosis (n=1, 3.1%), cerebral abscess (n=1, 3.1%), and cerebral infarction (n=1, 3.1%). Involvement of the ethmoid and maxillary sinuses was significantly more frequent in younger children (p<0.01), whereas involvement of the sphenoid and frontal sinuses was more common in older patients (p=0.03). When evaluated by complication type, orbital complications predominated in younger patients, while intracranial complications were more frequent in older age groups (p=0.02). This indicates a statistically significant age-related shift in the patterns of sinus involvement and distribution of complications.

Conclusion: Magnetic resonance imaging plays a critical role in detecting and characterizing sinusitis-related complications in pediatric patients. Beyond confirming a diagnosis, it provides valuable information for clinical decision-making and surgical planning. Recognizing age-dependent sinus involvement patterns helps predict the potential routes and severity of the spread of complications, ultimately improving outcomes and reducing morbidity.

Keywords: Child, sinusitis, complications, magnetic resonance imaging

Introduction

Sinusitis is common in children and is usually associated with upper respiratory tract infections. Acute sinusitis typically occurs due to viral agents and follows a self-limited course. However, bacterial superinfections may develop in some cases, increasing the risk of complications (1). Although sinusitis is a significant health problem in pediatric patients, it can lead to serious complications if not diagnosed and treated promptly.

Symptoms of sinusitis in children may include nasal congestion, mucopurulent nasal discharge, cough, fever, and facial pain (2). Although radiographic imaging is usually unnecessary, it can be used to confirm the diagnosis in selected cases. However, plain radiography

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Received: 25.03.2025 **Accepted:** 17.01.2026 **Publication Date:** 30.01.2026

Cite this article as: Ozturk M, Ersoz Polat N, Caliskan E, Erdur O. Magnetic resonance imaging in the evaluation of sinusitis related complications in children. Med Bull Haseki. 2026;64(1):35-41

in children may be misleading; therefore, more advanced imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) are preferred (3,4). While CT provides high sensitivity in evaluating bony structures, MRI offers superior soft-tissue resolution and, importantly, does not involve ionizing radiation—an advantage in pediatric patients (5). Complications of sinusitis include preseptal and postseptal cellulitis, subperiosteal abscess, meningitis, cerebritis, epidural and subdural empyema, cavernous sinus thrombosis, and cerebral venous sinus thrombosis (6). Ethmoid and maxillary sinus infections are more frequent in younger children, whereas sphenoid and frontal sinus infections are more common in older age groups (7). Magnetic resonance imaging allows clear visualization of soft tissue and intracranial structures, making it particularly valuable in detecting the extension and nature of sinusitis-related complications (8,9). Recent studies highlight the importance of a multidisciplinary approach to the management of pediatric sinusitis complications (10). Diffusion-weighted MRI sequences, particularly for early detection of intracranial involvement, have been shown to enhance diagnostic accuracy (11). Moreover, combining surgical and medical management strategies provides optimal outcomes for these patients (12). We hypothesized that MRI could effectively demonstrate both orbital and intracranial complications related to acute sinusitis in pediatric patients, thereby improving diagnostic confidence and clinical management.

This study aimed to investigate the MRI findings of complications resulting from the local spread of acute paranasal sinusitis in pediatric patients. By defining the characteristic MRI features of these complications, the study seeks to improve diagnostic accuracy and promote the earlier recognition of serious disease extension. This, in turn, is expected to facilitate timely clinical management and multidisciplinary decision-making, thereby contributing to better patient outcomes and advancing the diagnostic approach in pediatric radiology.

Materials and Methods

Compliance with Ethical Standards

This retrospective study was approved by the Selcuk University Rectorate Local Ethics Committee (approval no.: 2024/447, date: 18.09.2024). The research was conducted in accordance with the principles of the Declaration of Helsinki (2013 revision). Patient confidentiality was maintained throughout the study, and all data were anonymized prior to analysis. Due to the retrospective design, obtaining informed consent from individual participants was deemed unnecessary by the ethics committee.

