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Changes in the epidemiology of pediatric brain abscesses pre- and post-COVID-19 pandemic: a single-center study

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Abstract

Background An increased incidence of brain abscesses was observed post-COVID-19 pandemic. However, it remains unclear how the COVID-19 pandemic influenced the epidemiology of brain abscesses. This study aimed to investigate changes in the epidemiology of brain abscesses pre- and post-COVID-19 pandemic.

Methods A retrospective study of demographic, clinical, radiological, and laboratory characteristics of patients with brain abscesses in Children's Hospital of Soochow University from 2015–2023 was performed.

Results A total of 34 patients were admitted to the hospital during the study. The post-COVID-19 cohort had an average of 5.5 cases/year, which is a 129.2% increase compared to the pre-COVID-19 cohort's average of 2.4 cases/year. Additionally, the rates of fever upon admission (86.36% vs 50%, $p=0.04$) and experiencing high-grade fever within 6 weeks before admission (40.91% vs 8.33%, $p=0.044$) were significantly increased. A potential rise in the rate of intensive care unit admission was observed (36.36% vs 8.33%, $p=0.113$). The average value of globulin in the post-COVID cohort was significantly higher compared to the pre-COVID cohort (31.60 ± 5.97 vs 25.50 ± 5.08, $p=0.009$). Streptococcal infections were the predominant cause of brain abscesses in both cohorts (40% vs 43.75%, $p=0.57$).

Conclusions There was a significant increase in the number of brain abscess patients after the COVID-19 pandemic. This underscores the importance of children receiving the streptococcal vaccine.

Keywords Brain abscess, Empyema, Epidemiology, COVID-19

Background

Brain abscess is a localized infection of the central nervous system, characterized by a 20% mortality rate within one year, and survivors may still experience neurological sequelae [1]. Over the past few decades, a decline in the incidence of brain abscesses has been observed due to factors such as vaccination, correction of early congenital heart defects, and appropriate antimicrobial therapy [2–4]. However, an increased incidence of brain abscesses was observed post-COVID-19 pandemic.

The COVID-19 pandemic is a global phenomenon, impacting people's lifestyles and social interactions worldwide [5]. Several studies have indicated that COVID-19 can lead to widespread and enduring immune dysfunction [6–10]. Unfortunately, the incidence of brain abscesses is higher in individuals with immune dysfunction [11]. In 2022, the American Centers for Disease

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Control and Prevention (CDC) reported a multicenter study involving 40 children's hospitals, suggesting a possible increasing trend in pediatric brain abscesses following the COVID-19 pandemic [12].

However, this report still has limitations as it focused only on streptococcal infections and lacked more detailed information due to its reliance on administrative databases. It remains unclear how the COVID-19 pandemic influenced the epidemiology of brain abscesses. The objective of this study was to investigate changes in the epidemiology of brain abscesses pre- and post-COVID-19 pandemic by comparing individuals' demographics, clinical presentations, management strategies, imaging findings, and laboratory tests.

Methods

Study design and setting

The Children's Hospital of Soochow University is the only tertiary children's hospital in Suzhou, China. The hospital provides services to most children in the Suzhou area, admitting more than 70,000 inpatients annually. All patients aged ≤ 18 years with a primary or secondary discharge diagnosis of intracranial abscess, subdural abscess, or extradural abscess from January 2015 to December 2023 were included. This retrospective study was approved by the medical ethics committee at the Children's Hospital of Soochow University (2024CS061). Due to the retrospective nature of this study, the need for informed consent was waived by the Research Ethics Committee.

COVID-19 pandemic in Suzhou, China

In January 2020, Suzhou reported its first case of COVID-19 and officially implemented a city-wide lockdown on January 24 of the same year. Public places were mandated to close during the lockdown, and residents were encouraged to stay home as much as possible. From January to August 2020, Suzhou reported only 87 cases of COVID-19. However, the reopening of the city in August 2020 led to an abrupt outbreak of COVID-19. It has been reported that after China terminated its zero-COVID policy, 80% of the population was infected by January 22, 2023 [13]. Although China declared the epidemic to be over in February 2023, widespread outbreaks of influenza A began at that time [10].

