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Magnetic Resonance Imaging Examination for the Detection of Cranial Complications in Pediatric Patients with Post-Coronavirus Disease 2019 Infection

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Abstract

Objective: Coronavirus disease 2019, caused by the novel coronavirus severe acute respiratory syndrome coronavirus 2, has affected millions of people worldwide since its emergence in late 2019. Although children generally experience milder symptoms compared to adults, there have been reports of severe cases and post-infectious complications, including neurological manifestations. This article discusses the role of magnetic resonance imaging in detecting cranial complications in pediatric patients with a history of coronavirus disease 2019 infection.

Methods: In our study, we retrospectively scanned the images of 246 pediatric patients who had coronavirus disease 2019 between April 2020 and June 2022 and then underwent cranial magnetic resonance imaging with diverse complaints at a tertiary healthcare center. Pathologies that were identified were classified and recorded as final data.

Results: In a study of 246 pediatric coronavirus disease 2019 patients, neurological complications were relatively rare. Most children experience mild or asymptomatic cases. Serious complications such as multisystem inflammatory syndrome in children developed in 8 patients (3%), acute disseminated encephalomyelitis developed in 10 patients (4%), a cerebral vascular infarct developed in 20 patients (8%), non-specific T2 Weight imaging and Fluid attenuated Inversion Recovery(T2WI -Flair) hyperintensity developed in 120 patients (48.6%), and meningoencephalitis developed in 10 patients (4%).

Conclusion: Of the patients examined in our study, 67.8% exhibited pathology. T2WI and FLAIR sequences revealed non-specific hyperintensity foci as the most prevalent pathology. Further research is needed to determine the optimal timing and indications for magnetic resonance imaging in this population, as well as the correlation between magnetic resonance imaging findings and long-term neurological outcomes.

Keywords: Complications, magnetic resonance imaging, post-COVID-19, stroke, T2WI hyperintensity

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has had a significant global impact on public health and healthcare systems since its emergence in late 2019. While the majority of COVID-19 cases have been reported in adults, children, and adolescents are not immune to the infection, and they can also experience both acute and long-term complications.[1,2] Although pediatric patients with COVID-19 generally exhibit milder symptoms compared to adults, emerging evidence suggests that some children may develop post-acute sequelae of SARS-CoV-2 infection or "long COVID," with symptoms persisting for months after the acute phase of the infection.[1] Among these complications, neurological manifestations have been increasingly recognized, including meningoencephalitis, acute disseminated encephalomyelitis (ADEM), Guillain–Barré syndrome (GBS), and acute flaccid myelitis.[3]

Magnetic resonance imaging (MRI) is a non-invasive, radiation-free imaging modality that has been widely employed to detect and characterize various neurological complications in both adult and pediatric patients with COVID-19.[4] In particular, MRI has proven to be a valuable tool for detecting inflammatory and ischemic changes, white matter abnormalities, and other cerebral lesions in patients with neurological manifestations of COVID-19.[5]

In this article, we aim to provide an overview of the role of MRI in detecting and characterizing cranial complications in pediatric patients with a post-COVID-19 infection. We will discuss the various MRI findings associated with different neurological complications as well as the potential mechanisms underlying these abnormalities. Furthermore, we will explore the clinical implications of these findings and the challenges of differentiating between primary COVID-19-related neurological complications and those resulting from other etiologies.

METHODS

In our study, we retrospectively scanned the images of 246 pediatric patients who had COVID-19 between April 2020 and June 2022 and then underwent cranial MRI with diverse complaints at a tertiary healthcare center. Since our study was retrospective, we did not obtain ethical approval. After recovering from COVID-19, we included patients between the ages of 1 and 17 who presented with diverse complaints. Our study excluded patients with congenital diseases, tumors, epilepsy, hydrocephalus, etc. Pathologies that were identified were classified and recorded as final data.

Magnetic Resonance Imaging Protocol

A cranial MRI scan taken with a 1.5-T (Magnetom Aera, Siemens Healthineers, Erlangen, Germany) MR machine is a non-invasive imaging test that uses a powerful magnetic field and radio waves to produce detailed images of the brain and surrounding structures. The technical parameters for a typical cranial MRI may include a magnetic field strength of 1.5 Tesla and various sequence types such as T1-weighted, T2-weighted, Fluid atteniation inversion recovery (FLAIR), Diffusion Weighted Imaging (DWI), and Gradient echo sequences (GRE). The slice thickness is typically 3 mm or less, and the matrix size is usually 256 × 256 or higher. The field of view is typically 22-24 cm, and the scan time can range from 15 to 30 minutes for a routine cranial MRI. The repetition time (TR) and echo time (TE) may vary depending on the sequence type and specific imaging parameters but typically range from 2000 to 6000 ms for TR and 80-150 ms for TE. The flip angle may vary from 90° to 180°.

