

## CLINICAL AND ULTRASONOGRAPHIC EVALUATION OF THE NEUROLOGICAL STATUS OF CHILDREN WITH MILD BRAIN INJURY IN ACUTE PHASE

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**Background.** The intracranial changes in children with mild traumatic brain injury in acute period are identified by a combination of clinical-neurological and ultrasonographic evaluations of the condition severity.

**Aim.** The aim of the study was to assess the possibility of performing comprehensive clinical and ultrasonographic evaluations in for determining the severity of the neurological condition of children with mild traumatic brain injury in an acute phase.

**Materials and Methods.** Clinical and ultrasonographic assessment of the severity of the neurological condition was performed on 256 patients with clinical criteria suggesting mild traumatic brain injury. Ultrasonography was used as the main neuroimaging.

**Results.** We found that the diagnostic sensitivity of clinical and ultrasonographic examination for detecting traumatic structural intracranial changes in children with mild traumatic brain injury was 90% (95% confidence interval [CI] 0.71–0.98), diagnostic specificity was 97% (95% CI 0.96–0.98), and diagnostic efficiency was 94.9% (95% CI 0.918–0.971).

**Conclusions.** A comprehensive clinical ultrasonographic approach can be effectively used to assess the severity of the neurological condition of children with mild traumatic brain injury in the acute phase.

**Keywords:** children, mild traumatic brain injury, neurological examination, transcranial ultrasonography.

## КОМПЛЕКСНАЯ КЛИНИКО-СОНОГРАФИЧЕСКАЯ ОЦЕНКА ТЯЖЕСТИ НЕВРОЛОГИЧЕСКОГО СОСТОЯНИЯ ДЕТЕЙ ПРИ ЛЕГКОЙ ЧЕРЕПНО-МОЗГОВОЙ ТРАВМЕ В ОСТРОМ ПЕРИОДЕ

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**Актуальность.** Выявление внутричерепных изменений у детей при легкой черепно-мозговой травме в остром периоде путем сочетания клинико-неврологической и сонографической оценки тяжести состояния.

**Цель исследования** — изучить возможности комплексной клинико-сонографической оценки тяжести неврологического состояния у детей при легкой черепно-мозговой травме в остром периоде.

**Материалы и методы.** Клинико-сонографическая оценка тяжести неврологического состояния проведена 256 пострадавшим с клиническими критериями легкой черепно-мозговой травмы. В качестве основного метода нейровизуализации применяли ультрасонографию.

**Результаты.** Установлено, что диагностическая чувствительность клинико-сонографического осмотра в выявлении травматических структурных внутричерепных изменений у детей при легкой черепно-мозговой травме составила 90,0 % (95 % ДИ 0,71–0,98), диагностическая специфичность — 97,0 % (95 % ДИ 0,96–0,98), диагностическая эффективность — 94,9 % (95 % ДИ 91,8–97,1).

**Выводы.** Комплексный клинико-сонографический подход может быть эффективно использован для оценки тяжести неврологического состояния у детей при легкой черепно-мозговой травме в остром периоде.