Patient cohort and data collection

Patients are categorized into the pre-COVID-19 cohort if their hospital admission precedes January 1, 2020, and into the post-COVID-19 cohort if their admission follows September 1, 2020. Electronic medical records were reviewed retrospectively to collect basic demographic, clinical, radiological, and laboratory data by clinicians. Clinical data included the patient's history of infections within 6 weeks before admission, symptoms at admission, treatments during hospitalization, and outcomes at discharge. Children under the age of 5 were assessed using the children's Glasgow Coma Scale (GCS), while those over 5 years old were evaluated with the standard GCS [14]. Fever was classified as an axillary temperature of 37.5 °C or higher, and altered mental status was considered as a GCS score below 15. The criteria for admission to the Intensive Care Unit (ICU) typically include patients in critical condition who require intensive monitoring and treatment. The specific criteria are as follows: (1) Persistent cyanosis with oxygen saturation below 90% despite oxygen therapy or the need for ventilatory support; (2) Patients with concurrent sepsis; (3) Worsening consciousness leading to coma; (4) Patients who underwent emergency surgery due to brain herniation caused by an abscess visible on a cranial CT scan. Outcomes were assessed using the Glasgow Outcome Scale (GOS). A GOS score of 5 was classified as a favorable outcome, while scores of 1–4 were classified as unfavorable. The radiological features of brain abscesses were obtained from the descriptions provided by radiologists in the magnetic resonance imaging (MRI) reports. The laboratory data were obtained from blood routine, biochemistry, and coagulation function tests conducted upon admission.

Statistical analysis

The data were analyzed using SPSS 26.0, and graphical representations were created using Origin 2021. Descriptive statistics were performed using mean and standard deviation for normally distributed continuous variables, the median and interquartile range for continuous variables, and frequency and percentage for categorical variables. Fisher's exact test, χ^2-test, Mann–Whitney U test, or t-test were used to compare variables between the pre-COVID-19 and post-COVID-19 cohorts. Two-tailed tests with $p < 0.05$ were considered significant.

Results

A total of 34 patients were enrolled. The number of patients with brain abscesses from 2015 to 2023 were 2 (5.9%), 3 (8.8%), 3 (8.8%), 2 (5.9%), 2 (5.9%), 3 (8.8%), 5 (14.7%), 6 (17.6%), and 8 (23.5%), respectively. After the COVID-19 pandemic, a sustained rise in brain abscess cases has been observed, persistently exceeding the average over three consecutive years and culminating in a peak in 2023 (Fig. 1).

Patient characteristics

The pre-COVID-19 cohort included 12 (35.3%) patients, at an average rate of 2.4 cases/year, while the