Statistical Analysis

Descriptive analyses were performed to summarize the data collected in the study. For categorical variables, frequency tables were used to present the distribution of the different categories, while for continuous variables, such as age, the mean and standard deviation (±SD) were calculated, along with the minimum (min) and maximum (max) values observed.

RESULTS

In a study of 246 pediatric COVID-19 patients, 100 of the scanned images were of females and 146 were of males. The patients were between 1 and 17 years old. The mean age was 9.87 ± 4.69 (min: 1; max: 17). The mean age of girls is 105 (min: 1-max: 17). The mean age of boys is 95 (min:1-max:17). Serious complications such as multisystem inflammatory syndrome in children (MIS-C) (Figure 1) developed in 8 patients (3%), ADEM developed in 10 patients (Figure 2) (4%), cerebrovascular infarct (Figure 3) developed in 20 patients (8%), non-specific T2 Weight and Fluid Attenuation Inversion Recovery(T2WI-FLAIR) hyperintensity (Figure 4) developed in 120 patients (48%, 6%), and meningoencephalitis (Figure 5) developed in 10 patients (4%). The defined data are shown in Table 1.

MAIN POINTS

- Classification of cranial complications after Covid 19 infection in pediatric patients by MRI
- Detection of the most common neurological finding after covid in pediatric patients
- Classification of neurological complications after covid in pediatric patients by age and gender

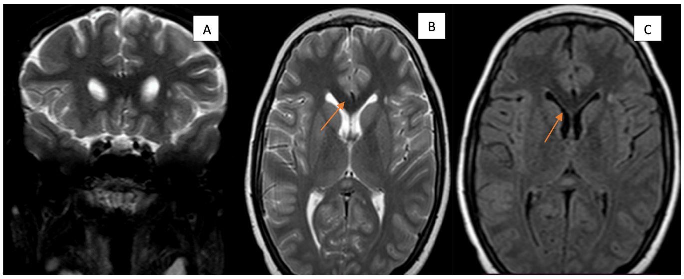

Figure 1. Left periventricular hyperintense lesion in an 8-year-old child with MIS-C after COVID was observed on frontal subcortical (indicated by an arrow). (A) Coronal T2WI, (B) axial T2WI, and (C) FLAIR sequences. MIS-C, multisystem inflammatory syndrome in children; COVID, coronavirus disease.

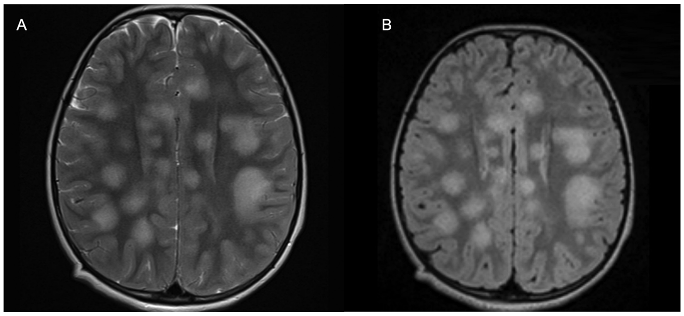

Figure 2. A 11-year-old girl was diagnosed with acut disseminated encephalomyelitiss (ADEM). She had hyperintense plaque formations in the periventricular white matter and the centrum semiovale. (A) T2 Weight Imaging T2WI and (B) Fluid atteniation recovery FLAIR scans.

