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Surgically treated pediatric intracranial abscesses and empyemas: Characteristics and outcomes from a single-center experience

Cerrahi tedavi uygulanan pediyatrik intrakraniyal apse ve ampiyemler: Tek merkezli bir deneyimden özellikler ve sonuçlar

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ABSTRACT

Aim: Pediatric intracranial abscesses and empyemas are neurosurgical emergencies associated with significant morbidity and mortality. This study evaluated the clinical, radiological, and microbiological characteristics of surgically treated pediatric intracranial suppurative infections, as well as surgical management strategies, functional outcomes, and prognostic factors.

Material and Methods: Twenty-one pediatric patients who underwent surgery for intracranial abscess or empyema between November 2022 and 2025 were retrospectively reviewed. Demographic, clinical, radiological, laboratory, microbiological, and treatment-related data were analysed. Outcomes were assessed using the Glasgow Outcome Scale (GOS) at 6 months and classified as favourable (GOS 5) or unfavourable (GOS ≤ 4). Neurological sequelae were evaluated separately. Non-parametric statistical methods were applied.

Results: Subdural empyema was the most common diagnosis (66.7%), and most lesions were supratentorial (95.2%). The median age was 87 months, and 71.4% of patients were male. Craniotomy with drainage was performed in 95.2% of cases. Post-treatment C-reactive protein and white blood cell levels significantly decreased ($p<0.001$). At 6-month follow-up, 66.7% of patients achieved favourable functional outcomes. A Glasgow Coma Scale score <15 at presentation was strongly associated with unfavourable outcomes (100% vs. 6.7%; $p<0.001$). No significant association was found between outcomes and midline shift, cerebral edema, infection extent, seizure presence, or etiology. Neurological sequela occurred in 23.8% of patients, and no mortality or recurrence was observed.

Conclusion: Successful outcomes can be achieved in pediatric intracranial suppurative infections with appropriate surgical drainage and antibiotic therapy. Neurological status at presentation is the strongest determinant of functional outcome, whereas isolated radiological mass-effect findings have limited prognostic value.

Keywords: Brain abscess, subdural empyema, epidural abscess, child

ÖZ

Amaç: Pediatrik intrakraniyal abse ve ampiyemler, mortalite/morbidite riski taşıyan nöroşirürjik acillerdendir. Bu çalışmada, cerrahi olarak tedavi edilen pediatrik intrakraniyal süpüratif enfeksiyon olgularının klinik, radyolojik ve mikrobiyolojik özellikleri ile cerrahi yönetim stratejileri ve fonksiyonel sonlanımları değerlendirilmiş; prognozu belirleyen faktörler analiz edilmiştir.

Gereç ve Yöntemler: Kasım 2022–2025 arasında intrakraniyal abse veya ampiyem nedeniyle cerrahi uygulanan 21 pediatrik hasta retrospektif incelendi. Demografik, klinik, radyolojik, laboratuvar, mikrobiyolojik ve tedaviye ait veriler analiz edildi. Sonlanım 6. aydaki Glasgow Sonuç Ölçeği (GOS) ile değerlendirildi ve iyi (GOS 5) ve kötü (GOS ≤ 4) olarak ikili sınıflandırıldı. Nörolojik sekel ayrı bir sonlanım ölçütü olarak ele alındı. İstatistiksel analizlerde parametrik olmayan yöntemler kullanıldı.

Bulgular: En sık tanı subdural ampiyemdi (%66,7) ve büyük çoğunluğu supratentoryaldi (%95,2). Medyan yaş 87 aydı, hastaların %71,4'ü erkekti. Olguların %95,2'sine kraniyotomi ile drenaj uygulandı. Tedavi sonrası C-reaktif protein ve beyaz küre değerlerinde anlamlı düşüş saptandı (her ikisi için $p<0,001$). Altı aylık takipte %66,7'sinde iyi fonksiyonel sonlanım görüldü. Başvuru anında GKS <15 olması kötü sonlanım ile güçlü şekilde ilişkiliydi (%100 vs. %6,7; $p<0,001$). Buna karşın orta hat şifti ($p=0,638$), beyin ödemi ($p=1,000$), enfeksiyon yaygınlığı ($p=0,659$), nöbet varlığı ($p=0,061$) ve etiyoloji ($p=1,000$) ile sonlanım arasında anlamlı ilişki saptanmadı. Nörolojik sekel oranı %23,8 idi. Mortalite ve enfeksiyon nüksü izlenmedi.

Sonuç: Pediatrik intrakraniyal enfeksiyonlarda uygun cerrahi ve antibiyoterapi ile başarılı sonuçlar mümkündür. Başvuru sırasındaki nörolojik durum, fonksiyonel sonlanımın en önemli belirleyicisidir; izole radyolojik kitle etkisi bulgularının ise prognostik değeri sınırlıdır.

Anahtar Kelimeler: Beyin apsesi, subdural ampiyem, epidural apse, çocuk

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Highlights

- Subdural empyema was the most common diagnosis among surgically treated pediatric intracranial abscess and empyema cases, with predominantly supratentorial localization.
- Craniotomy with drainage combined with antibiotic therapy resulted in a significant reduction in inflammatory markers (CRP and WBC).
- At six-month follow-up, two-thirds of patients achieved complete functional recovery (GOS 5), with no mortality or recurrence observed.
- Neurological status at presentation (GCS <15) was the strongest factor associated with unfavorable functional outcome.
- Isolated radiological mass-effect findings (midline shift and cerebral edema) and infection extent did not significantly predict functional outcome.