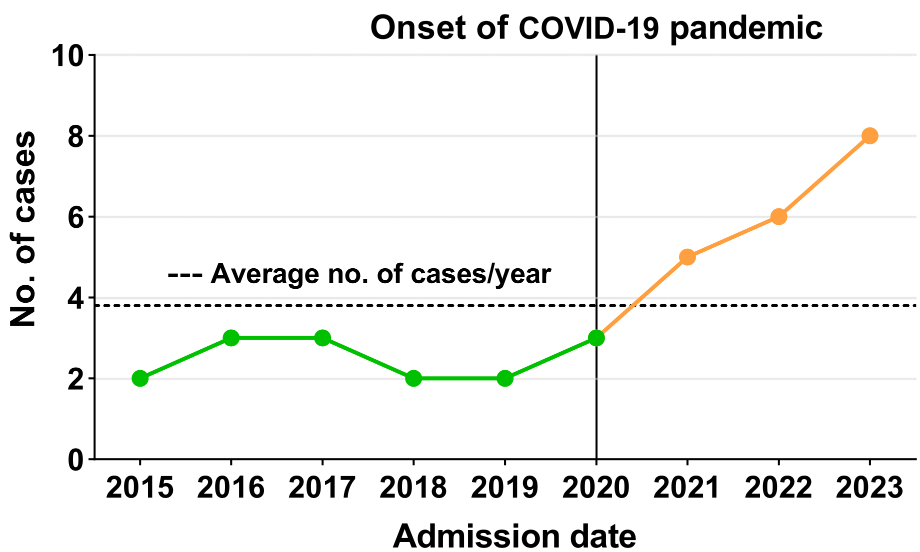

Fig. 1 The annual number of patients with brain abscesses from 2015 to 2023

post-COVID-19 cohort included 22 (64.7%) patients, at an average rate of 5.5 cases/year. The average of cases/year of the post-COVID-19 cohort increased by 129.2% compared to the pre-COVID-19 cohort. Additionally, the incidence rate of respiratory infections within 6 weeks before admission in the post-COVID-19 cohort was 68.18% (15/22), significantly higher than the 25% (3/12) in the pre-COVID-19 cohort. The distributions of age at admission, sex, body mass index (BMI), and underlying health conditions showed no significant differences between cohorts (Table 1).

Overall, there was a marked rise in the number of patients with brain abscesses following the COVID-19 pandemic, with a larger proportion of these patients having a history of respiratory infections.

Clinical presentation and management

The proportion of fever patients in the post-COVID-19 cohort was significantly higher than that in the pre-COVID-19 cohort (86.36% vs 50%, $p=0.04$) (Table 2). In addition, 40.91% (9/22) of patients in the post-COVID-19 cohort experienced high-grade fever within 6 weeks before admission, which was significantly higher than the 8.33% (1/12) observed in the pre-COVID-19 cohort (Fig. 2).

Moreover, after the COVID-19 pandemic, patients appeared to exhibit more clinical symptoms and required a greater extent of treatment (Fig. 3).

Radiological and laboratory data

MRI of the brain examined all patients. Among them, brain abscesses were located in the parietal lobe in 10/34 (29.41%), in the occipital lobe in 2/34 (5.88%), in the frontal lobe in 4/34 (11.76%), in the temporal lobe in 7/34 (20.59%), in the deep brain structures in 3/34 (8.82%), in the epidural space in 3/34 (8.82%), and 5/34 (14.71%) had multiple brain abscesses. At the time of diagnosis, the median cross-sectional area of brain abscesses in the pre-COVID-19 cohort was 5.64 cm^2 (IQR:4.34, 11.89), compared to 7.12 cm^2 (IQR: 2.02, 23.68) in the post-COVID-19 cohort (Table 3).

All patients underwent blood routine, biochemistry, and coagulation function tests upon admission. The median C-reactive protein was 28.31 mg/L (IQR: 10.56, 67.69) and the median white blood cell count was 11.06×10^9/L (IQR: 9.57, 14.13), showing similar in both cohorts. The average value of globulin (GLB) in the post-COVID cohort was significantly higher compared to the pre-COVID cohort (31.60 ± 5.97 vs 25.50 ± 5.08, $p=0.009$). Similar laboratory test results from both cohorts are presented in the Supplementary Table 1. Abscess cultures were performed in 26/34 cases (76.47%). The most frequent organism identified was *Streptococcus* (42.31%). In 46.15% of cases, cultures remained sterile after the patients had already been on antibiotics. Blood cultures were performed in 28/34 cases (82.35%). Only 3/31 cases (15%) yielded positive results, all of which were in the post-COVID cohort (Table 3).

Discussion

Previous epidemiological studies of brain abscesses reported an incidence ranging from 0.4 to 0.9 cases per 100,000 individuals [15, 16]. However, in this retrospective study, it was observed that the annual hospital admission rates for brain abscesses more than doubled following the COVID-19 pandemic compared to the

Table 1 Baseline characteristics of patients before and after the emergence of COVID-19

