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Severity-Related Structural MRI Changes in Children with Viral Panencephalitis

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Abstract

Viral panencephalitis in children is associated with heterogeneous clinical manifestations and variable patterns of structural brain involvement. Standard magnetic resonance imaging plays a central role in the evaluation of inflammatory lesions of the central nervous system; however, the relationship between MRI findings and clinical severity of pediatric viral panencephalitis remains insufficiently systematized. To evaluate structural magnetic resonance imaging changes in children with viral panencephalitis and to determine their relationship with the clinical severity of central nervous system involvement. This retrospective study included 122 pediatric patients with viral panencephalitis divided into three groups according to clinical severity of neurological involvement. Group I included 41 children with relatively favorable disease course, Group II included 43 patients with moderate neurological impairment, and Group III consisted of 38 children with severe central nervous system involvement. All patients underwent standard brain magnetic resonance imaging. Structural MRI patterns, anatomical distribution of lesions, edema-dislocation changes, and chronic structural sequelae were analyzed comparatively between the study groups. MRI findings demonstrated progressive transition from focal and limited brain lesions in Group I toward multifocal and diffuse structural involvement in children with more severe clinical manifestations. Diffuse brain abnormalities were identified in 73.7% of patients from Group III compared with 7.3% in Group I. Severe forms of viral panencephalitis were associated with extensive involvement of subcortical and deep white matter structures, basal ganglia, brainstem, and cerebellum. Pronounced cerebral edema, mass effect, and midline shift became progressively more frequent with increasing disease severity. Chronic MRI sequelae, including gliosis, cerebral atrophy, enlargement of cerebrospinal fluid spaces, and ventriculomegaly, were predominantly observed in children with severe forms of panencephalitis. Structural MRI demonstrates a clear association between the extent of brain involvement and the clinical severity of viral panencephalitis in children. Diffuse white matter injury, deep structure involvement, and edema-dislocation changes may serve as important radiological markers of severe central nervous system injury and unfavorable disease course.

Keywords: Viral panencephalitis; pediatric encephalitis; magnetic resonance imaging; brain edema; white matter injury; pediatric neuroradiology; diffuse brain involvement; central nervous system infection; gliosis; ventriculomegaly.

Introduction

Viral panencephalitis in children represents a severe form of inflammatory involvement of the central nervous system, in which the pathological process may affect cortical, subcortical, deep white matter, basal ganglia, brainstem, and cerebellar structures. The clinical course of the disease is highly variable, ranging from relatively favorable forms with limited neurological manifestations to severe variants accompanied by impaired consciousness, persistent seizures, cerebral edema, and signs of diffuse brain injury. This variability makes early assessment of disease severity clinically important, especially in pediatric patients, where rapid progression of inflammatory brain damage may lead to persistent neurological consequences [1, 2].

Magnetic resonance imaging remains the principal method for structural assessment of brain involvement in children

with viral encephalitic disorders. Standard MRI allows visualization of lesion distribution, involvement of different anatomical regions, perifocal edema, mass effect, midline shift, and delayed structural sequelae such as gliosis, atrophy, enlargement of cerebrospinal fluid spaces, and ventriculomegaly [3]. However, the interpretation of MRI findings in viral panencephalitis is not always straightforward, since focal, multifocal, and diffuse patterns may reflect different stages and severities of the same pathological process. In clinical practice, the extent of brain involvement, depth of white matter damage, and severity of edema may be more informative than the mere presence of isolated lesions.

A clinically relevant issue is the relationship between MRI patterns and the severity of central nervous system involvement [4]. Children with mild or relatively favorable disease may demonstrate limited focal changes or even absence of visible structural abnormalities, whereas severe cases are more often associated with diffuse brain involvement, deep white matter lesions, basal ganglia, brainstem or cerebellar involvement, and edema-dislocation changes [5, 6]. At the same time, chronic MRI sequelae after viral panencephalitis may persist even when clinical symptoms partially regress, indicating that structural imaging provides important information not only for acute assessment but also for follow-up evaluation.

Despite the routine use of MRI in pediatric neuroinfection, the structural patterns of viral panencephalitis according to clinical severity remain insufficiently systematized [7]. A clearer description of severity-related MRI profiles may improve early radiological interpretation, help identify children at higher risk of complicated disease course, and support more individualized monitoring during the acute and recovery periods.

The aim of this study was to evaluate structural MRI changes in children with viral panencephalitis and to determine their relationship with the clinical severity of central nervous system involvement.