INTRODUCTION

Pediatric intracranial suppurative infections (brain abscess, subdural empyema, and epidural empyema) are life-threatening neurosurgical emergencies that require early diagnosis and prompt, effective intervention (1,2). Although these infections are uncommon, the risk of permanent neurological sequelae and mortality persists, with reported mortality rates ranging from 4% to 32% across different series (3-7). Advances in modern imaging, microbiological diagnostics, rapid antibiotic therapy, and early surgical approaches have been associated with a marked reduction in mortality over the past 15 years (8-11). Brain abscesses have been reported to account for approximately 8% of all intracranial lesions, with nearly 25% of cases occurring during childhood; they are most commonly observed between 4 and 7 years of age and occur more frequently in males (11-17). Etiology varies with age; while meningitis-related complications predominate in younger children, contiguous foci such as sinusitis and otitis–mastoiditis, as well as a history of trauma or surgery, become more prominent in older children. Recent series report that sinusitis and trauma or iatrogenic causes are increasingly predominant, whereas congenital heart diseases have become less common, likely due to effective prophylaxis (4,8,18-20).

Clinical presentation is often nonspecific; the classic triad of headache, fever, and focal neurological deficit has been reported in only 9% to 28% of cases, with symptoms ranging from headache and fever to seizures, altered consciousness, and focal neurological deficits (12,15,21-24). In laboratory follow-up, C-reactive protein (CRP) levels are typically elevated, whereas leukocyte counts (WBC) may be normal or low (8,18,25,26). Combined surgical drainage and antibiotic therapy is the gold standard of treatment (13,27-30). Although burr-hole drainage is a minimally invasive option for subdural and epidural empyemas, some series have reported higher rates of reoperation and recurrence; craniotomy has been widely preferred, particularly in multiloculated or extensive lesions or in cases with an intracerebral component, as it allows effective drainage and, when necessary, decompression (20,22,31-34). With respect to prognosis, neurological status at presentation has been emphasized as one of the strongest determinants, with decreased level of consciousness and signs of herniation associated with poor outcomes (14,16,31,35-37).

In this study, the clinical, radiological, and microbiological characteristics of surgically treated pediatric intracranial suppurative infections, the surgical approaches applied, and their associations with functional outcomes were evaluated.

MATERIAL and METHODS

Study Design and Patient Selection

This study was designed as a single-center, retrospective, observational surgical series. Pediatric patients who underwent surgical treatment for intracranial suppurative infections at our institution between November 1, 2022, and November 1, 2025, were retrospectively reviewed. Patients operated on with a diagnosis of intracerebral abscess, subdural empyema, or epidural empyema and who had at least six months of postoperative clinical follow-up were included in the study.

The pediatric age group was defined as patients aged 18 years or younger. During the study period, a total of 21 patients who underwent surgical intervention for the specified diagnoses and met the follow-up criteria were included. Patients managed medically without surgical treatment and those with incomplete clinical or radiological data were excluded. All study data were obtained from the hospital's electronic medical record system.

Because pediatric intracranial suppurative infections requiring surgical treatment represent a relatively rare clinical entity, all consecutive patients who met the predefined inclusion criteria within the study period were included in the study. No a priori sample size calculation was performed.

Clinical, Radiological, and Laboratory Variables

For each patient, demographic data (age, sex), presenting symptoms (fever, headache, seizure, altered consciousness, focal neurological deficit, and signs of meningeal irritation), neurological status at admission, and etiological factors were recorded. Neurological status at presentation was assessed using the Glasgow Coma Scale (GCS). Neurological deficits at admission were also recorded.

All radiological evaluations were based on computed tomography (CT) and magnetic resonance imaging (MRI) studies obtained at the time of diagnosis. Images were retrospectively reviewed through the hospital's digital archive system.

Radiological assessment included infection type (subdural empyema, epidural empyema, or intracerebral abscess), supratentorial or infratentorial location, localization pattern (hemispheric, interhemispheric, or combined involvement), extent of infection (localized or extensive), presence of cerebral edema, and midline shift. With respect to infection extent, collections confined to a single anatomical compartment (frontal, temporal, parietal, occipital, or posterior fossa) or limited to the anterior, middle, or posterior one third of the interhemispheric region were classified as localized, whereas collections involving multiple compartments or wide interhemispheric areas were classified as extensive. Cerebral edema was defined as the presence of parenchymal edema, demonstrated as diffuse hypodensity surrounding the lesion on CT or increased signal intensity on T2 or FLAIR sequences on MRI, and was recorded as a binary variable (present or absent). Midline shift was recorded as present or absent.

Laboratory parameters included CRP levels (mg/L) and white blood cell (WBC) counts ($\times 10^3/\mu L$) measured at diagnosis and after treatment. Changes in CRP and WBC levels were analyzed as biochemical indicators of treatment response.

Culture results of purulent materials obtained during surgery were reviewed. Culture positivity, isolated microorganisms, and blood culture results were recorded. Culture results of purulent material obtained during surgery were reviewed. Culture positivity, isolated microorganisms, and blood culture results were recorded. Preoperative antibiotic exposure was recorded as a binary variable (yes/no) and defined as receipt of any systemic antimicrobial therapy prior to surgical drainage, including antibiotics initiated at our institution (e.g., by emergency or infectious diseases teams) as well as ongoing outpatient antibiotic therapy started at an outside center for any indication. The association between preoperative antibiotic exposure and intraoperative pus culture positivity was analyzed.

Antibiotic treatment regimens were also evaluated. The duration of antibiotic therapy was calculated in days, and total treatment duration was included in the statistical analysis.