Study Design and Population

The step-by-step process for selecting patients included in this retrospective cohort study is illustrated in the flowchart below (Figure 1). This study had a retrospective cohort design. Pediatric patients aged 0-18 years who underwent contrast-enhanced brain MRI and diffusion-weighted MRI between May 2017 and April 2024 for suspected sinusitis-related complications were included. The hospital's Radiology Information System and Picture Archiving and Communication System were searched using the keywords "sinusitis," "orbital cellulitis," "subperiosteal abscess," "intracranial complication," and "paranasal sinus infection."

Inclusion and Exclusion Criteria

Inclusion criteria were (1) age 0-18 years; (2) clinical diagnosis of sinusitis; and (3) availability of contrast-enhanced brain MRI and diffusion MRI with diagnostic image quality. Exclusion criteria included history of trauma, congenital craniofacial anomalies, known malignancy, prior sinus surgery, or non-diagnostic or artifactual images.

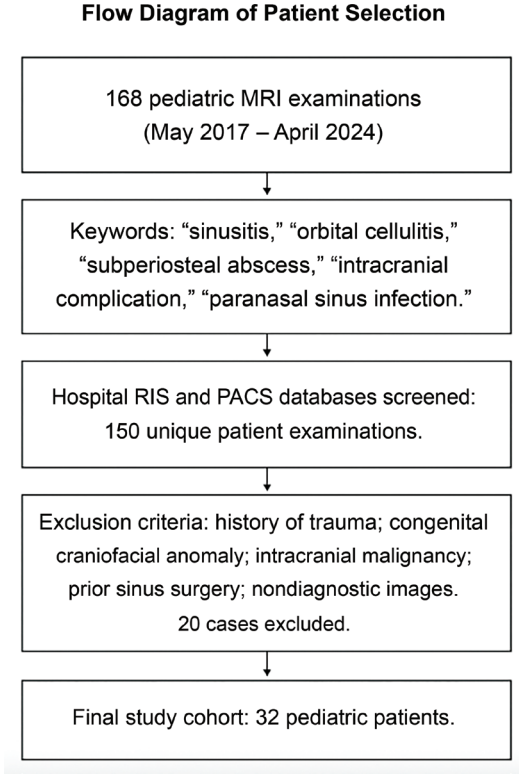

Figure 1. Flow diagram illustrating the step-by-step selection process of pediatric patients included in the retrospective cohort study. The diagram summarizes the total number of MRI examinations reviewed, applied inclusion and exclusion criteria, and the final study cohort of 32 patients

MRI: Magnetic resonance imaging, RIS: Radiology information system, PACS: Picture archiving and communication system

Based on these criteria, 32 pediatric patients were included.

MRI Protocol

All MRI examinations were performed on a 1.5-Tesla system (Siemens Magnetom Aera, Erlangen, Germany) using a standardized pediatric brain protocol optimized to evaluate complications of sinusitis. The sequences included an axial T1-weighted spin-echo sequence (TR/TE =500/10 ms; slice thickness =4 mm; interslice gap =1 mm; matrix =256 × 256; field of view =220 × 220 mm). Axial T2-weighted turbo spin-echo (TR/TE: 4000/100 ms, echo train length: 15, same slice parameters). Axial and coronal FLAIR (TR/TE/TI: 9000/90/2500 ms, slice thickness: 4 mm, FOV: 220 × 220 mm). Axial diffusion-weighted imaging (b-values: 0 and 1000 s/mm², TR/TE: 3500/90 ms, slice thickness: 4 mm, matrix: 192 × 192). Post-contrast T1-weighted sequences were acquired in axial, coronal, and sagittal planes following intravenous administration of 0.1 mmoL/kg gadolinium-based contrast agent, using acquisition parameters identical to those of the pre-contrast T1-weighted imaging. Fat-suppressed sequences were used in the orbital and paranasal sinus regions to enhance soft-tissue contrast. All images were interpreted by a pediatric neuroradiologist with 10 years of experience.

