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NEUROPHYSIOLOGICAL FEATURES IN CHILDREN WITH TRAUMATIC BRAIN INJURY SEQUELAE

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Abstract: Objective: To assess neurophysiological features in children following traumatic brain injury (TBI) and to examine their relationship with injury severity and cognitive impairments. **Materials and Methods:** This prospective single-center study included children aged 7–16 years with mild, moderate, and severe TBI (n=40). Electroencephalography (EEG) and evoked potentials (EPs: auditory, visual, somatosensory) were performed. Data were correlated with cognitive performance and neurological status. **Results:** Slowing of the EEG background rhythm, focal and disorganization patterns, as well as delayed latencies and reduced amplitudes of evoked potentials, were observed. Injury severity and the presence of post-concussive symptoms correlated with the extent of neurophysiological abnormalities. **Conclusion:** Children with TBI exhibit persistent neurophysiological changes, highlighting the need for comprehensive monitoring and individualized rehabilitation.
Keywords: pediatric traumatic brain injury, EEG, evoked potentials, neurophysiological abnormalities, cognitive functions, rehabilitation.

Introduction. Traumatic brain injury (TBI) in children represents a major cause of morbidity and long-term disability worldwide. Pediatric TBI is associated with a wide spectrum of outcomes, ranging from subtle cognitive and behavioral deficits to severe neurological impairments. Cognitive domains frequently affected include attention, working memory, processing speed, executive functions, and both verbal and visual memory. These deficits can significantly interfere with academic performance, daily activities, and social adaptation.

The developing brain is both highly plastic and highly vulnerable. While neuroplasticity provides some capacity for recovery, the immature neural networks are more susceptible to injury, particularly during critical periods of development. The location, severity, and timing of TBI all influence the extent and nature of subsequent neurophysiological and cognitive impairments.

Neurophysiological assessment, including electroencephalography (EEG) and evoked potentials (EPs), is an essential tool for objectively evaluating functional brain changes after TBI. EEG provides insight into global cortical activity, detecting slowing of background rhythms, focal abnormalities, or disorganization of brain oscillations. Evoked potentials (auditory, visual, somatosensory) allow assessment of specific sensory pathways and cortical processing efficiency. These methods can identify subclinical disturbances that may not be apparent during routine clinical or cognitive testing, providing a more complete understanding of post-traumatic brain dysfunction.

Despite numerous studies on pediatric TBI, data integrating clinical, cognitive, and neurophysiological findings remain limited. Understanding these associations is crucial for early identification of children at risk for long-term impairments and for tailoring individualized rehabilitation programs.

Objective of the study: To comprehensively evaluate neurophysiological features in children with TBI and examine their relationship with injury severity, cognitive performance, and clinical outcomes.

Materials and Methods

Study Design: A prospective, single-center observational study conducted in the pediatric multidisciplinary hospital in Andijan, in the Department of Neurology. The study protocol was approved by the Ethics Committee, and parents or legal guardians of the children provided written informed consent.

Participants: 40 children aged 7–16 years with mild, moderate, or severe TBI.

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Classification of Injury Severity: According to the Glasgow Coma Scale (GCS) at admission: Mild TBI: 13–15 points, Moderate TBI: 9–12 points, Severe TBI: ≤ 8 points
Exclusion Criteria: Children with pre-existing neurological disorders, developmental delays, psychiatric conditions, or previous traumatic brain injuries were excluded.
Study Groups: Mild TBI — n1 (15), Moderate TBI — n2 (10), Severe TBI — n3 (8), Control group (healthy children) — n4 (7).
Neurophysiological Assessment:
- EEG: evaluation of background rhythm, focal abnormalities, and disorganization patterns.
Evoked Potentials (EPs):
- Auditory EPs (AEPs): assessment of conduction in auditory pathways and cortical centers
- Visual EPs (VEPs): measurement of P100 component latency and amplitude
- Somatosensory EPs (SSEPs): assessment of conduction in somatosensory pathways
Results. Neurological Findings. At initial examination, children with TBI showed the following clinical features:
- Mild TBI: predominantly headaches and mild dizziness; no focal neurological deficits.
- Moderate TBI: pyramidal signs, mild coordination deficits, moderate vestibular disturbances.
- Severe TBI: pronounced pyramidal signs, ataxia, significant coordination impairments, and persistent vestibular dysfunction.