Outcome Measures

Functional outcome was assessed at 6 months postoperatively using the Glasgow Outcome Scale (GOS). The GOS is a scale that classifies neurological and functional status from 1 (death) to 5 (good recovery). For analysis, GOS 5 was defined as a favorable functional outcome, whereas GOS ≤ 4 was defined as an unfavorable functional outcome. This definition was adopted to reflect complete neurological recovery as the principal therapeutic target in pediatric patients, in whom even minor residual deficits may have long-term developmental consequences. Because the GOS scores may not fully capture subtle neurological impairments, neurological sequelae were additionally analyzed as a separate outcome parameter. Neurological sequelae were defined based on the presence of persistent motor deficit, chronic epileptic seizures, or permanent impairment of consciousness or cognitive function at the end of the follow-up period. This parameter was not included in the favorable or unfavorable functional outcome classification (GOS 5 vs. GOS ≤ 4) and was evaluated as an independent descriptive outcome variable. Radiological detection of a new abscess or empyema after completion of antibiotic therapy was considered recurrence. Reoperation requirements and their indications were also evaluated.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics software (IBM Corp., Armonk, NY, USA; version 26.0). The distribution of continuous variables was assessed using the Shapiro-Wilk test. Variables not normally distributed were presented as median and interquartile range (IQR), whereas categorical variables were expressed as counts and percentages. The Wilcoxon signed rank test was used to compare pretreatment and posttreatment CRP and WBC values. Functional outcome was dichotomized according to GOS scores as favorable (GOS 5) and unfavorable (GOS ≤ 4). Associations between functional outcome and categorical variables were analyzed using Fisher's exact test or, when appropriate, Pearson chi-square test. Continuous variables were compared using the Mann-Whitney U test. All statistical tests were two-sided, and $p<0.05$ was considered statistically significant. Because of the limited sample size, secondary analyses were considered exploratory, and no correction for multiple comparisons was applied.

RESULTS

Descriptive statistics of the study are summarized in Table 1, and comparative analyses are presented in Table 2.

Study Population

Twenty-one pediatric patients with surgically treated intracranial suppurative infections were included. The median age was 87 months (interquartile range [IQR]: 26 to 127 months). Fifteen patients (71.4%) were male and six (28.6%) were female.

Clinical Presentation

The most common primary complaint leading to hospital admission was headache (7/21, 33.3%), followed by seizures (5/21, 23.8%) and altered consciousness (5/21, 23.8%). When all clinical findings were considered, fever was the most frequent symptom and was present in 20 patients (95.2%). Seizures occurred in 11 patients (52.4%) and headache in seven patients (33.3%). Signs of meningeal irritation were observed in five patients (23.8%), and focal neurological deficits in four patients (19.0%). The median GCS score at presentation was 15 (IQR: 14 to 15). Six patients (28.6%) presented with GCS <15.

Infection Type, Location, and Radiological Findings

Subdural empyema was the most common diagnosis, accounting for more than two thirds of cases (14/21, 66.7%). Epidural empyema and intracerebral abscess were each identified in three patients (14.3%). One patient (4.8%) had combined intracerebral abscess and subdural empyema. Most lesions were supratentorial (20/21, 95.2%), and one patient (4.8%) had infratentorial involvement.

Among patients with extra-axial infections without intracerebral abscess (n=17), hemispheric localization was most frequent (9/17, 52.9%). Isolated interhemispheric involvement was observed in three patients (17.6%), and combined hemispheric and interhemispheric involvement in four patients (23.5%). One hemispheric collection (5.9%) was located in the posterior fossa. Among the three patients with isolated intracerebral abscess, lesion locations were frontal (n=1), parietal (n=1), and frontoparietal (n=1). In the patient with combined intracerebral abscess and subdural empyema, a frontal intracerebral abscess was accompanied by interhemispheric subdural empyema. Eleven patients (52.4%) had localized infection and ten (47.6%) had extensive involvement. Cerebral edema was observed in six patients (28.6%), midline shift in seven (33.3%), and both findings in five patients (23.8%).

Etiological Factors

Sinusitis was the most common etiological factor (8/21, 38.1%), followed by otitis media or mastoiditis (4/21, 19.0%). No etiological cause was identified in four patients (19.0%). Infection was considered postoperative or iatrogenic in three patients (14.3%). Other causes, including foreign body and intra-abdominal infection focus, were present in two patients (9.5%).

Table 1: Demographic, clinical, radiological, and treatment characteristics of the study population

Characteristic	Value, n (%)
Number of patients	21 (100)
Age (months)	
Median (IQR)	87 (26–127)
Sex	
Male	15 (71.4)
Female	6 (28.6)
Type of infection	
Subdural empyema	14 (66.7)
Epidural empyema	3 (14.3)
Intracerebral abscess	3 (14.3)
Combined (abscess + empyema)	1 (4.8)
Symptoms	
Fever	20 (95.2)
Seizure	11 (52.4)
Headache	7 (33.3)
Meningeal signs	5 (23.8)
Focal neurological deficit	4 (19.0)
Admission GCS	
GCS=15	15 (71.4)
GCS <15	6 (28.6)
Etiology	
Sinusitis	8 (38.1)
Otitis media / mastoiditis	4 (19.0)
Postoperative / iatrogenic	3 (14.3)
Idiopathic	4 (19.0)
Other	2 (9.5)
Preoperative antibiotic exposure	
Yes	8 (38.1)
No	13 (61.9)
Microbiology	
Positive pus culture	7 (33.3)
Sterile pus culture	14 (66.7)
Positive blood culture	3 (14.3)
Functional outcome at 6 months	
GOS 5	14 (66.7)
GOS ≤ 4	7 (33.3)
Neurological sequelae at 6 months	5 (23.8)
Recurrence	0 (0)
Mortality	0 (0)
Reoperation required	4 (19.0)