Image Analysis

Evaluated parameters included the involved sinuses (maxillary, ethmoid, frontal, and sphenoid); orbital complications (preseptal/postseptal cellulitis, subperiosteal abscess); intracranial complications (meningitis, cerebritis, epidural/subdural empyema, abscess, sinus vein thrombosis, and cavernous sinus thrombosis); and bone changes (osteomyelitis and erosion). Preseptal cellulitis was defined as anterior orbital septum edema or enhancement, postseptal cellulitis as posterior orbital septum inflammation, and subperiosteal abscess as a fluid collection between the periosteum and the underlying bone.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA). The normality of data distribution was evaluated using the Shapiro-Wilk test. Continuous variables were expressed as mean ± standard deviation for normally distributed data or as median (interquartile range) for non-normally distributed data; categorical variables were presented as frequencies and percentages. For comparisons between groups, the Student's t-test and the Mann-Whitney U test were used for parametric and non-parametric data, respectively. Categorical variables were analyzed using the chi-square test or Fisher's exact test, as appropriate. To enhance the analytical rigor of the study, inferential and correlational analyses were incorporated. Specifically, the relationship between age and type of complication (orbital vs. intracranial) was analyzed using the Spearman's rank correlation coefficient.

The association between frontal sinus involvement and the presence of intracranial complications was evaluated using the chi-square test. Additionally, the co-occurrence of orbital and intracranial complications was assessed to compare the age distribution and clinical characteristics between groups. All statistical analyses were two-tailed, and a p-value <0.05 was considered statistically significant.

Results

The mean age of the 32 pediatric patients included in the study was 8.7±3.4 years (range: 2-17 years). Of these patients, 19 (59.4%) were male and 13 (40.6%) were female, yielding a male-to-female ratio of 1.46:1 (p=0.41, not statistically significant).

On MRI, ethmoid sinus involvement was identified in 28 patients (87.5%) and was the most frequently affected paranasal sinus. This rate was significantly higher than those for maxillary (81.3%), frontal (53.1%), and sphenoid (28.1%) sinus involvement (p<0.01). Involvement of multiple sinuses was present in 22 patients (68.8%), and the most frequent combination was the concurrent involvement of the ethmoid and maxillary sinuses (n=18, 56.3%).

Sinusitis-related complications were classified into two major categories: orbital and intracranial. Orbital complications were identified in 28 patients (87.5%), whereas intracranial complications occurred in 7 patients (21.9%). Both orbital and intracranial complications coexisted in 3 patients (9.4%). The mean age of patients with orbital complications was significantly lower than that of those with intracranial complications (p=0.02).

Among orbital complications, subperiosteal abscesses were the most common finding, detected in 15 patients (46.9%). Most of these abscesses were localized to the periorbital region (n=10, 31.3%; Figure 2), whereas frontal subperiosteal abscesses occurred in five patients (n=5, 15.6%; Figure 3). All periorbital subperiosteal abscesses were confined to the medial orbital wall (p<0.01). Preseptal cellulitis occurred in 13 patients (40.6%) and was the second most common orbital pathology, followed by postseptal cellulitis in 5 patients (15.6%). Notably, all cases of postseptal cellulitis also demonstrated concomitant preseptal cellulitis (n=5; 100%), supporting the progressive spread of infection from the preseptal to the postseptal compartment (p<0.01).

Regarding intracranial complications, subdural empyema was identified in 2 patients (6.3%; Figure 4), whereas epidural empyema, sinus vein thrombosis, cerebral abscess, cerebral infarction, and transient callosal

lesion were each observed in 1 patient (3.1%; Figure 5). The majority of intracranial complications (n=5, 71.4%) were associated with frontal sinusitis; this association was statistically significant (p=0.03).

A single complication was detected in 19 patients (59.4%), whereas multiple complications were present in 13 patients (40.6%) (p=0.27; not statistically significant). The most frequent combination was preseptal cellulitis with periorbital subperiosteal abscess (n=7, 21.9%).

When stratified by age group, orbital complications were predominant in the 0-5-year age group (n=8; 87.5%), while both orbital and intracranial complications were most common in the 6-12-year age group (n=15; 73.3% orbital, 26.7% intracranial). Intracranial complications were more frequently observed in the 13-17-year age group (33.3%), and this age-related increasing trend was statistically significant (p=0.04).

Correlation analyses further supported these findings. A significant positive correlation (r=0.38, p=0.04) was identified between age and complication type (orbital vs. intracranial), indicating that intracranial complications were more likely to occur in older children. The association between frontal sinus involvement and intracranial complications was also statistically significant (p=0.03). Additionally, patients with orbital complications were found to be significantly younger than those with intracranial involvement (p=0.02).