Characteristics	Total ($n=34$)	Pre-COVID-19 ($n=12$)	Post-COVID-19 ($n=22$)	*P*
Age at admission, years, M (IQR)	5.78 (2.73, 10.75)	5.88 (1.56, 10.65)	5.78 (3.46, 10.75)	0.692
Sex assigned at birth, n (%)				> 0.99
Male	22 (64.71)	8 (66.67)	14 (63.64)	
Female	12 (35.29)	4 (33.33)	8 (36.36)	
BMI, n (%)				0.929
Underweight	8 (23.53)	2 (16.67)	6 (27.27)	
Normal	17 (50.00)	7 (58.33)	10 (45.45)	
Overweight	1 (2.94)	0 (0.00)	1 (4.55)	
Obesity	8 (23.53)	3 (25.00)	5 (22.73)	
Underlying health conditions[a], n (%)				0.729
No	18 (52.94)	7 (58.33)	11 (50.00)	
Yes	16 (47.06)	5 (41.67)	11 (50.00)	
Predisposing conditions[b], n (%)				
Previous neurosurgery or head trauma	4 (11.76)	3 (25.00)	1 (4.55)	0.115
Preceding meningitis	6 (17.65)	2 (16.67)	4 (18.18)	> 0.99
Dental infections	4 (11.76)	1 (8.33)	3 (13.64)	> 0.99
Respiratory infections[c]	18 (52.94)	3 (25.00)	15 (68.18)	0.030
Otogenic infections	4 (11.76)	0 (0.00)	4 (18.18)	0.273

M Median, *IQR* Interquartile range, *BMI* Body mass index

[a] Including anemia (one), congenital heart disease (twelve), solid cancer (one), and other congenital diseases (two)

[b] Diagnosis of infections within 6 weeks prior to admission

[c] Including COVID-19, influenza, sinusitis, respiratory syncytial virus, mycoplasma pneumonia and other respiratory infections with unspecified pathogens

period prior. Moreover, patients appeared to exhibit more clinical symptoms and required a greater extent of treatment.

Increase in brain abscess patients post-COVID-19 pandemic

An increase in the number of brain abscesses was also observed in both the American and European populations [12, 17–19]. Our research additionally offers corroborative evidence, particularly in the Chinese population. The study conducted by the American CDC reported an increase in cases starting from the summer of 2021. By March 2022, the cases had peaked before starting to decline. Ultimately, the CDC concluded that these trends were within historical norms [12]. However, until the end of the study period, we also did not observe a declining trend. This could potentially be attributed to the American study's exclusive focus on streptococcal infections. Additionally, respiratory virus infections were found to be associated with pediatric invasive bacterial infections [20, 21]. The continued presence of widespread respiratory infections in China following the COVID-19 pandemic, including influenza, respiratory syncytial virus (RSV), and adenovirus, may contribute to the increased incidence of brain abscesses [22, 23]. This underscores the need to enhance the management of patients with respiratory infections and maintain early vigilance for potential central nervous system infections.

Heightened severity of brain abscess patients post-COVID-19 pandemic

In this study, patients in the post-COVID-19 cohort were observed to present more clinical symptoms, consistent with findings from American and European studies [18, 19]. In our study, further investigation revealed increases in the proportion of ICU admissions and repeated neurosurgical interventions. This may indicate that the presentation of patients with brain abscesses became more severe post-COVID-19 pandemic. Previous studies also indicated that neurological complications were associated with severe COVID-19 disease in hospitalized children [24, 25]. This appears to account for the heightened need for ICU admissions for mechanical ventilation support among patients with brain abscesses.

Regarding laboratory tests, consistent with similar studies, no significant changes were observed in CRP levels and WBC counts in patients following the COVID-19 pandemic. Continuing our analysis of other blood test results, it was interesting to find that patients with brain abscesses exhibited higher levels of GLB. GLB is a protein

Table 2 Clinical presentation and management of patients before and after the emergence of COVID-19