GCS: Glasgow Coma Scale, **GOS:** Glasgow Outcome Scale

Table 2: Comparison of variables according to functional outcome

Variable	GOS 5 (n=14)	GOS ≤ 4 (n=7)	p
*Admission GCS <15 (categorical)	0 (0%)	6 (100%)	<0.001
*Admission GCS median (IQR) (continuous)	15 (15–15)	12 (11.5–13.5)	<0.001
Seizure at presentation	6 (42.9%)	5 (71.4%)	0.061
Midline shift	4 (28.6%)	3 (42.9%)	0.638
Cerebral edema	4 (28.6%)	2 (28.6%)	1.000
Extensive involvement	6 (42.9%)	4 (57.1%)	0.659
Sinogenic etiology	5 (35.7%)	3 (42.9%)	1.000
Age (months) median (IQR)	68 (26–120.8)	110 (57–180)	0.433
CRP at diagnosis (mg/L) median (IQR)	96.35 (50.37–136.0)	175.67 (56.98–251.65)	0.488
WBC at diagnosis (×10³/μL) median (IQR)	13.94 (11.18–17.98)	12.59 (10.07–16.25)	0.443
Antibiotic duration (days) median (IQR)	34 (20.75–45.5)	39 (31–42)	0.575

*p<0.05. Values are presented as number (%) for categorical variables and median (interquartile range) for continuous variables. Admission GCS was analysed both as a categorical variable (<15 vs 15) and as a continuous variable. **GCS:** Glasgow Coma Scale; **GOS:** Glasgow Outcome Scale.

Microbiological Findings

Purulent material cultures obtained during surgery were positive in seven patients (33.3%) and sterile in fourteen (66.7%). Isolated microorganisms included Streptococcus pneumoniae, Streptococcus anginosus, Streptococcus constellatus, Staphylococcus aureus, and Staphylococcus intermedius. Blood cultures were positive in three patients (14.3%).

Preoperative antibiotic exposure was present in 8 of 21 patients (38.1%), whereas 13 patients (61.9%) had not received antibiotics prior to surgery. Culture positivity was observed in 1 of 8 patients (12.5%) with preoperative antibiotic exposure and in 6 of 13 patients (46.2%) without prior antibiotic exposure. Although culture positivity tended to be lower in patients who had received antibiotics before surgery, this association did not reach statistical significance (Fisher's exact test, p=0.174).

Surgical and Antibiotic Treatment

Craniotomy with drainage was performed in 20 patients (95.2%), and burr hole drainage in one patient (4.8%). All patients received intravenous antibiotic therapy. The most commonly used regimens included combinations of third-generation cephalosporins, metronidazole, and/or vancomycin. Treatment protocols were modified in selected cases according to culture results and clinical response. The median duration of antibiotic therapy was 34 days (IQR: 23 to 42 days).

Laboratory Findings

Median CRP at diagnosis was 100.33 mg/L (IQR: 47.6 to 175.67) and decreased to 2.19 mg/L (IQR: 1.43 to 5.90) after treatment (p<0.001). Median WBC decreased from 13.02 ×10³/μL (IQR: 10.89 to 18.10) to 7.40 ×10³/μL (IQR: 4.85 to 9.09) after treatment (p<0.001).

Outcome and Associated Analyses

At 6-month follow-up, 14 patients (66.7%) had GOS 5 and seven (33.3%) had GOS ≤ 4. When admission GCS was analysed as a categorical variable (<15 vs 15) using Fisher's exact test, all patients presenting with GCS <15 had unfavourable outcomes (100%, 6/6), whereas only one patient (6.7%, 1/15) with GCS 15 had an unfavourable outcome (p<0.001) (Figure 1).

When analyzed as a continuous variable using the Mann–Whitney U test, admission GCS values were also significantly lower in the GOS ≤ 4 group compared with the GOS 5 group (p<0.001), confirming the robustness of this association.

Persistent neurological sequelae were observed in five patients (23.8%). Sequelae consisted of varying degrees of brain injury manifested as impaired consciousness or cognitive dysfunction in all five patients, with additional hemiparesis in one case.

In categorical analyses performed using Fisher's exact test, seizures (p=0.061), midline shift (p=0.638), cerebral edema (p=1.000), extensive involvement (p=0.659), and sinogenic etiology (p=1.000) were not significantly associated with functional outcome.

In continuous variable analyses performed using the Mann–Whitney U test, age (p=0.433), CRP at diagnosis (p=0.488), WBC at diagnosis (p=0.443), and antibiotic treatment duration (p=0.575) were likewise not significantly associated with outcome.