**Ключевые слова:** дети, легкая черепно-мозговая травма, неврологическая оценка, транскраниальная ультрасонография.

## Background

Mild traumatic brain injury (MTBI) is the most common type of head injury among children. According to the Russian national classification of traumatic brain injury (TBI), MTBIs include injuries in patients with a total Glasgow Coma Scale (GCS) score of 13–15 points (brain concussion: 506.1 and mild contusion of the brain: 506.3) [1]. According to previous studies, in 1.5%–8% of cases, the following significant traumatic structural intracranial changes (SICs) are observed in children who fulfill the clinical criteria of MTBI: epidural hematomas in 16%, subdural hematomas in 37%, parenchymal hemorrhages in 44%, subarachnoid hemorrhages in 24%, and intraventricular hemorrhages in 4% [2, 3]. The transient nature of cerebral and focal neurological symptoms observed at an early age reduces the importance of performing clinical evaluations for detecting complicated MTBIs, necessitating the use of methods such as neuroimaging to determine CCI severity [4, 5]. A brain computed tomography (CT) scan is the primary method of performing neuroimaging of CCIs to detect traumatic SICs [1]. In addition, the use of CT scans in children is associated with the negative effects of ionizing radiation in the child's body, necessitating the use sedation in injured children and those in a state of psychomotor agitation [6, 7]. Therefore, previous studies discourage the widespread use of CT in children as a screening method for MTBIs [8]. The development of clinical decision rules for performing brain CT scans in patients with MTBIs contributes to the reduction in the number of studies conducted by identifying clinical and anamnestic risk factors for the development of traumatic SICs [9]. However, the use of clinical decision rules does not provide helpful information at the stage of preclinical development [10]. Over the past 20 years, transcranial ultrasonography (TUS) has generated increasing interest as an alternative method of noninvasive neuroimaging screening in children [5, 11, 12].

**Aims.** We aimed to study the feasibility of conducting a complex clinical sonographic evaluation to

determine the severity of the neurological status of pediatric patients with MTBIs during the acute phase.

## Materials and methods

This study presents data on the results of clinical sonographic studies conducted at Children's municipal hospital No. 19 and Children's municipal hospital No. 5 in St. Petersburg during 2013–2014. The guardians of all pediatric patients voluntarily signed the informed consent form permitting the use of their personal data and participation in the study. The study population comprised children aged 0–18 years ( $n = 256$ ) with an average age of  $8.10 \pm 5.56$  years [95% confidence interval (CI) 7.42–8.79].

The study included injured pediatric patients who, as per the initial assessment of the clinical severity, had a CCI corresponding to the MTBI criteria (according to Konovalom [1]) and exhibited neurological disorders characteristic of traumatic complications [1]. This study excluded pediatric patients with suspected head trauma or concomitant somatic and/or infectious diseases. On hospital admission, anamnestic data of the pediatric patients were collected and a neurological examination was performed according to the standard procedure followed in the Neuropediatrics Department. An evaluation to determine the severity of the neurological condition was performed using the conditioned suppression procedure. The standard GCS and a GCS modified for pediatric patients were used [13, 14]. A neurological examination was used for assessing brain damage symptoms, which are the most characteristic features of traumatic SICs, including signs of intracranial hypertension (post-traumatic cephalgia, vomiting, and/or suppression of consciousness), focal neurological symptoms (hemispherical, cerebellar, and/or stem), and clinical manifestations of the skull fracture (presence and localization of the subgaleal hematoma, bleeding or suspected liquorrhea from the nasopharynx and/or the ears, raccoon sign, and/or ecchymosis in the mastoid process area). Craniography in

two projections and ultrasonography (US) were performed for all patients with suspected minor brain injuries within the first hours of admission. Transcranial–transfontanel ultrasonography was performed for the pediatric patients with an open fontanel while TUS was performed for those with a closed fontanel for the diagnostic screening and monitoring of SIC. A brain CT scan was performed for the pediatric patients to detect significant clinical and neurological disorders and/or SICs, according to the US results. To rule out the acute progression of SICs, a dynamic clinical sonographic evaluation for assessing the severity of the condition was performed within the first three days, that is, at 12, 24, and 72 h after hospital admission. A repeat CT scan was performed for patients with worsening clinical conditions, as identified using normal US results, and in those with increased SICs, according to the repeat US results. To assess and study the significance of anamnestic, clinical, and neurological risk factors in the development of traumatic SICs, all patients were divided according to their age group as follows: group I [patients <2 years of age,  $n = 56$  (21.9%)] and group II [patients >2 years of age,  $n = 200$  (79.1%)].