Characteristics	Total (*n* = 34)	Pre-COVID-19 (*n* = 12)	Post-COVID-19 (*n* = 22)	*P*
Symptoms[a], n (%)				
Fever	25 (73.53)	6 (50.00)	19 (86.36)	0.040
Nausea or vomiting	21 (61.76)	7 (58.33)	14 (63.64)	> 0.99
Seizures before admission	6 (17.65)	1 (8.33)	5 (22.73)	0.389
Neck stiffness	6 (17.65)	2 (16.67)	4 (18.18)	> 0.99
Altered mental status	17 (50.00)	5 (41.67)	12 (54.55)	0.721
Neurological deficits[b]	11 (32.35)	5 (41.67)	6 (27.27)	0.459
Complication, n (%)				
Hydrocephaly	5 (14.71)	2 (16.67)	3 (13.64)	> 0.99
Cerebral hernia	3 (8.82)	1 (8.33)	2 (9.09)	> 0.99
Pyemia	2 (5.88)	0 (0.00)	2 (9.09)	0.529
Treatment, n (%)				> 0.99
Aspiration	23 (67.65)	9 (75.00)	14 (63.64)	
Excision	4 (11.76)	1 (8.33)	3 (13.64)	
Medication	7 (20.59)	2 (16.67)	5 (22.73)	
Repeated neurosurgical interventions, n (%)	8 (30.77)	2 (20.00)	6 (37.50)	0.420
Antibiotics, n (%)				
Vancomycin	27 (79.41)	9 (75.00)	18 (81.82)	0.677
Ceftriaxone	23 (67.65)	6 (50.00)	17 (77.27)	0.138
Vancomycin combined with ceftriaxone	21 (61.76)	6 (50.00)	15 (68.18)	0.462
ICU admission, n (%)				0.113
No	25 (73.53)	11 (91.67)	14 (63.64)	
Yes	9 (26.47)	1 (8.33)	8 (36.36)	
Length of stay, days, M (IQR)	43.5 (38.3, 54.5)	41(38.8, 44.3)	46 (37.3, 56.8)	0.460
Outcome[c], n (%)				0.641
Unfavorable	6 (17.65)	3 (25.00)	3 (13.64)	
Favorable	28 (82.35)	9 (75.00)	19 (86.36)	

ICU Intensive care unit, *M* Median, *IQR* Interquartile range, *GOS* Glasgow outcome scale

[a] Fever was classified as an axillary temperature of 37.5 °C or higher, and altered mental status was considered as a GCS score below 15

[b] Including visual disturbances (three) and muscle weakness (seven)

[c] A GOS score of 5 was classified as a favorable outcome, while scores of 1–4 were classified as unfavorable

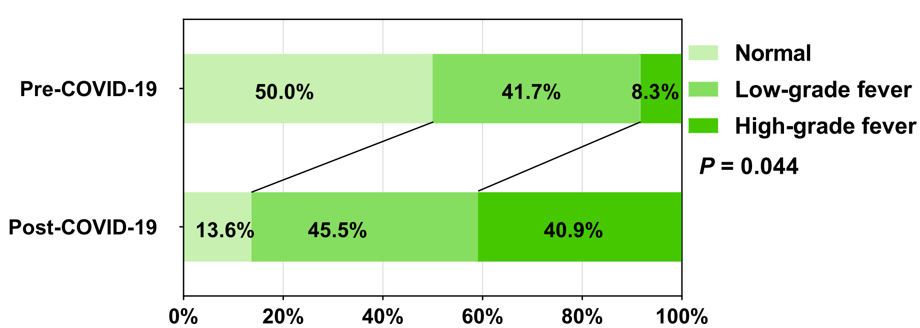

Fig. 2 Comparison of fever occurrence within 6 weeks before admission for patients before and after the COVID-19 pandemic. If the maximum temperature within 6 weeks before admission of patients was < 37.5 °C, it was considered a normal temperature; ≥ 39 °C was categorized as a high-grade fever, otherwise it was categorized as a low-grade fever