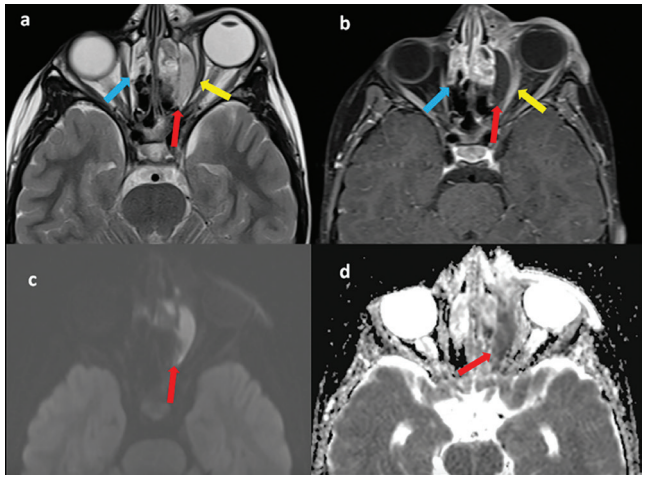

Figure 2. Thirteen-year-old female with ethmoidal sinusitis complicated by orbital subperiosteal abscess. Contrast-enhanced brain MRI (a, b) and diffusion-weighted imaging (c, d) show ethmoidal sinusitis with erosion of the lamina papyracea (blue arrow) and a rim-enhancing, loculated retro-orbital subperiosteal collection exhibiting diffusion restriction (red arrow), consistent with an abscess. The medial rectus muscle appears thickened and displaced laterally (yellow arrow), indicating inflammatory involvement and mass effect from the adjacent abscess. These findings highlight the typical pathway of infection spread from the ethmoid sinus through the lamina papyracea into the orbital compartment

MRI: Magnetic resonance imaging

Discussion

This study provides a detailed analysis of MRI findings in pediatric patients with acute paranasal sinusitis and its complications, emphasizing data specific to our cohort. The results indicate that ethmoid sinus involvement was the most frequent finding, while frontal sinus involvement was significantly associated with intracranial complications, underscoring a potential anatomical pathway for the spread of infection. Moreover, the significant positive correlation between age and the occurrence of intracranial complications indicates that the type and severity of complications vary across age groups. These findings not only align with existing literature but also extend current knowledge by defining MRI-based diagnostic patterns and risk associations specific to the pediatric population evaluated in this study.

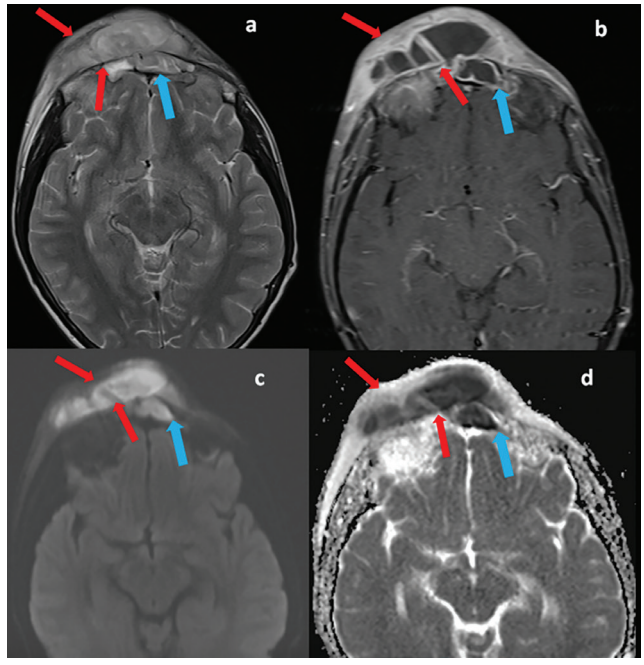

Figure 3. Twelve-year-old male with frontal sinusitis complicated by subperiosteal abscess formation. Contrast-enhanced brain MRI (a, b) and diffusion-weighted imaging (c, d) demonstrate frontal sinusitis with erosion of the anterior sinus wall and a rimenhancing, loculated subperiosteal collection along the frontal bone (red arrow), showing diffusion restriction consistent with an abscess. The affected frontal sinus exhibits mucosal thickening and fluid accumulation (blue arrow), indicating active inflammation. Adjacent subgaleal soft tissue edema and enhancement are also evident, supporting the diagnosis of Pott's puffy tumor secondary to frontal sinusitis

