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FEATURES OF CEREBRAL HEMODYNAMICS IN CHILDREN AFTER TRAUMATIC BRAIN INJURY

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✓ ***Resume***

The article presents a study of the dynamics of cerebral blood flow, its relationship with cerebrospinal fluid hypertension, as well as the nature and degree of autoregulation impairment in patients with traumatic brain injury. For this purpose, we examined 170 children who had suffered closed TBI: concussions, mild to moderate contusions, who were treated in the Department of Surgical Injuries of Children of the Bukhara Branch of the Scientific Center for Emergency Medicine at the age of 1-14 years. For a more accurate determination of the state of hemodynamics, patients were divided into mild (comparison group) and moderate (main group) TBI into 2 groups depending on age: the first 1-6 years, the second 7-14 years, taking into account the side of the lesion.

Keywords: Traumatic brain injury, cerebral hemodynamics, cerebrospinal fluid, transcranial Doppler ultrasound.

BOLALARDA MIYA TRAVMATİY JARAHATIDAN KEYIN MIYAGA QON OQIMINING XUSUSIYATLARI

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✓ ***Rezyume***

Maqolada miya qon oqimining dinamikasi, uning miya omurilik suyuqligining gipertenziyasi bilan bog'liqligi, shuningdek, miya shikastlanishi bilan og'rigan bemorlarda avtoregulyatsiya buzilishining tabiati va darajasi o'rganilgan. Shu maqsadda biz shoshilinch tibbiy yordam ilmiy markazining Buxoro filiali 1-14 yoshli bolalarning jarrohlik jarohatlari bo‘limida davolanayotgan yopiq TBI: miya chayqalishi, engil va o‘rtacha og‘irlikdagi kontuziya bilan og‘rigan 170 nafar bolalarni tekshirdik. va o'rtacha (asosiy guruh) TBI yoshga qarab 2 guruhga bo'linadi: birinchi 1-6 yil, ikkinchisi 7-14 yil, zarar tomonini hisobga olgan holda.

Kalit so’zlar: Travmatik miya shikastlanishi, miya qon oqimi, miya omurilik suyuqligi, transkranial Doppler sonografiyasi.

Relevance of the problem

In the structure of childhood morbidity, traumatic brain injury (TBI) occupies one of the first places, from which the percentage of disability and mortality is very high, which characterizes it as the most important medical and social problem of modern medicine. According to the World Health Organization (WHO), disabled people worldwide make up 10% of the total population. In the structure of childhood disability, diseases of the nervous system (19.5%) and mental disorders (14.5%) prevail. TBI is a leading neurological disease in children, since the number of such patients increases annually by 2%, of which 1.5 million die, and 2.5 million become disabled [1,2,9,10].

The traumatic factor leads to neurodynamic disorders of the brain; tissue respiration, brain tissue metabolism, cerebrospinal fluid production, and cerebral circulation are disrupted. Another pathogenetic mechanism of the formation of TBI consequences is also associated with the vascular

factor - a violation of cerebrospinal fluid dynamics, as a result of which cerebrospinal fluid hypertension is possible [6].

The activity of the cerebral circulation regulation system is aimed at compensating for two types of disturbances. When the conditions of blood inflow or outflow from the skull change, the regulation system strives to reduce deviations in blood flow through the brain, and its ability to maintain cerebral blood flow is demonstrated when systemic circulation changes. This is the phenomenon of autoregulation. It has been established that autoregulation of cerebral blood flow is a protective mechanism aimed at maintaining cerebral blood flow in response to changes in cerebral perfusion pressure and cerebrovascular resistance [4,5,7].

It is accepted to consider TBI, first of all, as a problem of adequate cerebral perfusion, for the maintenance of which there is a system of autoregulation of cerebral blood flow. There are several circuits of cerebral blood flow insurance: neurogenic, myogenic and humoral. It is they that together ensure autoregulation of cerebral blood flow.