Methods

This retrospective observational study included 122 pediatric patients with viral panencephalitis who underwent clinical neurological evaluation and magnetic resonance imaging of the brain during the acute phase of the disease. All patients were treated in a specialized pediatric neurological center and were divided into three subgroups according to the clinical severity of central nervous system involvement. Group I included 41 children with relatively favorable clinical course and limited neurological manifestations. Group II consisted of 43 patients with moderate neurological impairment. Group III included 38 children with severe forms of panencephalitis accompanied by impaired consciousness, persistent seizure syndrome, and signs of generalized central nervous system involvement.

The diagnosis of viral panencephalitis was established based on clinical presentation, neurological examination, laboratory findings, and neuroimaging data. Assessment of disease severity was based on the degree of neurological dysfunction, presence of seizures, level of consciousness impairment, and progression of cerebral symptoms during hospitalization.

All patients underwent standard magnetic resonance imaging of the brain. MRI analysis included evaluation of the character and extent of structural brain involvement, distribution of lesions within different anatomical regions, severity of cerebral edema, presence of mass effect and midline shift, as well as delayed structural changes identified during follow-up examinations. Structural MRI patterns were classified as focal, multifocal, or diffuse. Anatomical involvement of the cerebral cortex, subcortical white matter, deep white matter structures, basal ganglia, brainstem, and cerebellum was assessed comparatively between the study groups.

Special attention was paid to edema-dislocation changes, including severity of cerebral edema, development of mass effect, and displacement of midline structures. In addition, chronic structural sequelae after viral panencephalitis were analyzed, including gliosis, atrophic changes, enlargement of cerebrospinal fluid spaces, and ventriculomegaly.

Statistical analysis was performed using descriptive methods. Quantitative variables were presented as absolute numbers and percentages. Comparative analysis of MRI patterns and structural changes between the three clinical severity groups was carried out to identify radiological features associated with progression of central nervous system involvement.

Results

Structural magnetic resonance imaging demonstrated a progressive increase in the extent and severity of brain involvement with worsening clinical course of viral panencephalitis in children. Patients from Group I with relatively favorable neurological manifestations predominantly showed focal and limited MRI abnormalities, whereas children from Groups II and III demonstrated a gradual shift toward multifocal and diffuse structural brain injury. Diffuse MRI patterns became particularly characteristic of severe forms of panencephalitis associated with impaired consciousness and persistent seizure syndrome (table 1).

Table 1. Structural MRI patterns and extent of brain involvement according to clinical severity of viral panencephalitis

MRI pattern	Group I (n=41)	Group II (n=43)	Group III (n=38)
No structural abnormalities	6 (14.6%)	1 (2.3%)	0
Focal lesions	21 (51.2%)	9 (20.9%)	2 (5.3%)
Multifocal lesions	11 (26.8%)	18 (41.9%)	8 (21.1%)
Diffuse brain involvement	3 (7.3%)	15 (34.9%)	28 (73.7%)

Limited distribution pattern	24 (58.5%)	7 (16.3%)	1 (2.6%)
Multifocal distribution pattern	13 (31.7%)	19 (44.2%)	8 (21.1%)
Diffuse distribution pattern	4 (9.8%)	17 (39.5%)	29 (76.3%)

MRI findings revealed a clear transition from focal and localized abnormalities in Group I toward multifocal and diffuse involvement in children with more severe neurological impairment. Diffuse structural changes were detected in nearly three quarters of patients from Group III, whereas focal lesions predominated in children with relatively favorable clinical course. Multifocal and generalized MRI patterns became progressively more frequent with increasing severity of central nervous system involvement.

More severe forms of viral panencephalitis were additionally associated with progressive extension of pathological changes into deep anatomical brain structures, increasing edema-dislocation abnormalities, and development of chronic structural sequelae. Involvement of deep white matter, basal ganglia, brainstem, and cerebellum was observed predominantly in Group III patients and frequently coexisted with severe cerebral edema and mass effect (table 2).

Table 2. Major anatomical involvement, edema-related changes, and chronic MRI sequelae in children with viral panencephalitis

MRI feature	Group I	Group II	Group III
Cortical involvement	18 (43.9%)	27 (62.8%)	30 (78.9%)
Subcortical white matter involvement	14 (34.1%)	29 (67.4%)	34 (89.5%)
Deep white matter involvement	6 (14.6%)	18 (41.9%)	29 (76.3%)
Basal ganglia involvement	2 (4.9%)	11 (25.6%)	21 (55.3%)
Brainstem involvement	1 (2.4%)	6 (14.0%)	18 (47.4%)
Severe cerebral edema	3 (7.3%)	13 (30.2%)	25 (65.8%)
Mass effect	1 (2.4%)	8 (18.6%)	22 (57.9%)
Midline shift	0	4 (9.3%)	15 (39.5%)
Gliosis	6 (14.6%)	14 (32.6%)	22 (57.9%)
Atrophic changes	1 (2.4%)	6 (14.0%)	18 (47.4%)
Ventriculomegaly	1 (2.4%)	7 (16.3%)	17 (44.7%)

Severe viral panencephalitis was characterized by extensive involvement of deep brain structures, pronounced edema-dislocation changes, and higher frequency of chronic MRI abnormalities. Brainstem and basal ganglia lesions were observed mainly in children with severe neurological manifestations and were commonly associated with diffuse white matter injury. Chronic structural sequelae, including gliosis, cerebral atrophy, and ventriculomegaly, became progressively more frequent with increasing clinical severity, indicating persistent structural consequences of severe inflammatory brain injury.