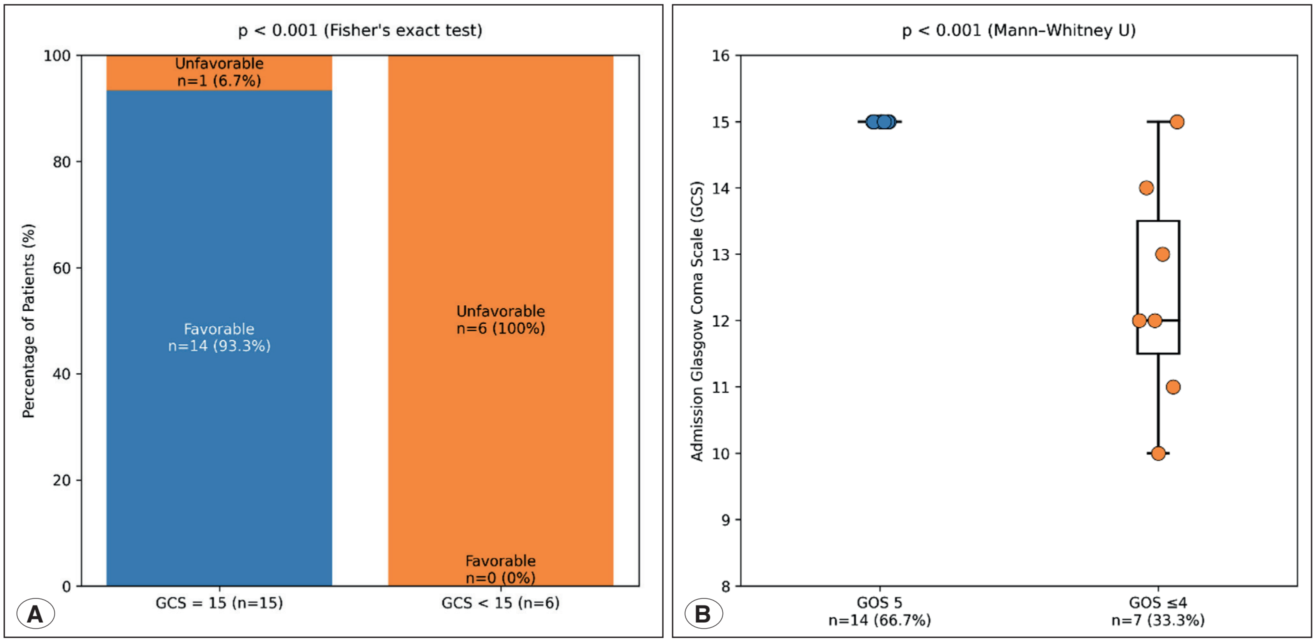

Figure 1: Association between admission Glasgow Coma Scale (GCS) and 6-month functional outcome. **A)** Categorical analysis of admission GCS (GCS = 15 vs GCS < 15) in relation to functional outcome (GOS 5 vs GOS ≤ 4). All patients presenting with GCS < 15 had unfavourable outcomes, whereas the vast majority of patients with GCS 15 achieved favourable recovery (Fisher's exact test, $p < 0.001$). **B)** Continuous analysis of admission GCS values according to outcome groups. Admission GCS scores were significantly lower in the unfavourable outcome group compared with the favourable group (Mann–Whitney U test, $p < 0.001$). Dots represent individual patients; boxplots display median and interquartile range.

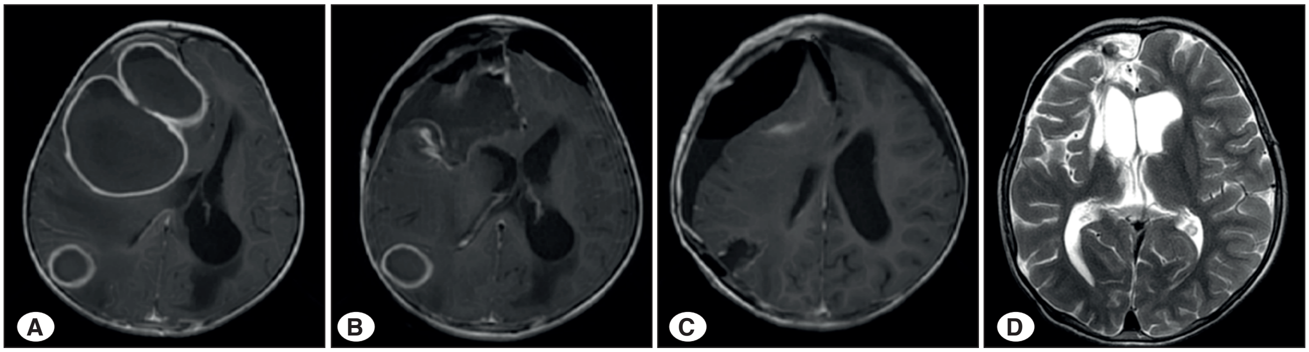

Figure 2: Representative case of a multiloculated intracerebral abscess in a 9-year-old boy. **A)** Contrast-enhanced T1-weighted (T1CE) magnetic resonance imaging (MRI) at presentation demonstrates multifocal intracerebral abscesses in the right frontal and right parietal lobes; the patient presented with a Glasgow Coma Scale (GCS) score of 14 and left-sided hemiparesis. **B)** Postoperative T1CE MRI following craniotomy and drainage of the right frontal abscess. **C)** Postoperative T1CE MRI obtained two days after the initial frontal surgery, following craniotomy and excision of the right parietal abscess. **D)** Follow-up T2-weighted MRI at 2 months after 8 weeks of parenteral antimicrobial therapy, showing complete radiological resolution; at this time point, the patient had fully recovered neurologically with a GCS score of 15 and no residual neurological deficit.

Radiological detection of a new collection after completion of antibiotic therapy was defined as recurrence; no recurrence was observed during the six-month follow-up. Four patients (19.0%) required reoperation. Indications for reoperation included multiloculation (n=2) (Figure 2), early postoperative increase in residual collection (n=1) (Figure 3), and insufficient drainage (n=1). One patient who required reoperation developed sudden central facial paralysis six days after the initial surgery and was found to have increased residual collection; both clinical and radiological findings resolved after early reoperation (Figure 3). The patient reoperated for insufficient drainage was the only case initially treated with burr hole drainage.