MRI: Magnetic resonance imaging

The most common complication in our study was subperiosteal abscess, consistent with studies reporting that it is among the most common complications in pediatric sinusitis (1). The anatomical proximity of the ethmoid sinuses to the orbital periosteum explains the high incidence of subperiosteal abscesses. The direct spread of ethmoid sinus infections across the lamina papyracea into the periorbital tissues facilitates abscess formation. Notably, all periorbital subperiosteal abscesses in our cohort were localized to the medial orbital wall, supporting the view that the most frequent route by which infection spreads from the ethmoid sinus to the orbit is through the lamina papyracea (12). Additionally, the proportion of frontal subperiosteal abscesses among all subperiosteal abscesses in our series (33.3%) was comparable to the 25% rate reported in the literature (13). The high frequencies of preseptal (40.6%) cellulitis and postseptal cellulitis (15.6%) align with reports identifying preseptal cellulitis as a common early-stage orbital complication in pediatric sinusitis (3). The observation that all postseptal cellulitis cases were accompanied by preseptal cellulitis supports the notion of stepwise infectious progression through the orbital septum. Although postseptal cellulitis is less common, it remains clinically important because it can progress to severe complications, such as orbital abscess or cavernous sinus thrombosis (4). In addition to these literature-supported observations, our findings emphasize that localization to the medial orbital wall and combined ethmoid and maxillary sinus involvement were particularly distinctive features of this cohort, suggesting that the anatomical configuration of the pediatric paranasal sinuses may predispose to this characteristic pattern of spread. Furthermore, the relatively higher incidence of frontal subperiosteal abscesses in our study may indicate an age-related increase in frontal sinus aeration and susceptibility to infection, thereby providing

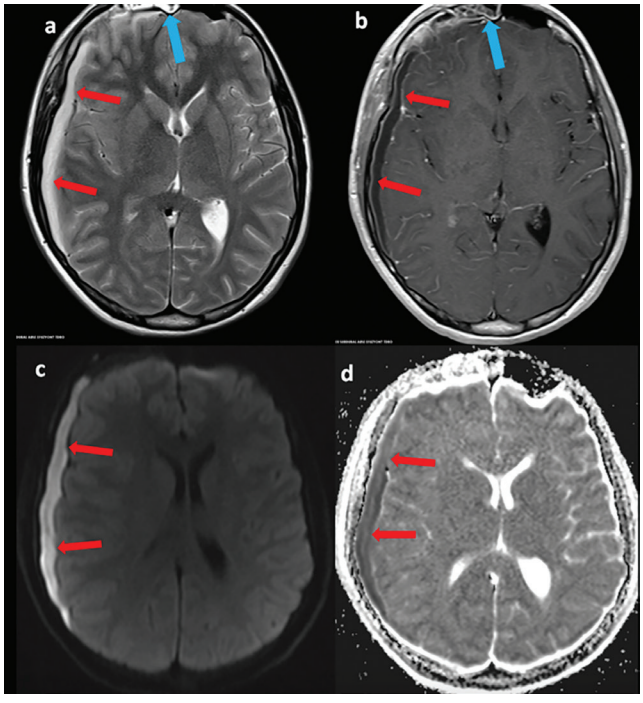

Figure 4. Nine-year-old male with frontal sinusitis complicated by subdural empyema. Contrast-enhanced brain MRI (a, b) and diffusion-weighted imaging (c, d) demonstrate right frontal sinusitis with mucosal thickening and enhancement (blue arrow). In the adjacent right frontotemporal region, a crescent-shaped extra-axial collection with peripheral enhancement and marked diffusion restriction is seen (red arrow), consistent with subdural empyema. Associated dural thickening and enhancement are evident, indicating inflammatory spread from the frontal sinus. Mild adjacent cortical edema and mass effect on the frontal lobe further support the diagnosis of intracranial extension secondary to sinusitis