An important informative method for studying cerebral blood flow in TBI is ultrasound Dopplerography. With the help of USDG, it is possible to study the hemodynamics of the main vessels of the brain - the middle cerebral artery (MCA) in the area of injury and on the opposite side as accurately as possible. The study of the biomechanical features of TBI confirmed that foci of contusion-crushing of the brain are formed both on the side and opposite to the place of impact [6,8,10].

The aim of the study is to study the dynamics of cerebral blood flow, its relationship with cerebrospinal fluid hypertension, as well as the nature and degree of autoregulation impairment in patients with traumatic brain injury.

Material and methods of the study. The study involved 170 children who had suffered closed TBI: concussions, mild and moderate contusions, who were treated in the pediatric surgical injury department of the Bukhara branch of the Russian Scientific Center for Emergency Medicine at the age of 1-14 years.

In our studies, the leading causes of injuries were domestic trauma (72.4%) and road traffic accidents (RTA) (21.2%); there were also violent (3.5%), sports (1.2%), high-altitude (1.2%) and street (0.6%) injuries (Fig. 1).

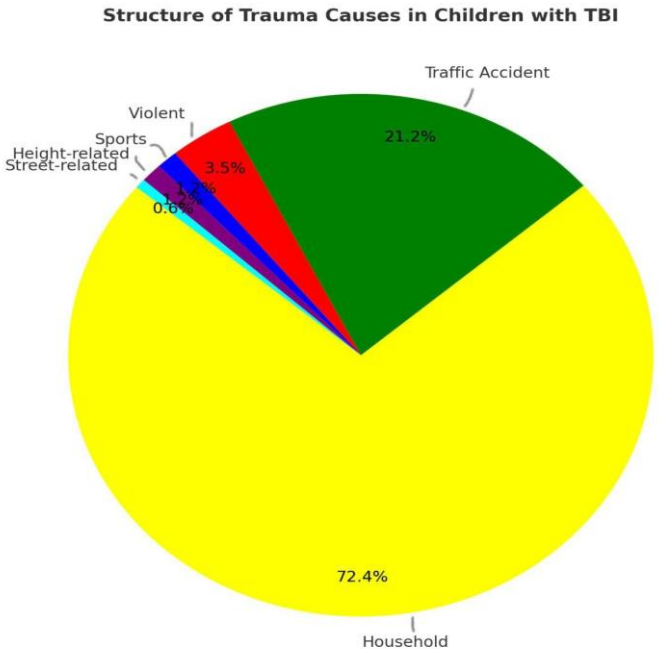

Fig. 1. Distribution of children with TBI by causes of injury.

The ratio of girls to boys was 1:1.8. The average age was 7.71±0.36 years. Analysis of the age composition of children showed the presence of 4 peaks - at the age of 1-3 years, 7, 11 and 13-14 years (Fig. 2).