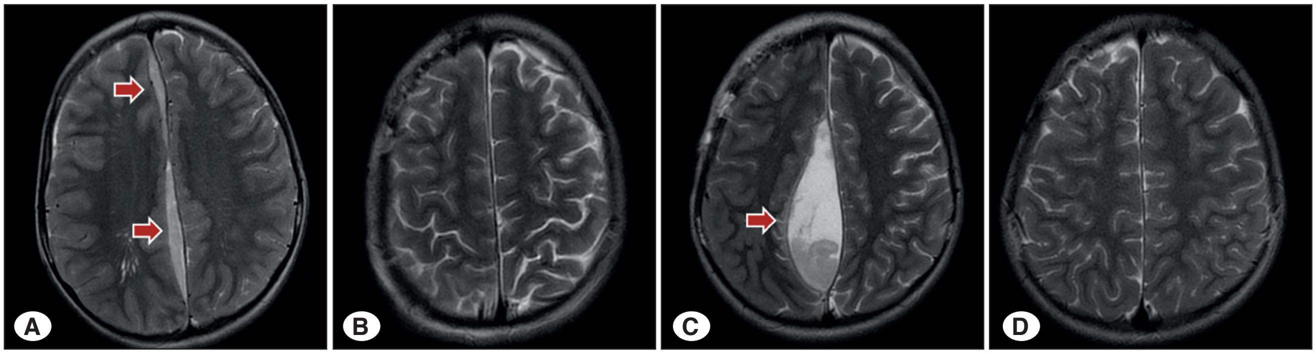

Figure 3: A 7-year-old boy with interhemispheric subdural empyema who required a second surgery due to early residual empyema progression. **A)** Axial T2-weighted magnetic resonance imaging (MRI) demonstrates a diffuse right-sided interhemispheric subdural empyema (red arrows). **B)** Early postoperative axial T2 MRI after initial surgical drainage shows effective evacuation of the empyema; however, the right cortical hemisphere remains markedly edematous. **C)** Axial T2 MRI obtained on postoperative day 6 following the development of acute right central facial palsy reveals progression of the subdural empyema in the posterior interhemispheric region (red arrow), prompting urgent reoperation; the facial palsy completely resolved by postoperative day 2 after the second surgery. **D)** Follow-up axial T2 MRI at 3 months after completion of 10 weeks of antibiotic therapy demonstrates complete resolution of the empyema without residual collection.

DISCUSSION

In this single-center surgical series, the clinical presentation, radiological localization patterns, microbiological profiles, surgical and medical treatment strategies, and functional outcomes of pediatric intracranial suppurative infections were evaluated comprehensively. Our findings indicate that, despite the heterogeneous presentation of pediatric intracranial suppurative infections, favorable functional outcomes can be achieved in most patients with appropriate surgical drainage and antibiotic therapy. In our series, neurological status at presentation, as assessed by the GCS, was the variable most strongly associated with functional outcome, whereas infection localization, extent of involvement, and isolated radiological mass effect findings such as edema or midline shift did not demonstrate significant differentiation. The absence of mortality and recurrence during the six-month follow-up supports the potential benefit of effective diagnostic and therapeutic organization.

Demographic Pattern: Age and Sex

In our series of 21 patients, male predominance (71.4%) is consistent with studies reporting that intracranial suppurative infections occur more frequently in boys (11,14,15). The median age of 87 months and the predominance of cases in the preschool and school age groups are consistent with the literature reporting that pediatric brain abscesses occur more frequently during childhood, particularly between 4 and 7 years of age (12,13,16). These findings suggest that our series reflects a typical epidemiological pediatric population.

Clinical Presentation: Limitations of the Classic Triad and Fever as the Most Common Presenting Symptom

In pediatric cases, the classic triad of headache, fever, and focal neurological deficit has been reported in only 9% to 28% of patients (8). In the present cohort, headache being the most common primary complaint leading to admission is consistent with this framework. However, the notably high frequency of fever observed in 95.2% of patients is remarkable. Considering that fever is described in the literature as a nonspecific and early finding in pediatric intracranial infections, reported in approximately 30% to 70% of cases, the high rate observed in this cohort may be related to the fact that a substantial proportion of patients presented during the active infection phase with a pronounced inflammatory response (38-40).

Seizures are known to represent a significant component of the clinical spectrum (15,24). In this cohort, seizures were frequently observed both as a presenting complaint and as a symptom; the variable occurrence of accompanying altered consciousness and focal deficits is consistent with the heterogeneous clinical spectrum reported in the literature (12,15,21-24). These findings support maintaining a low threshold of clinical suspicion for intracranial infections and underscore the importance of evaluating common symptoms such as headache and fever in the context of potential intracranial complications.

Disease Spectrum and Anatomical Distribution

Pediatric intracranial suppurative infections comprise a spectrum that includes subdural empyema, epidural empyema, and intracerebral abscess, and their management principles largely overlap (40-42). In this cohort, the predominance of subdural empyema as the principal infection type is consistent with reports indicating that subdural empyema accounts for 15% to 25% of purulent intracranial infections and underscores the prominent role of these collections in pediatric clinical practice (43).

The marked predominance of supratentorial lesions is consistent with previous series. Canpolat et al. also reported that 80% of cases were supratentorial (44). Within the supratentorial compartment, convexity and interhemispheric localizations have been emphasized. The coexistence of hemispheric and interhemispheric patterns in extra-axial infections in this cohort is consistent with this anatomical spectrum and highlights the practical value of carefully defining collection localization during surgical planning (45,46). Subtentorial empyema, although rare, has been reported to carry a higher risk of complications. The limited observation in this cohort is consistent with the literature describing this subgroup (47).

Inflammatory Markers

In children with intracranial infectious lesions, leukocytosis and elevated CRP levels are commonly reported; although CRP elevation is almost consistently present, normal WBC counts or even leukopenia may be observed in a subset of cases (8,18,25,26). In this cohort, elevated CRP and WBC levels at diagnosis and their marked decline after treatment are consistent with the literature as biological indicators of infection control (25,26). In particular, the view that CRP is a practical parameter for monitoring treatment response is supported by laboratory observations reported in pediatric series (8,18). This observation supports the use of CRP as a practical biomarker for monitoring treatment response.