MRI: Magnetic resonance imaging

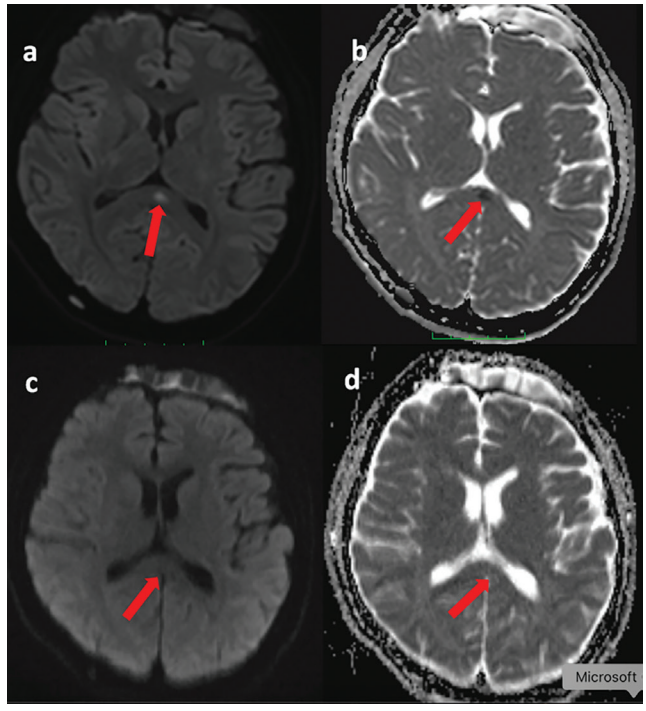

Figure 5. Fourteen-year-old male with pansinusitis and transient splenial lesion of the corpus callosum. Diffusion-weighted MRI obtained on admission (a, b) demonstrates a well-defined focus of restricted diffusion in the splenium of the corpus callosum (red arrow), without corresponding contrast enhancement, consistent with a transient cytotoxic lesion. Follow-up MRI performed 16 days later (c, d) shows complete resolution of the diffusion abnormality, confirming its reversible nature. This transient splenial lesion likely represents a secondary inflammatory or metabolic response associated with systemic infection and sinusitis, rather than direct infectious involvement of the corpus callosum

MRI: Magnetic resonance imaging

a pathophysiological explanation specific to the pediatric population evaluated.

Intracranial complications, including meningitis, cerebral abscess, epidural empyema, subdural empyema, and venous sinus thrombosis, were observed in 21.9% of patients in our cohort, underscoring the considerable prevalence of these severe outcomes. This rate is comparable to the 15-20% incidence reported in previous studies (14). The detected intracranial complications included subdural empyema (6.3%), epidural empyema (3.1%), venous sinus thrombosis (3.1%), cerebral abscess (3.1%), and cerebral infarction (3.1%). Notably, 71.4% of these cases were associated with frontal sinusitis, indicating that frontal sinus involvement represents a significant anatomical and clinical risk factor for intracranial spread. In our cohort, both patients who developed neurological sequelae had intracranial complications, further emphasizing their clinical significance and potential for long-term morbidity. Moreover, the single case of cerebral abscess required surgical drainage and prolonged antibiotic therapy, which confirms the aggressive clinical course of this complication despite early recognition and management (7). These findings indicate that although the frequency of intracranial complications parallels previous reports, their clinical presentation and treatment requirements in our study underscore the importance of early MRI evaluation for timely detection and intervention, particularly in cases related to frontal sinusitis.

The results of our study demonstrated that the distribution of complications varied significantly among age groups, revealing characteristic patterns at different developmental stages. Orbital complications predominated in younger children (0-5 years, 87.5%), whereas intracranial complications were more frequent in adolescents (13-17 years, 33.3%). This age-related shift in complication patterns corresponds to the progressive pneumatization and anatomical maturation of the frontal sinuses, which facilitates the superior and posterior spread of infection in older patients. These findings are consistent with reports indicating an increased risk of intracranial complications in adolescents due to greater frontal sinus development and increased venous drainage complexity (15). Furthermore, the meta-analysis conducted by Patel et al. (15) confirmed a higher incidence of intracranial complications in this age group. In our cohort, this correlation between age and type of complication ($r=0.38$, $p=0.04$) supports the pivotal role of anatomical maturation in the pathophysiological transition from orbital to intracranial involvement and represents a key age-dependent risk factor specific to pediatric sinusitis.