DISCUSSION

The COVID-19 pandemic has had significant and wide-ranging effects on global health, with numerous complications and sequelae identified in both adult and pediatric populations. Children, while generally experiencing milder symptoms during the acute phase of the infection, are not immune to the post-acute sequelae of the SARS-CoV-2 infection.[1,2] As a result, it is crucial to investigate the potential complications and long-term effects of COVID-19 in pediatric patients. One area of particular concern is the potential for cranial complications, which can have significant impacts on cognitive, emotional, and physical development. Magnetic resonance imaging examinations have been

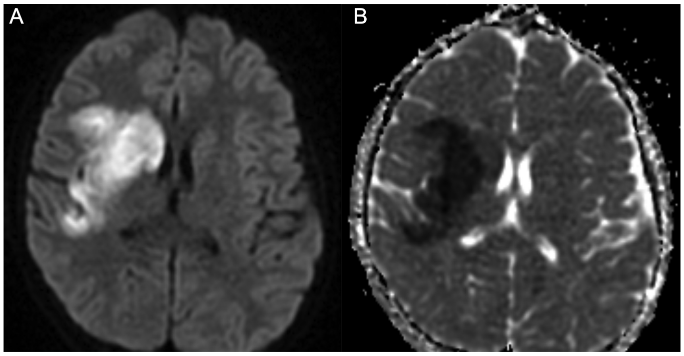

Figure 3. Fourteen days after COVID, a 15-year-old male patient developed an infarct in the right Middle Cerebral Artery (MCA) irrigation area. (A) Diffusion weighted imaging (DWI) and (B) apparent diffusion coefficient (ADC). COVID, coronavirus disease.

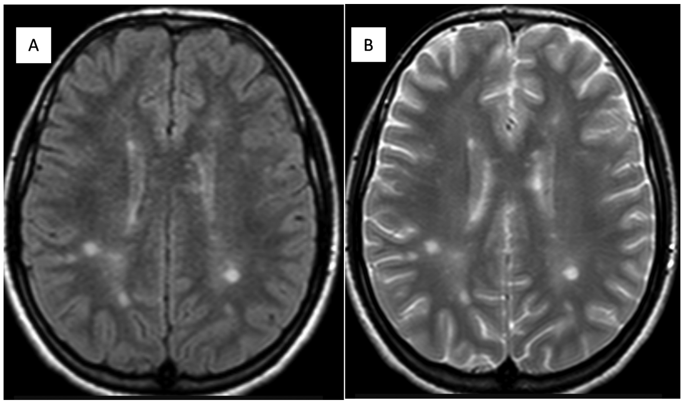

Figure 4. On the MRI of a 17-year-old female patient with headache after COVID, a few non-specific (A) T2 Weight and Fluid Attenuation Inversion Recovery (T2WI (B) FLAIR) hyperintense foci located posteriorly in the periventricular white matter and centrum semiovale observed 2 months after COVID. COVID, coronavirus disease; MRI, magnetic resonance imaging.

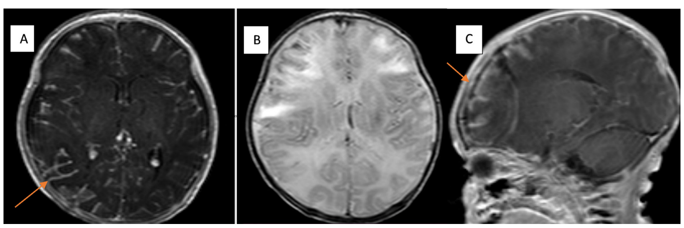

Figure 5. A 4-year-old boy patient with meningoencephalitis after COVID (indicated by an arrow) (A) On the post-contrast T1 Weight Imaging (T1WI) axial image cranial MRI, dural thickening and meningeal enhancement were observed at the right back parietal level. (B) On the axial Fluid Attenuation Inversion Recovery (FLAIR) image, cortical-subcortical edema is observed. (C) Increased enhancement of the meninges and dura is observed on sagittal T1WI sagital image. COVID, coronavirus disease; MRI, magnetic resonance imaging.

proposed as a valuable tool for detecting these complications in pediatric patients. Severe acute respiratory syndrome coronavirus 2 can potentially invade the nervous system, including the brain, either via the bloodstream or by crossing the nasal cavity and entering the olfactory nerve, which connects directly to the brain. The virus has been found in brain tissue and cerebrospinal fluid in some cases, but not consistently.The body's immune response to the virus can lead to a state of systemic inflammation. When this inflammation involves the brain and nervous system, it can potentially result in various neurological complications. This mechanism is supported by the observation that many people with severe COVID-19 have high levels of inflammatory markers in their blood, even if the virus cannot be detected in their nervous system. Coronavirus disease 2019 can lead to a state of increased blood clotting, which can result in strokes even in young, healthy individuals. This increased clotting can potentially lead to other neurological complications as well if it affects blood flow to the brain. After the acute phase of COVID-19, some individuals may experience a post-infectious autoimmune reaction, where the immune system mistakenly attacks the body's own tissues instead of the virus. This is thought to be the mechanism behind some cases of GBS following COVID-19. Emerging research suggests that the virus might trigger neurodegenerative processes in the brain leading to symptoms similar to Parkinson's disease or Alzheimer's disease. However, much more research is needed to confirm and understand these potential effects. It is important to note that these mechanisms are not mutually exclusive and could all contribute to the neurological complications observed in different individuals. In fact, individual variations in factors like genetics, immune response, and viral load could potentially explain why different people experience different neurological complications following COVID-19.