Microbiology: Limited Culture Positivity, Streptococcal–Staphylococcal Spectrum, and Low Blood Culture Positivity

In this cohort, the limited rate of positive pus cultures is consistent with the sterile culture rates reported in the literature. Previous studies have reported sterile culture rates ranging from 10% to 32%, with potential contributing factors including inadequate sampling, difficulties in isolating anaerobic organisms, and empirical antibiotic use before surgery (3,8,25,28,48,49). The 66.7% rate of sterile cultures observed in this cohort, which is higher than that reported in some series, may be related to the frequent exposure to antibiotics before referral to a tertiary care center and to the difficulty of isolating anaerobic pathogens under routine culture conditions. In our cohort, preoperative antibiotic exposure was documented in 38.1% of patients and was associated with a numerically lower culture positivity rate (12.5% vs 46.2%). Although this difference did not reach statistical significance, likely due to the limited sample size, the observed trend supports the hypothesis that prior antimicrobial exposure contributes to reduced microbiological yield. Moreover, contemporary guidance emphasizes obtaining microbiological specimens prior to antimicrobial escalation whenever feasible, while acknowledging that pre-treatment exposure commonly reduces culture yield in real-world practice. Therefore, our sterile culture rate should be interpreted in the context of frequent referral after empirical antibiotic initiation and the inherent limitations of routine culture methods for anaerobic pathogens (49).

In culture-positive cases, the isolation of microorganisms within the streptococcal and staphylococcal spectrum is consistent with the well-established understanding that spread from contiguous foci such as sinusitis, otitis, or mastoiditis commonly involves streptococci, staphylococci, and polymicrobial pathogens (50). Large series have reported that streptococci and staphylococci are the most common isolates from pus cultures, with enterobacteria and *Bacteroides* species also constituting a significant proportion (50). The pathogen profile identified in this cohort represents the spectrum commonly encountered in pediatric clinical practice.

The limited rate of blood culture positivity is consistent with the clinical observation that intracranial suppurative infections often develop through local contiguous spread and are not always accompanied by systemic bacteremia. This underscores that microbiological confirmation cannot always be achieved through blood cultures alone and highlights the importance of appropriate sampling, timing, and surgical specimen collection (3,8,25,28,48).

Etiology: Predominance of Sinusitis and Changing Predisposing Factors in the Modern Era

The predominance of sinusitis as an etiological factor is consistent with publications indicating that sinusitis and postoperative causes account for a substantial proportion of pediatric intracranial suppurative infections in the modern era (8). Before 2000, otitis and congenital heart diseases were reported as more predominant etiological factors; in recent years, improvements in prophylactic protocols have been associated with a decline in cases related to congenital heart diseases, and increased awareness among pediatricians regarding the diagnosis and treatment of otitis media has contributed to a relative reduction in intracranial suppurative infectious complications arising from otitis (18,19,51). Although contemporary series report varying frequencies of sinusitis, otitis, and postoperative or iatrogenic causes, the etiological distribution in this cohort is consistent with modern epidemiological patterns (18,25,40,50). This variation may be related to the increasing prevalence of sinusitis in the community and to persistent limitations in access to timely and effective treatment. This pattern aligns with recent pediatric sinogenic empyema series highlighting sinusitis as a leading driver of intracranial suppurative complications requiring surgical management in the contemporary era (20).

Surgical Approach

In intracranial infectious collections, including abscesses and empyemas, treatment has historically been based on drainage followed by antibiotic therapy, and in the modern era, surgical drainage combined with empirical antibiotic therapy followed by pathogen-directed treatment remains the gold standard (13,27-30). Among surgical strategies, the choice between burr hole drainage and craniotomy may vary among institutions. Although favorable outcomes have been reported with both techniques, some cases managed with aspiration or burr hole drainage alone have been associated with the need for reoperation and decompression (20,22,31). This literature framework allows the predominance of craniotomy in this cohort to be framed as an effective approach in a selected patient group, without implying technical superiority.

The observed rate of reoperation in this cohort is consistent with the literature, in which secondary surgical intervention has been reported in 10% to 50% of cases; reported indications for secondary surgery include a second infectious focus, inadequate clinical resolution, or recurrence (42,52,53). In this context, detailing the indications for reoperation in this cohort, including multiloculation, suspected early recurrence, and inadequate drainage, provides practical insight into clinical decision-making.

Antibiotic Regimens and Treatment Duration: Consistency with Literature Ranges and Guideline-Based Practice

Although the duration of antibiotic therapy varies across pediatric series, treatment courses of 4 to 6 weeks are generally recommended for epidural and subdural empyemas with close clinical and radiological follow-up, whereas durations of 6 to 8 weeks are frequently suggested for intracerebral abscesses (25,54). The duration of antibiotic therapy applied in this cohort, which falls within these ranges, supports both an adequate treatment approach and a balanced avoidance of unnecessarily prolonged therapy (7,54).

Guidelines recommend a combination of a third-generation cephalosporin and metronidazole for community acquired intracranial abscess or empyema, whereas meropenem combined with vancomycin or linezolid is suggested for postoperative cases. In our cohort, the empiric combinations (third-generation cephalosporin + metronidazole, with glycopeptide coverage when indicated) were consistent with these recommendations, and regimen adjustments were performed in accordance with culture results and clinical/radiological response (49). In this cohort, treatment regimens were similarly structured along this principal axis, incorporating third generation cephalosporins, metronidazole, and glycopeptides when indicated, demonstrating consistency with current guideline based antibiotic management (49). In recent years, combinations of vancomycin, third-generation cephalosporins, and nitroimidazoles have become more widely used (21). This context explains the variability of regimens observed in clinical practice and helps to contextualize the individualized treatment approaches used in this cohort.