In our study, MRI proved highly effective in evaluating pediatric sinusitis complications due to its superior soft tissue contrast and absence of ionizing radiation. The combined use of diffusion-weighted and contrast-enhanced sequences enabled the accurate detection of abscesses and dural enhancement, and the differentiation between empyema and cellulitis (8). The consistent peripheral enhancement in all subperiosteal abscesses further underscored the diagnostic value of post-contrast imaging. Moreover, FLAIR and T2-weighted sequences effectively demonstrated meningeal inflammation and parenchymal edema, particularly in cases with intracranial extension (9). Our findings showed that subperiosteal abscess was the most frequent complication, and that frontal sinus involvement was significantly correlated with intracranial spread, confirming the strength of MRI in identifying patients at high risk. Based on these results, MRI stands as the cornerstone imaging modality for the early diagnosis and management of pediatric sinusitis complications. Prospective multicenter studies employing standardized protocols and advanced MRI techniques—including perfusion imaging, MR spectroscopy, and susceptibility-weighted imaging—are needed to validate and extend these findings for clinical practice (10).

Study Limitations

This study has several limitations that should be acknowledged. The retrospective design and limited sample size may restrict the generalizability of the findings. Additionally, being a single-center study limits the ability to compare diagnostic and management approaches across different institutions. Future multicenter, prospective studies with larger cohorts are needed to validate these results and better define institutional variability (10). Moreover, potential selection bias may have occurred because only patients who underwent MRI were included; individuals with milder forms of sinusitis complications who did not require MRI were therefore not represented. This could have influenced the observed incidence of complications. Furthermore, the absence of long-term follow-up data limits the evaluation of delayed or recurrent complications. Another limitation of the study is the lack of prognostic data on intracranial complications, which limits assessment of long-term neurological outcomes and recovery patterns in affected patients. Despite these limitations, this study provides a comprehensive MRI-based evaluation of sinusitis complications in pediatric patients. The inclusion of both contrast-enhanced and diffusion-weighted sequences, detailed clinical correlation, and age- and location-specific analyses enhances the scientific strength of the study and provides clinically meaningful insight into the diagnostic and prognostic value of MRI in this setting.

Conclusion

This study provides definitive evidence that MRI is an indispensable tool for diagnosing and managing

complications of pediatric sinusitis, revealing that subperiosteal abscesses predominate overall, while intracranial complications—more common in adolescents—are associated with more severe outcomes. MRI's superior soft-tissue contrast, multiplanar capabilities, and absence of ionizing radiation make it uniquely valuable for pediatric imaging; diffusion-weighted sequences are particularly effective at detecting abscesses and ischemic changes. Our age-stratified findings provide clinicians with critical guidance for risk assessment and intervention planning, emphasizing that early, accurate diagnosis through appropriate MRI protocols significantly reduces morbidity and mortality in these potentially serious conditions. Optimizing MRI techniques and protocols for complications of pediatric sinusitis is a crucial area for ongoing clinical research and development.

Ethics

Ethics Committee Approval: This retrospective study was approved by the Selcuk University Rectorate Local Ethics Committee (approval no.: 2024/447, date: 18.09.2024). The research was conducted in accordance with the principles of the Declaration of Helsinki (2013 revision).

Informed Consent: Due to the retrospective design, obtaining informed consent from individual participants was deemed unnecessary by the Ethics Committee.

Footnotes

Authorship Contributions

Surgical and Medical Practices: O.E., Concept: M.O., E.C., Design: N.E.P., O.E., Data Collection or Processing: M.O., E.C., Analysis or Interpretation: N.E.P., O.E., Literature Search: M.O., E.C., Writing: N.E.P.

Conflict of Interest: No conflicts of interest were declared by the authors.

Financial Disclosure: This study received no financial support.

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