The relationship between clinical and neurological disorders and the incidence of SICs (traumatic, nontraumatic, and/or residual and organic) was determined between the groups. In addition, the diagnostic efficiency of the clinical and

sonographic methods for assessing the neurological status to determine the traumatic SICs in the patients with MTBIs was evaluated. Statistical analyses were performed using the chi-square test or Fisher's exact test. Data were analyzed using SPSS 13. A  $p$  value of 5% was considered statistically significant.

## Results and discussion

The severity of the clinical condition on admission in 218 (85.2%) pediatric patients was assessed as satisfactory (total GCS score: 15 points); in 38 (14.8%) patients, the severity was assessed as average (total GCS score: 13–14 points). In 188 (73.4%) injured patients with complicated MTBIs, the main cause of the injury was a fall from height: it was the main cause in 37 (66.1%) pediatric patients in group I and 91 (45.5%) patients in group II. The clinical and neurological disorders detected in the injured patients in the two groups during the acute phase of MTBI are shown in Table 1.

According to the craniography results, 112 (43.8%) injured patients exhibited roentgenographic evidence of traumatic cranial injury: 48 (18.8%) pediatric patients in group I and 64 (25.0%) in group II. Using CT, traumatic SICs were observed in 14 (5.4%) injured pediatric patients with verified skull fractures.

In the primary clinical sonographic evaluation, significant traumatic SICs were diagnosed in

Table 1

Clinical and neurological disorders detected in the injured pediatric patients in the two study groups during the acute phase of MTBI

Clinical and neurological disorders		Group I ( $n = 56$ )		Group II ( $n = 200$ )	
		$n$	%	$n$	%
Short-term loss of consciousness		3	5.3	64	32
Retrograde amnesia		–	–	31	15.5
Post-traumatic headache		–	–	165	82.5
Vomiting		7	12.5	116	58
Focal neurological symptoms		6	10.7	24	12
	Injury of cranial nerves	1	1.7	2	0.8
	Motor dysfunction	1	1.7	2	0.8
	Cerebellar injury	–	–	7	3.5
	Diffuse neurological dysfunction	4	7.2	14	7.0
Symptoms of vegetative dysfunction		31	55.4	177	88.5

Table 2

Распределение выявленных структурных внутричерепных изменений у пострадавших с клиническими критериями легкой черепно-мозговой травмы

Структурные внутричерепные изменения		Group I (n = 56)		Group II (n = 200)	
		n	%	n	%
<b>Traumatic intracranial changes</b>					
	Epidural hematoma	–	–	6	3.0
	Subdural hematoma	–	–	1	0.5
	Subarachnoid hemorrhage	2	3.6	4	2.0
	Focus of brain contusion	–	–	1	0.5
	Associated traumatic lesions	2	3.6	2	0.8
<b>Nontraumatic intracranial changes</b>					
	Hydrocephaly	2	3.6	2	1.0
	Leptomeningeal cyst	–	–	2	1.0
	Conformational abnormalities in the brain	1	1.8	1	0.5
	Genetic diseases	–	–	1	0.5
	Residual and organic changes	12	4.7	59	23
<b>Norm</b>		33	59.1	121	60.5

18 (7.0%) injured pediatric patients. Group I had 4 (7.2%) patients while group II had 14 (7.0%) patients with significant traumatic SICs. Nontraumatic SICs were registered in 4 (1.6%) injured pediatric patients in group I and 5 (1.6%) patients in group II. The group-wise distribution of these SICs among the injured pediatric patients who fulfilled the clinical criteria of MTBI is presented in Table 2.