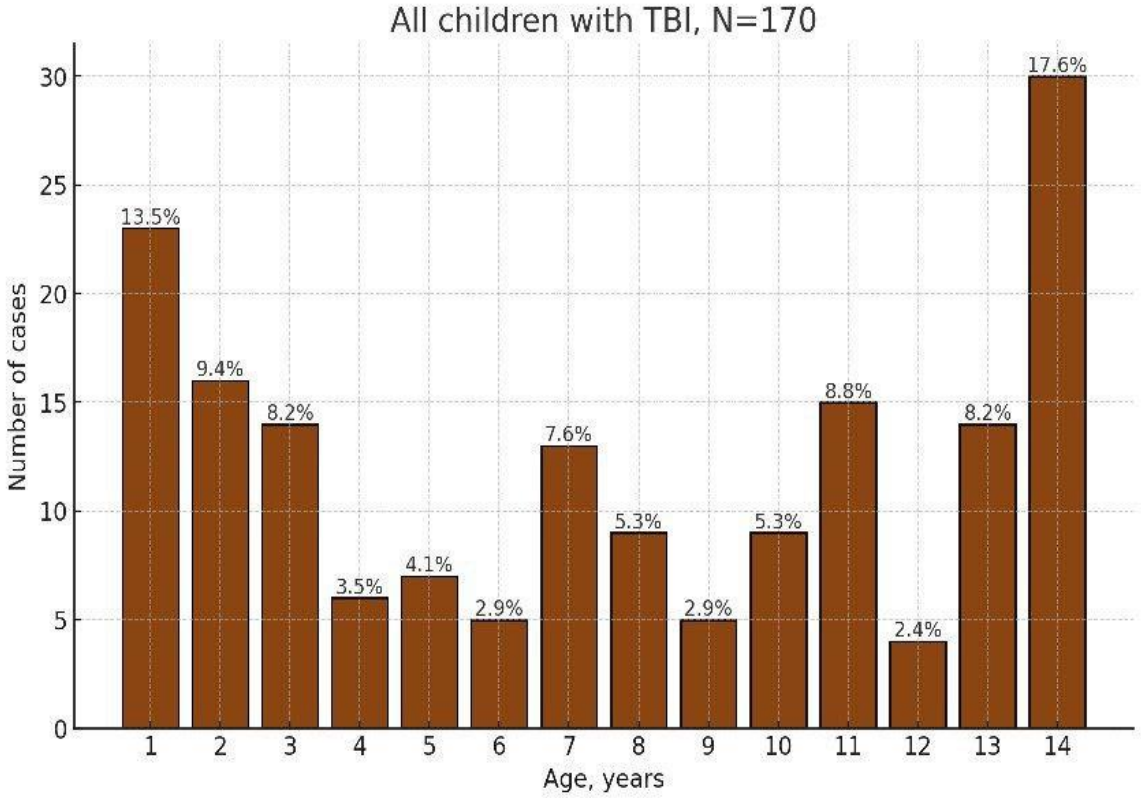

Fig. 2. Age histogram of examined children with TBI.

However, a more detailed analysis of the age-sex composition using histograms showed that the age peaks in boys and girls differ significantly. Boys had 5 age peaks - at 1 year, 3, 7, 11 and 14 years (Fig. 3).