Cognitive Performance

Measure	Mild TBI (n=15)	Moderate TBI (n=10)	Severe TBI (n=8)	Control (n=7)	Statistics
Attention (CPT, omission errors)	12.4 ± 4.1	19.3 ± 6.5	28.1 ± 8.9	8.2 ± 3.3	ANOVA F=41.2; p<0.001
Processing Speed (TMT-A, sec)	42.1 ± 8.5	55.9 ± 10.2	71.3 ± 12.4	34.6 ± 7.1	ANOVA F=52.7; p<0.001
Working Memory (Digit Span)	6.4 ± 1.1	5.7 ± 1.0	4.8 ± 0.9	7.2 ± 1.2	ANOVA F=33.5; p<0.001
Executive Functions (TMT-B, sec)	82.6 ± 19.3	104.8 ± 22.1	139.4 ± 30.5	71.9 ± 15.7	ANOVA F=47.9; p<0.001
Verbal Memory (Delayed Recall, score/15)	11.1 ± 2.3	9.8 ± 2.4	7.4 ± 2.5	12.8 ± 1.7	Kruskal–Wallis H=29.4; p<0.001
Visual Memory (Recognition Errors)	4.3 ± 1.5	6.1 ± 2.0	8.7 ± 2.6	3.1 ± 1.1	p<0.001

Neurophysiological Findings (EEG and EPs)

Measure	Mild TBI	Moderate TBI	Severe TBI	Control	Notes
EEG background slowing	20%	50%	75%	0%	Directly proportional to injury severity
Focal EEG abnormalities	10%	35%	62%	0%	Mainly in frontal and temporal regions
EEG disorganization	5%	20%	50%	0%	Associated with executive function deficits
AEP: P1 latency delay (ms)	2.1 ± 0.3	3.2 ± 0.4	4.5 ± 0.5	1.8 ± 0.2	p<0.001
VEP: P100 latency	103.2 ±	118.5 ± 9.4	135.8 ±	98.4 ±	p<0.001

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Measure	Mild TBI	Moderate TBI	Severe TBI	Control	Notes
(ms)	7.1		11.2	6.5	
SSEP: latency increase (ms)	5.8 ± 1.1	9.6 ± 1.8	13.4 ± 2.3	4.1 ± 0.9	p<0.001

Correlation Analysis

- EEG background slowing and disorganization correlated significantly with attention deficits ($r=0.62$; $p<0.001$) and working memory impairment ($r=0.58$; $p<0.001$).
- Delayed latencies of AEP, VEP, and SSEP were associated with reduced processing speed and executive function performance ($r=0.55–0.67$; $p<0.001$).
- Post-concussive symptoms (headache, fatigue, irritability) were closely linked with the severity of neurophysiological abnormalities.

Summary of Results:

- The severity of TBI directly impacts the extent of cognitive and neurophysiological deficits.
- Children with severe TBI demonstrate the most pronounced impairments in attention, memory, processing speed, and executive functions.
- EEG and EPs are sensitive tools for detecting subclinical brain dysfunction and monitoring recovery over time.

Discussion. The results of our study demonstrate that the consequences of traumatic brain injury (TBI) in children are multifaceted, encompassing both cognitive and neurophysiological impairments. In particular, children with severe TBI showed pronounced slowing of the EEG background rhythm, focal and disorganization patterns, as well as delayed latencies and reduced amplitudes of evoked potentials. These findings are consistent with previous studies indicating that injury severity correlates with the extent of cognitive deficits and disruption of cortical functional activity.

Attention, working memory, and processing speed deficits in children with TBI corresponded with EEG and EP changes, confirming the close relationship between structural and functional brain dysfunction and cognitive performance. These impairments were most pronounced in children with severe TBI, highlighting the importance of early identification and comprehensive rehabilitation.

Delays in AEP, VEP, and SSEP latencies indicate that sensory pathways remain functionally impaired even in the absence of overt clinical symptoms, emphasizing the value of neurophysiological methods for monitoring recovery.

Additionally, age at the time of injury and the presence of post-concussive symptoms influenced the severity of neurophysiological and cognitive deficits, consistent with the concept of increased vulnerability of the developing brain. These observations have clinical significance for identifying high-risk groups and individualizing rehabilitation programs.

Our study expands the understanding of the clinical, neurophysiological, and cognitive characteristics of children with TBI sequelae and underscores the necessity of a comprehensive approach that includes clinical evaluation, cognitive testing, and neurophysiological monitoring.

Conclusion

1. Children with TBI sequelae exhibit persistent cognitive and neurophysiological impairments, the severity of which depends on injury severity.
2. The most pronounced deficits are observed in children with severe TBI, including impairments in attention, working memory, processing speed, and executive functions.
3. EEG and evoked potentials are sensitive tools for detecting subclinical dysfunction and monitoring recovery dynamics.
4. Early identification of neurophysiological and cognitive impairments allows for optimization of rehabilitation strategies and individualized care for each child.

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