Group I showed correlation dependence of traumatic SICs with a reduction in the level of wakefulness, as indicated by the pediatric GCS score of 13-14 points ( $p = 0.002$ ) and with the development of focal neurological symptoms ( $p = 0.001$ ). Group II showed correlation dependence of the development of traumatic SICs with the suppression of consciousness, which was indicated by a GCS score of 13-14 points ( $p = 0.001$ ), with multiple/repeated vomiting ( $p = 0.033$ ), increasing post-traumatic cephalgia ( $p = 0.023$ ), and the development of focal neurological symptoms ( $p = 0.001$ ). Traumatic skull injuries were significantly more frequent in group I ( $\chi^2 = 51.29$ ,  $p < 0.001$ ). However, fractures of the base of the skull and associated traumatic injuries of the skull ( $\chi^2 = 7.44$ ,  $p < 0.001$ ) were significantly more prevalent in group II, and fractures of the bones of the cranial vault ( $\chi^2 = 13.80$ ,  $p < 0.001$ )

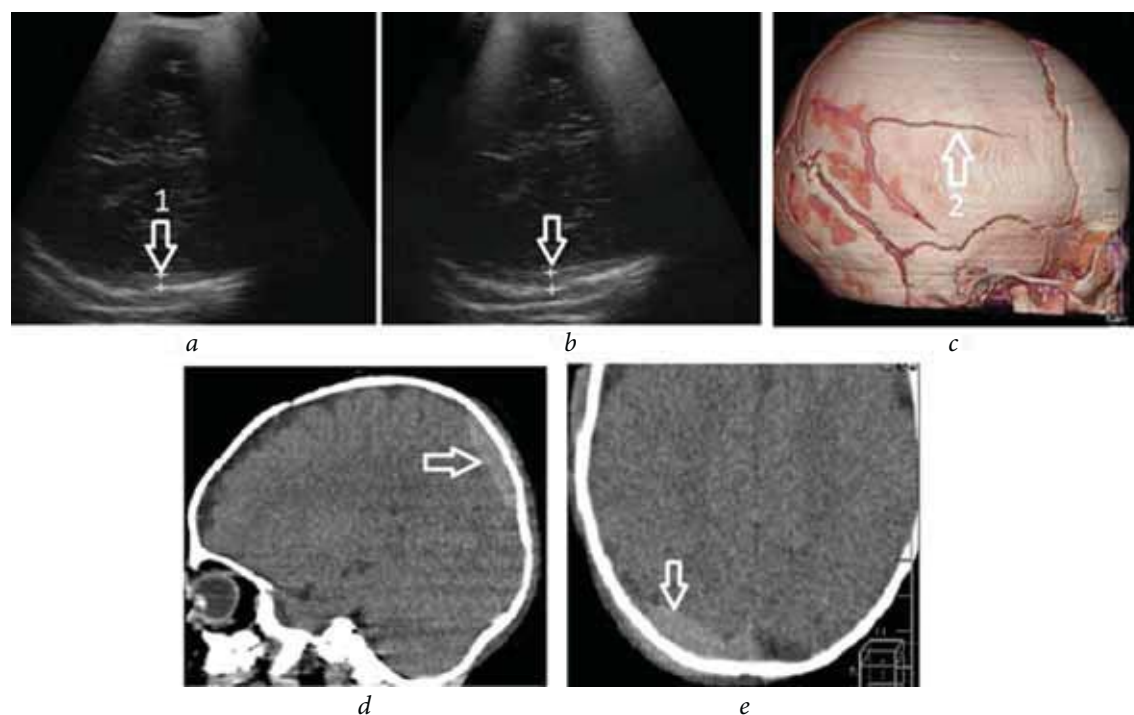
were significantly more common in group I. In both groups, correlation dependence was revealed between the development of traumatic SICs, the high-energy mechanism of trauma, and signs of traumatic skull damage ( $p < 0.05$ ).

Thus, based on our study results, the diagnostic sensitivity of the clinical sonographic examination in detecting traumatic SICs in pediatric patients with MTBIs was 90% (95% CI: 0.71–0.98), the diagnostic specificity was 97% (95% CI: 0.96–0.98), and the diagnostic efficiency was 94.9% (95% CI: 91.8–97.1).

During the dynamic clinical sonographic evaluation 72 h after hospital admission, 2 (1.8%) injured pediatric patients exhibited regression of traumatic SICs, as indicated by a decrease in the size of the epidural hematoma and signs of cerebral edema; in 1 (0.4%) patient, cerebral edema had increased.