Mortality and Morbidity Spectrum

Mortality rates ranging from 4% to 32% have been reported in the literature for pediatric intracranial infections (3-6). Mortality in patients with subdural empyema has been reported to be approximately 4%; however, among survivors, morbidity may be higher, with permanent neurological deficits reported in up to 50% of cases (55). The absence of mortality in this cohort may be considered consistent with contemporary data indicating that advances in imaging, prompt antibiotic therapy, and timely surgical intervention have reduced mortality to approximately 5% to 10% in the modern era (8,10,11,48). Recent pediatric series have reported declining mortality rates in the modern era, largely attributed to earlier neuroimaging, improved surgical timing, and standardized antimicrobial protocols, supporting that contemporary outcomes are generally more favorable than those reported in historical cohorts (4,18).

Nevertheless, a defined spectrum of morbidity was observed in this cohort. Morbidity was identified in five patients, including mild brain injury in three, brain injury accompanied by hemiparesis in one, and established brain injury in one, highlighting the clinical reality of neurological sequelae despite the absence of mortality. When considered alongside literature reporting hemiparesis rates of 15% to 35% and persistent seizure rates of 12% to 37.5% in subdural empyema, the morbidity profile observed in this cohort suggests a distribution more favorable toward preserved functional status (55). This difference may be explained by the combined effects of early diagnosis, prompt drainage, effective antibiotic therapy, and close follow-up practices at the center; however, given the single-center design and limited sample size, such interpretations should not be construed as implying causality.

Neurological Status at Presentation (GCS) as the Strongest Determinant of Outcome

In cases of intracranial abscess or empyema, neurological status at presentation has traditionally been emphasized as one of the most important determinants of outcome (35,36). Mortality has been reported to range from 0% to 21% in patients presenting with preserved consciousness, to approximately 60% in those with signs of herniation, and to as high as 90% in patients presenting in coma (14,16,31). In this cohort, the strong association between admission GCS and functional outcome supports this established body of literature (14,16,31,35,36). This finding provides one of the most practical clinical messages: the initial neurological assessment serves not only as an indicator of disease severity but also as a risk stratification tool that may guide follow-up strategy.

Radiological Mass Effect And Outcome: Potential Explanations

The literature indicates that rapidly developing neurological symptoms in the presence of cerebral edema may be associated with poor prognosis, and imaging evidence of herniation has been described as a marker of unfavorable outcome (10,31,37,56). Despite this, the lack of a statistical association between mass effect findings such as cerebral edema and midline shift and functional outcome in this cohort suggests that reduced GCS at presentation cannot always be explained solely by mass effect. Systemic inflammatory response, meningeal involvement, seizures or postictal state, and metabolic factors accompanying infection may also influence the level of consciousness, potentially limiting the prognostic value of radiological mass effect findings alone. This observation does not contradict the established association between increased intracranial pressure and outcome but suggests that early drainage and effective antibiotic therapy may attenuate this relationship in selected cohorts (10,31,37,56).

Complication Spectrum and Clinical Follow-up

Complications of intracranial infections include hydrocephalus, ventriculitis, focal neurological deficits, increased intracranial pressure, and herniation (27). The absence of mortality and recurrent infection in this cohort suggests that effective management is achievable despite the high-risk complication spectrum. However, the presence of reoperation requirements and morbidity underscores that this disease group requires close clinical and radiological follow-up even when adequate control appears to have been achieved (7,27).

Limitations

This study has a retrospective design and reflects the experience of a single center, which may introduce risks related to data completeness, recording quality, and selection bias. The limited sample size may have reduced the statistical power of comparisons, particularly within subgroups such as specific etiologies, pathogens, or surgical technique subsets. However, pediatric intracranial suppurative infections requiring surgical intervention represent a relatively rare clinical entity, and single-center surgical series of comparable size have been frequently reported in the literature. Therefore, the present study should be interpreted as hypothesis-generating while still providing clinically relevant observational data that may contribute to the existing body of evidence.

In addition, the initiation of empirical antibiotic therapy before surgical sampling in some patients may have reduced culture positivity rates and limited the ability to fully characterize the microbiological profile. Functional outcomes were assessed using the GOS at 6 months, which may not capture neurological or epileptic sequelae emerging during longer-term follow-up. Finally, the marked predominance of craniotomy over burr hole drainage (20 vs. 1 case) limits comparative evaluation of surgical techniques and precludes statistical inferences regarding relative technical advantages.

Conclusion

This study demonstrates that pediatric intracranial suppurative infections requiring surgical treatment can be successfully managed with timely diagnosis, effective surgical drainage, and appropriate subsequent antibiotic therapy. Adequate drainage achieved through craniotomy, together with individualized antibiotic strategies guided by clinical response, was associated with prevention of mortality and acceptable functional outcomes. Nevertheless, despite treatment success, functional outcome was found to be closely related to neurological status at presentation. These findings are expected to provide a basis for future larger, prospective studies aimed at more clearly defining optimal surgical and medical management strategies and long-term neurological outcomes in pediatric intracranial suppurative infections.

Author Contributions

Study conception and design: **Muhammed Erkan Emrahoğlu, Erdal Reşit Yılmaz, Mehmet Erhan Türkoğlu;** data collection: **Muhammed Erkan Emrahoğlu, Mustafa Kavcar, Defne Şahinoğlu Berker, Şükriye Yılmaz, Ayşe Kaman;** analysis and interpretation of results: **Muhammed Erkan Emrahoğlu, Erdal Reşit Yılmaz, Şükriye Yılmaz, Ayşe Kaman, Mehmet Erhan Türkoğlu;** draft manuscript preparation: **Muhammed Erkan Emrahoğlu.** The authors reviewed the results and approved the final version of the article.

Conflicts of Interest

The authors declare that there is no conflict of interest to disclose.

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Ethical Approval

The study was approved by the Ankara Etlik City Hospital 1st Scientific Research Evaluation and Ethics Committee (January 14, 2026; No. AEŞH-BADEK1-2026-020). The study was conducted in accordance with the Declaration of Helsinki. Because of the retrospective design, the requirement for informed consent was waived.

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