Table 1. Distribution of Neurocranial Pathologies

	n	%
ADEM (acute disseminated encephalomyelitis)	10	4
Encephalitis	10	4
Infarct	20	8
MIS-C (multisystem inflammatory syndrome in children)	8	3,2
Non-specific T2WI-FLAIR hyperintensity	120	48,6
Normal	78	32,2
Total	246	100,0

Magnetic resonance imaging has been widely recognized as a non-invasive and highly effective imaging modality for detecting and diagnosing various neurological disorders.[6] A growing body of evidence suggests that COVID-19 can lead to neurological complications in both adults and children, including encephalopathy, seizures, and cerebrovascular accidents.[7,8] As such, the use of MRI to assess the risk of cranial complications in pediatric patients with a post-COVID-19 infection is a logical and well-supported approach.

Recent studies have reported various neurological complications in pediatric patients with COVID-19, such as ADEM, acute necrotizing encephalopathy, and GBS.[9] In addition, the MIS-C associated with COVID-19 can also present with neurological symptoms. These conditions may cause significant morbidity and long-term sequelae, making early detection and intervention crucial. Magnetic resonance imaging has also been instrumental in the diagnosis of MIS-C, a condition that can present with encephalopathy, seizures, and focal neurological deficits.[10] A case report by LaRovere et al described the use of MRI in diagnosing a pediatric patient with MIS-C and encephalopathy, highlighting the importance of MRI in the early detection of cranial complications in such patients.[12] In another case report published by Karavas et al, they described a rare case of COVID-19-associated acute necrotic encephalopathy in a 2-year-old child.[14]

In another study by Lindan et al,[8] MRI findings in 50 pediatric patients with post-acute sequelae of SARS-CoV-2 infection were assessed. The study reported that 60% of the patients exhibited abnormal findings, including white matter hyperintensities, leptomeningeal enhancement, and punctate ischemic lesions. These findings underscore the importance of MRI in detecting subtle cranial complications in pediatric patients with post-infection. Another study by Abdel-Mannan et al[13] evaluated 27 pediatric patients with neurological complications associated with COVID-19. Of these, 67% showed abnormalities on brain MRI, including leptomeningeal enhancement, myelitis, and encephalitis. Furthermore, the study found a correlation between the severity of neurological manifestations and extraabnormalities.

In another study by Gaur et al, the authors identified several MRI features that were associated with neurological complications in children with COVID-19, including intracranial hemorrhage, white matter abnormalities, and brainstem lesions.[6]

In our study, we examined patients who had recovered from 246 COVID-19 cases and subsequently underwent cranial MRI for various complaints. Pathology was identified in 67.8% of patients. Compared to the studies mentioned in the preceding paragraph, the patient population in our study was larger, and the diversity and pathology detection rates were greater and more inclusive. The age spectrum of patients was kept broad.

Our research has a number of limitations. As with any descriptive study, increasing the population size yields more accurate results. Only the pediatric population was evaluated; adult patients were not studied. One of the study's limitations is that it did not evaluate patients aged 0-1 years, and the number of patients aged 1-7 years is relatively low compared to other age groups.

Of the patients examined in our study, 67% exhibited pathology. The T2WI and FLAIR sequences revealed non-specific hyperintense foci as the most prevalent pathology. Further research is needed to determine the optimal timing and indications for MRI in this population, as well as the correlation between MRI findings and long-term neurological outcomes.

Ethics Committee Approval: Ethical approval was not required as it was a retrospective study and the data were collected from the data pool.

Informed Consent: Since the data were collected from the data pool, patient consent was not obtained.

Peer-review: Externally peer-reviewed.

Declaration of Interests: The author declare that they have no competing interest.

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