Discussion

The present study demonstrated a clear relationship between the severity of viral panencephalitis in children and the extent of structural brain abnormalities detected by standard magnetic resonance imaging [8]. As the clinical severity of central nervous system involvement increased, MRI patterns progressively shifted from limited focal lesions toward multifocal and diffuse brain injury with involvement of deeper anatomical structures [9]. These findings indicate that standard MRI reflects not only the presence of inflammatory brain damage but also the degree of progression and generalization of the pathological process.

One of the most important observations of the study was the gradual transition from predominantly cortical and subcortical involvement in clinically milder cases to widespread injury of deep white matter, basal ganglia, brainstem, and cerebellar structures in severe forms of panencephalitis. In children from Group I, structural abnormalities were usually limited and relatively localized, whereas Group III was characterized by extensive diffuse lesions affecting multiple anatomical levels of the central nervous system. Such distribution suggests that severe viral panencephalitis is associated with progressive disruption of both cortical and deep integrative brain structures, which may explain the development of impaired consciousness, persistent seizures, and generalized neurological dysfunction observed in these patients [10-13].

The study also showed that the extent of structural lesions alone does not fully characterize disease severity. Edema-dislocation changes represented an additional and clinically significant component of MRI assessment. While mild forms of panencephalitis were frequently associated with absence of edema or only moderate swelling, severe cases demonstrated pronounced cerebral edema, mass effect, and displacement of midline structures. These findings underline the importance of evaluating edema-related changes separately from the

distribution of inflammatory lesions, since rapidly progressing edema may substantially aggravate neurological status even in patients without extremely extensive focal abnormalities [14].

Another important finding was the increasing frequency of chronic structural sequelae with progression of disease severity. Gliosis, cortical and subcortical atrophic changes, enlargement of cerebrospinal fluid spaces, and ventriculomegaly were observed predominantly in children with severe forms of panencephalitis. This observation suggests that MRI abnormalities may persist beyond the acute inflammatory stage and reflect long-term structural consequences of brain injury. In some patients, significant residual MRI changes remained detectable despite partial clinical improvement, indicating a possible dissociation between neurological recovery and structural restoration of brain tissue [15, 16].

The results of the present study support the role of standard MRI as a valuable tool for severity-oriented assessment of pediatric viral panencephalitis. Structural MRI patterns may help identify children with higher risk of generalized brain involvement and complicated neurological course already at early stages of the disease. In practical terms, diffuse white matter injury, deep structure involvement, severe edema, and displacement of midline structures may be regarded as unfavorable radiological markers requiring closer monitoring and more intensive therapeutic management [17].

Several limitations of the study should be acknowledged. The investigation had a retrospective design and was performed in a single center. Viral etiological variants were analyzed within a combined cohort rather than as separate pathogen-specific groups. In addition, MRI assessment was based mainly on structural imaging without incorporation of advanced metabolic or diffusion techniques. Further prospective studies integrating structural, metabolic, and functional neuroimaging may provide a more comprehensive understanding of brain injury patterns in pediatric viral panencephalitis.

Conclusion

Structural magnetic resonance imaging demonstrates a clear association between the radiological pattern of brain involvement and the clinical severity of viral panencephalitis in children. Progression from mild to severe forms of the disease is accompanied by a gradual transition from limited focal lesions to multifocal and diffuse brain injury with involvement of deep white matter structures, basal ganglia, brainstem, and cerebellum. Severe forms of viral panencephalitis are additionally characterized by pronounced edema-dislocation changes, including mass effect and midline shift, as well as by a higher frequency of chronic structural sequelae such as gliosis, cerebral atrophy, enlargement of cerebrospinal fluid spaces, and ventriculomegaly. These findings indicate that standard MRI provides clinically important information regarding both the acute severity of central nervous system injury and the potential long-term structural consequences of the disease. The obtained results suggest that severity-oriented interpretation of structural MRI patterns may improve early radiological assessment and facilitate identification of pediatric patients with increased risk of generalized brain involvement and unfavorable neurological course in viral panencephalitis.

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