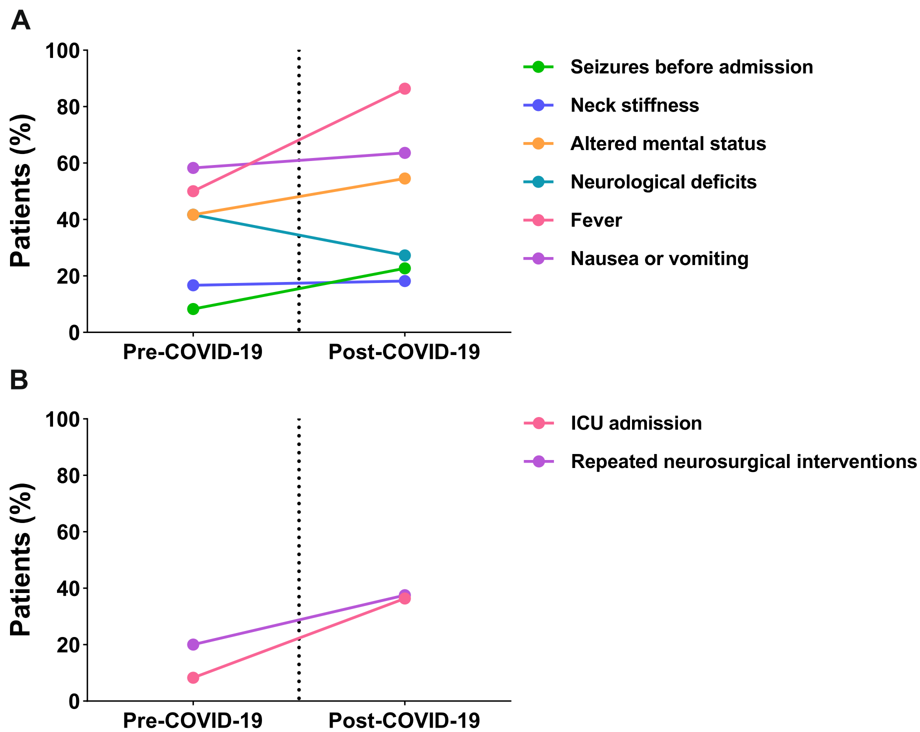

Fig. 3 Comparisons of clinical symptoms and treatments for patients before and after the COVID-19 pandemic

produced by immune organs, consisting of various pro-inflammatory proteins, and reflects the immune status [26]. A high GLB level during infection may suggest a more severe or active immune response to infection [27]. However, due to the limited existing research, the pathophysiological mechanisms underlying the exacerbation of symptoms in brain abscesses associated with GLB remain unclear and require further investigation.

Potential associations between the COVID-19 pandemic and Brain abscesses

Epidemiological changes in brain abscesses following the COVID-19 pandemic were observed. However, due to the limitations of the study, causality cannot be confirmed. We have speculated on several reasons for the increased incidence of brain abscesses in populations after the COVID-19 pandemic.

Induction of immune dysfunction

Several studies have indicated the potential for SARS-CoV-2 infection to persist in the body for several months [28]. Unfortunately, immune dysfunction can be induced under conditions of persistent viral infection. Current evidence suggests that in acute cases of SARS-CoV-2 infection, both the number and functional activity of dendritic cells (DC) are significantly reduced, and DC dysfunction may persist long-term [6]. Furthermore, COVID-19 patients may experience a decrease in natural killer cell count, leading to immune dysfunction [7]. Additionally, even patients with mild or moderate COVID-19 may experience immune dysfunction, which may last for up to eight months [9]. SARS-CoV-2 infection may lead to immune dysfunction, potentially increasing the risk of developing brain abscesses.

Impact on trained immunity

Recent studies have indicated that frequent exposure to various pathogens and subsequent "training" can enhance the effectiveness of innate immunity [29]. Following the COVID-19 outbreak, strict public health measures were implemented worldwide, including social distancing, mask-wearing, hand hygiene, and stay-at-home orders. These non-pharmaceutical interventions (NPIs) led to reduced exposure of children to specific pathogens associated with brain abscesses, potentially resulting in decreased immune training. Consequently, this may lower innate immunity in children, rendering a higher proportion of the population more susceptible to subsequent occurrences of brain abscesses.

Streptococcal vaccination delayed

Nearly half of the brain abscesses in our study were associated with streptococci. A study from Italy reported that streptococcal vaccination can effectively reduce

Table 3 Radiological and laboratory data of patients before and after the emergence of COVID-19

