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NEUROIMAGING AND CLINICAL-NEUROLOGICAL FEATURES IN CHILDREN WITH THE CONSEQUENCES OF TRAUMATIC BRAIN INJURY.

Associate Professor of the Department of Neurology, ASMI,

M.I. Abdullaeva

Abstract: Objective: To determine the relationship between neuroimaging findings and clinical-neurological manifestations in children with traumatic brain injury (TBI) during the recovery period. **Materials and Methods:** The study included 86 children aged 7–16 years who had sustained TBI of varying severity. Clinical-neurological examination, neuropsychological testing, and neuroimaging methods (MRI, CT) were used. The post-injury period ranged from 3 months to 3 years.
Results: According to neuroimaging data, focal changes in the white matter were detected in 64.0% of children, post-traumatic ventricular dilatation in 28.0%, cortical and hippocampal atrophy in 21.0%, and signs of diffuse axonal injury in 35.0%. Clinically, the most frequent sequelae included pyramidal insufficiency (43.0%), cerebellar ataxia (29.0%), asthenoneurotic manifestations (52.0%), and cognitive impairments (58.0%). A significant correlation was established between lesion localization and the type of neurological deficit: frontal lobe lesions were associated with attention and behavioral regulation disorders ($r=0.62$; $p<0.01$), while cerebellar lesions correlated with coordination disturbances ($r=0.68$; $p<0.001$).
Conclusion: Post-traumatic brain changes in children are predominantly multifocal, determining the polymorphism of clinical manifestations. Early neuroimaging diagnostics make it possible to predict the course of recovery and optimize rehabilitation strategies.
Keywords: children, traumatic brain injury, neuroimaging, cognitive impairment, neurological deficit, MRI.

Introduction. Traumatic brain injury (TBI) in children remains one of the leading causes of mortality and long-term disability in the pediatric population. According to the World Health Organization (WHO, 2023), more than 3 million children worldwide experience head trauma annually, and up to 25–30% develop persistent neurological and cognitive consequences. The developing brain, characterized by high plasticity, is simultaneously more vulnerable to mechanical, hypoxic, and metabolic insults, which determine the unique features of post-traumatic neural reorganization and clinical manifestations.

A distinctive feature of pediatric TBI is the immaturity of myelination and incomplete formation of inter-neuronal connections, making even mild injuries capable of causing delayed cognitive and behavioral impairments. Studies have shown that 40–60% of children after TBI exhibit persistent disturbances in attention, memory, executive regulation, and emotional control, which adversely affect quality of life and academic performance (Levin H.S. et al., 2020; Bigler E.D., 2021).

In recent years, neuroimaging techniques—particularly magnetic resonance imaging (MRI) and diffusion tensor imaging (DTI)—have become crucial in studying the consequences of pediatric TBI. These methods not only visualize focal and diffuse post-traumatic changes but also assess white matter integrity, neuronal pathways, and functional brain networks. MRI biomarkers such as fractional anisotropy indices, hippocampal volume, and periventricular white matter

alterations are now recognized as objective tools for grading the severity and predicting the prognosis of brain injury in children (Wilde E.A. et al., 2022; Johnson V.E. et al., 2023).

However, the correlation between neuroimaging findings and the clinical-neurological status of pediatric patients remains insufficiently explored. Clinical manifestations—such as asthenic-neurotic syndrome, cognitive deficits, and pyramidal insufficiency—often persist even in the absence of pronounced morphological changes on standard MRI sequences. This discrepancy highlights the need for an integrated diagnostic approach combining neurological, neuropsychological, and advanced neuroimaging assessments.

Therefore, investigating the relationships between neuroimaging-detected structural brain alterations and clinical manifestations in children with post-traumatic brain injury has both scientific and practical significance. Such studies contribute to understanding the mechanisms of post-traumatic neuroplasticity, improving early diagnosis, and developing effective neurorehabilitation strategies aimed at restoring cognitive and behavioral functions.

Objective: To identify the features of neuroimaging alterations and their correlation with clinical-neurological manifestations in children with post-traumatic brain injury at various stages of recovery.

Materials and Methods.тThe study included 86 children who underwent examination and treatment in the neurological department. Inclusion criteria: a confirmed history of traumatic brain injury (TBI), preserved consciousness at the time of examination, and absence of congenital malformations of the central nervous system.