Thus, the incidence of significant traumatic SICs was 7.0% and that of nontraumatic SICs was 3.6% in the pediatric patients with MTBIs; these findings are consistent with those reported in previous trials that evaluated the incidence of pediatric patients with MTBIs [3, 15].

False-negative results (under-diagnosis) were obtained in 7 (2.7%) injured patients owing



**Fig. MTBI** in a 6-year-old boy, P.A. Moderate brain contusion: *a*: US image in the S3.5 (H2) mode 6 h after the injury; *b*: US image in the S3.5 (H2) mode 72 h after hospital admission; *c*, *d*, and *e*: cranial CT; 1: epidural hematoma, 2: linear fracture (shown by arrows)

to the iso-echogenicity of pathological objects with subarachnoid hemorrhage, parenchymal hemorrhage of small size, mantle-like epidural hematoma, location (frontal lobe pole or posterior cranial fossa), and insufficient permeability of skull bones in older children. False-positive results (over-diagnosis) were obtained in 2 (0.7%) patients owing to the presence of US artifacts.

Thus, a comprehensive clinical sonographic approach can be effectively used for the assessment of the severity of the neurological condition in patients during the acute phase of MTBI. To demonstrate this, we provide our own clinical observation (figure).

Patient P.A., a 6-year-old boy, sustained a head injury due to a fall from a height of >2 m. He was examined at the hospital 6 hours after the injury. The severity of the condition at admission was judged as to be average (total score in the pediatric GCS: 14 points). Based on the results of the primary clinical sonographic evaluation of the severity of the condition and the patient's history, it was established that the patient had no loss of consciousness, headache, or vomiting. During the neurological examination, symmetrical brisk tendon reflexes were noted, which were more frequent in the lower limbs, and the presence of co-ordination disorders was also identified. The examination of

the soft tissues of the head revealed strained subgaleal hematoma in the right parietal region. Craniography revealed a linear fracture of the right parietal bone. US in the S3.5 (H0), S3.5 (H1), and S3.5 (H2) modes revealed a hyperechogenic mantle-like opacity under the fracture region without median structure displacement and cerebrospinal fluid space expansion. The clinical sonographic evaluation indicated the requirement of performing a brain CT scan; the CT scan revealed a linear fracture of the right parietal bone and mantle-like epidural hematoma in the right parietal region. No negative dynamics were identified during the dynamic clinical sonographic evaluation of the neurologic condition. Thus, a repeat CT scan or neurological treatment was not performed; conservative therapy and dynamic observation were continued.

Thus, according to the mechanism of the sustained trauma, the patient had cerebral clinical neurologic disorders; there were no typical symptoms of intracranial hypertension, such as vomiting, post-traumatic cephalgia, or loss and suppression of consciousness (total score in the pediatric GCS was 14 points). Anamnestic risk factors (fall from a height), roentgenographic evidence of the skull fracture, and SICs according to the results of primary US indicate a high risk of development of traumatic SICs. The dynamic



clinical sonographic observation did not indicate the need for neurosurgical intervention or performing a repeat CT scan.

## Conclusions

1. The incidence of traumatic SICs in the brain in pediatric patients with MTBIs is 7.2%, indicating the necessity of performing continuous screening of the condition in such patients.

2. US, which was performed by a neurologist, is a noninvasive diagnostic method for conducting the clinical sonographic evaluation of the neurological status to identify traumatic and nontraumatic SICs in pediatric patients with MTBIs. The diagnostic efficacy of the clinical sonographic examination was 94.9%.

3. Assessment of significant clinical and neurological disorders in combination with US enables the early detection and monitoring of traumatic SICs and facilitates the refining of indications for neurosurgical intervention or performing a brain CT scan.

4. Continuous neurological screening enables the detection of potentially dangerous nontraumatic SICs in pediatric patients; the incidence rate in our study was 3.6%.

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