Characteristics	Total (*n* = 34)	Pre-COVID-19 (*n* = 12)	Post-COVID-19 (*n* = 22)	*P*
Abscess characteristics, n (%)				0.816
Parietal	10 (29.41)	4 (33.33)	6 (27.27)	
Occipital	2 (5.88)	1 (8.33)	1 (4.55)	
Frontal	4 (11.76)	1 (8.33)	3 (13.64)	
Temporal	7 (20.59)	2 (16.67)	5 (22.73)	
Deep brain structures	3 (8.82)	1 (8.33)	2 (9.09)	
Multiple	5 (14.71)	3 (25.00)	2 (9.09)	
Epidural	3 (8.82)	0 (0.00)	3 (13.64)	
Abscess cross-sectional area[a], cm^2, M (IQR)	6.33 (2.25, 14.77)	5.64 (4.34, 11.89)	7.12 (2.02, 23.68)	0.719
Laboratory tests[b]				
CRP, mg/L, M (IQR)	28.31 (10.56, 67.69)	32.98 (2.84, 63.34)	28.31 (14.95, 77.93)	0.269
WBC, $\times 10^9$/L, M (IQR)	11.06 (9.57, 14.13)	10.21 (8.09, 13.72)	11.44 (9.75, 14.13)	0.443
GLB, g/dL, Mean ± SD	29.63 ± 6.31	25.50 ± 5.08	31.60 ± 5.97	0.009
Abscess cultures[c], n (%)				0.570
Streptococcus	11 (42.31)	4 (40.00)	7 (43.75)	
Staphylococcus aureus	1 (3.85)	1 (10.00)	0 (0.00)	
Staphylococcus epidermidis	2 (7.69)	0 (0.00)	2 (12.50)	
Negative	12 (46.15)	5 (50.00)	7 (43.75)	
Blood cultures[d], n (%)				0.536
Negative	25 (89.29)	8 (100.00)	17 (85.00)	
Positive	3 (10.71)	0 (0.00)	3 (15.00)	

M Median, *IQR* Interquartile range, *SD* Standard deviation, *CRP* C-reaction protein, *WBC* White blood cell, *GLB* Globulin

[a] The cross-sectional area was calculated based on the largest abscess for patients with multiple brain abscesses

[b] Including blood routine, biochemistry, and coagulation function tests

[c] Abscess cultures were performed in 26/34 cases (76.47%)

[d] Blood cultures were performed in 28/34 cases (82.35%)

the incidence of brain abscesses [4]. However, during the COVID-19 pandemic, many countries implemented lockdown policies. The strict NPIs resulted in almost all immunization programs being affected [30]. The American CDC reported a 21.5% decrease in childhood vaccination coverage in 2020 [31]. Moreover, vaccination rates did not fully recover after the end of the lockdown period. Therefore, the decrease in streptococcal vaccine coverage could be one of the contributing factors to the rising incidence of brain abscesses.

Limitation

This limited study was conducted at a single institution with a small sample size, affecting the power of the statistical analysis. Despite the apparent rise in ICU admission rates, the increase did not reach statistical significance, highlighting the need for multi-center studies with larger sample sizes. Additionally, after China lifted lockdown policies, there was a successive outbreak of respiratory infections caused by various pathogens, making it challenging for many patients to recall whether they had experienced SARS-CoV-2 infection. We were unable to establish a direct association between COVID-19 and brain abscesses. Regarding laboratory testing, the majority of abscess cultures did not undergo high-throughput sequencing, leading to a lack of microbiological characteristic-related data. Furthermore, many patients lacked immunological examinations, limiting us to analyzing changes in patients' immune cell levels.

Conclusions

The most crucial aspect of this study is demonstrating the increase in the number of brain abscess patients compared to before the COVID-19 pandemic. This suggests the need to strengthen awareness of streptococcal vaccination. Furthermore, a further multicenter cohort study is needed to clarify whether children with brain abscesses after the COVID-19 pandemic exhibit more symptoms and have higher ICU admission rates.

Abbreviations

CDC Centers for Disease Control and Prevention
NPIs Non-pharmaceutical interventions

GCS	Glasgow Coma Scale
GOS	Glasgow outcome scale
MRI	Magnetic resonance imaging
M	Median
IQR	Interquartile range
SD	Standard deviation
BMI	Body mass index
ICU	Intensive care unit
CRP	C-reaction protein
WBC	White blood cell
GLB	Globulin
RSV	Respiratory syncytial virus
DC	Dendritic cells

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12887-024-05082-6.

Supplementary Material 1.

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Authors' contributions
Y. L. conducted data collection, statistical analysis, visualization, and original draft writing. All authors contributed to the data curation, conceptualization, and supervision. All authors have approved the submitted version and agreed both to be personally accountable for the author's contributions and to ensure that questions related to the accuracy or integrity of any part of the work.

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Availability of data and materials
The data are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The authors declare no competing interests.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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