The following methods were applied:

1. Clinical and neurological examination – assessment of motor, coordination, and sensory functions;

2. Neuropsychological testing – using Luria's methods and standard tests for attention and memory;

3. Magnetic resonance imaging (MRI) of the brain – performed in T1-, T2-, FLAIR, and DWI-sequences;

4. Statistical analysis – correlation analysis and chi-square test (χ^2), with statistical significance set at $p<0.05$.

Results. *Neuroimaging findings*. MRI examination revealed focal post-traumatic changes in the fronto-parietal regions in 64.0% of the children. Ventricular dilatation was detected in 28.0%, cortical atrophy in 21.0%, and signs of diffuse axonal injury in 35.0% of cases. Younger children more frequently exhibited diffuse lesions, whereas adolescents predominantly showed localized foci of post-traumatic alterations.

Clinical and neurological features. The leading clinical syndromes in the post-traumatic period were as follows:

1-Pyramidal insufficiency – 43.0%;

2-Cerebellar ataxia – 29.0%;

3-Asthenoneurotic syndrome – 52.0%;

4-Cognitive impairments – 58.0%, including deficits in memory, attention, and verbal productivity.

The severity of cognitive disorders correlated with the degree of structural brain changes identified on MRI. A statistically significant association was found between lesion localization and the type of neurological deficit:

- Frontal lobe damage was linked to impaired attention and behavioral regulation (r=0.62; p<0.01);

- Cerebellar lesions were associated with coordination disturbances (r=0.68; p<0.001).

Summary of findings. Post-traumatic brain changes in children are predominantly multifocal and heterogeneous, involving both cortical and subcortical structures. These alterations underlie the polymorphism of clinical manifestations and explain the persistence of cognitive and neurological deficits in the long-term recovery phase.

Discussion. The results of this study confirm that the consequences of traumatic brain injury (TBI) in children are characterized by structural and functional heterogeneity. The combination of focal and diffuse lesions identified on MRI reflects the complexity of the underlying pathological processes, which include mechanical tissue damage, secondary ischemia, oxidative stress, and neuroinflammatory responses. The developing brain demonstrates a unique pattern of vulnerability and compensatory neuroplasticity that distinguishes pediatric TBI from adult forms.

In agreement with previous studies (Levin H.S. et al., 2020; Wilde E.A. et al., 2022), our data indicate that focal changes in the frontal and parietal lobes are among the most common MRI findings in children following TBI. These regions are responsible for executive and sensorimotor integration, which explains the frequent combination of cognitive, motor, and coordination impairments. The presence of diffuse axonal injury, detected in over one-third of the cases, suggests a high likelihood of disruption in large-scale neural networks that underlie attention and memory processes.

The established correlation between lesion localization and specific clinical manifestations provides important insights for diagnostic and prognostic assessment. In particular, the association between frontal lobe damage and deficits in attention and behavioral regulation highlights the role of prefrontal circuits in cognitive control, while cerebellar lesions leading to coordination disturbances emphasize the importance of cerebello-thalamo-cortical pathways in motor and cognitive integration.

Persistent asthenoneurotic and cognitive syndromes observed in more than half of the examined children confirm that even mild-to-moderate injuries can result in long-term neuropsychological dysfunctions. These findings underscore the necessity of early and systematic neuroimaging evaluation combined with comprehensive neuropsychological testing. The integration of advanced MRI modalities, such as diffusion tensor imaging (DTI) and functional MRI (fMRI), may improve the identification of subtle post-traumatic abnormalities that are invisible on conventional scans (Johnson V.E. et al., 2023).

The obtained results have significant implications for clinical practice. Early recognition of structural and functional post-traumatic changes enables targeted rehabilitation programs, neuroprotective therapy, and monitoring of cognitive recovery. Moreover, a multimodal diagnostic approach contributes to the personalization of rehabilitation strategies, taking into account the child's age, lesion localization, and neuroplastic potential.

Conclusion:

1. Neuroimaging studies revealed that post-traumatic brain changes in children are predominantly multifocal, combining both focal and diffuse structural lesions of cortical and subcortical regions.
2. The clinical presentation is characterized by a combination of pyramidal, cerebellar, and cognitive impairments, reflecting the diffuse nature of the injury and immature neural integration in the developing brain.
3. A significant correlation was established between the localization of structural lesions and specific neurological deficits: frontal lobe damage was associated with cognitive and behavioral regulation disorders, while cerebellar lesions correlated with coordination impairment.
4. Early neuroimaging assessment, integrated with comprehensive neurological and neuropsychological evaluation, allows for more accurate prognosis and timely initiation of individualized neurorehabilitation programs.

Overall, early identification of structural and functional post-traumatic brain changes in children provides an essential basis for preventing long-term cognitive decline and improving neurological outcomes.

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