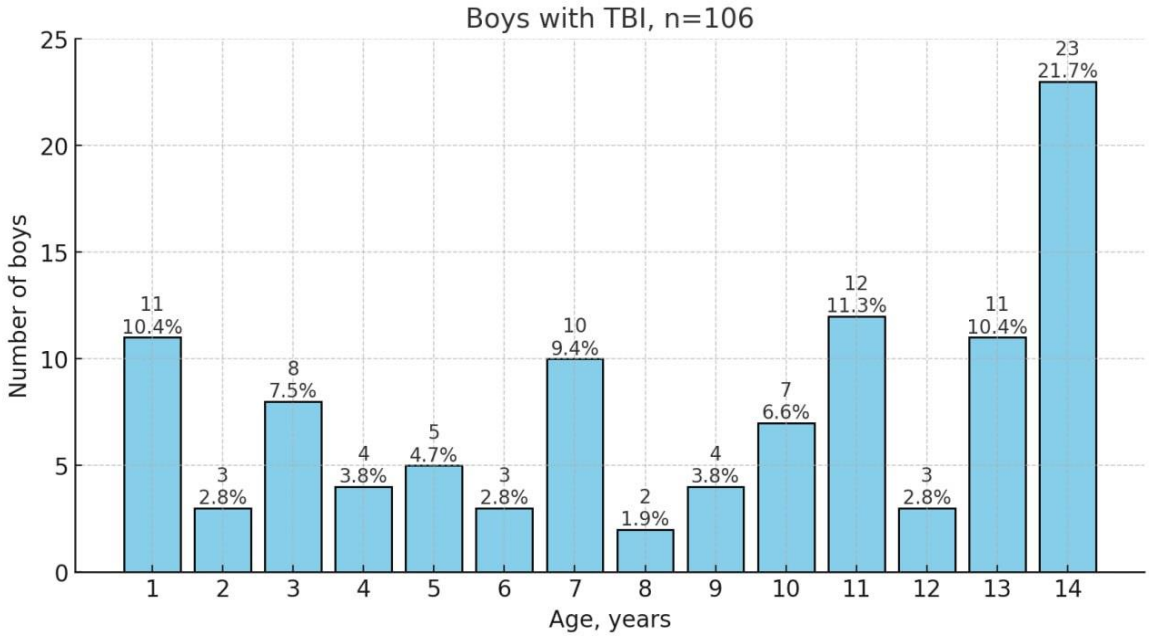

Fig. 3. Age histogram of boys with TBI.

Girls had 3 age peaks: at 1-2 years, 8 and 14 years (Fig. 4). This difference can be explained by the different levels of motor activity of boys and girls at different age periods due to the peculiarities of sexual development.

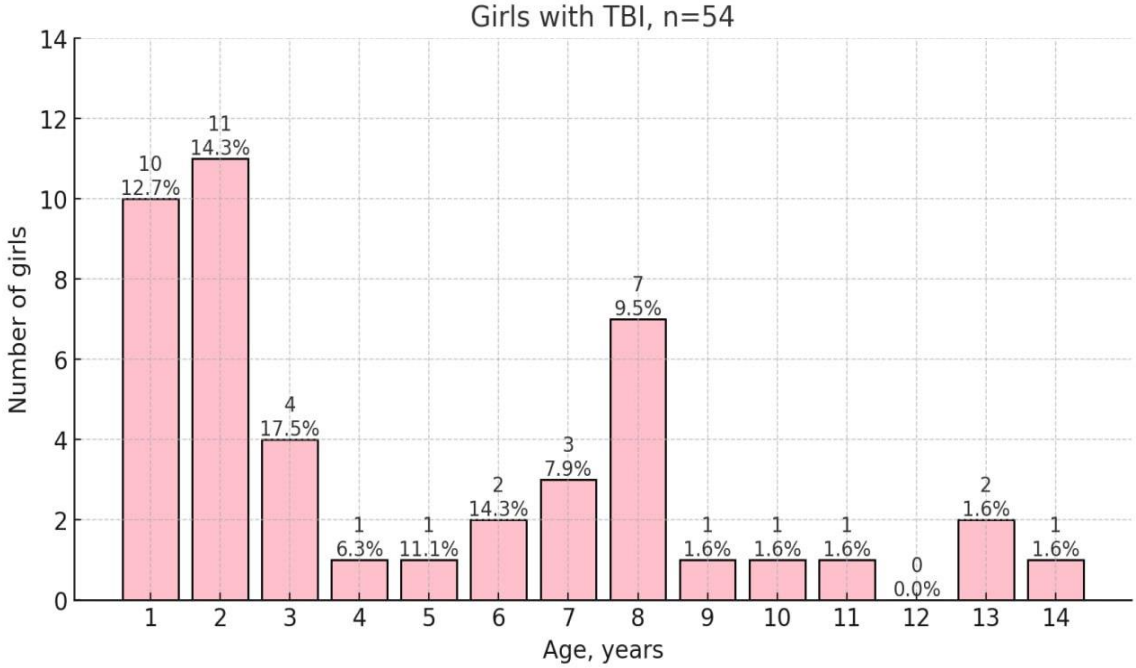

Fig. 4. Age histogram of girls with TBI.

The diagnosis was established according to the clinical classification of TBI in children [1]. All patients underwent a study of cerebral hemodynamics using the transcranial Doppler sonography method on the DC-7/DC-7S/DC-7E Diagnostic Ultrasound System (Mindray). On both sides, through the temporal acoustic "window", the MCA was located at a depth of 50-56 mm using a phased transducer with an operating frequency of 2 MHz. The maximum (Max V) and linear blood flow velocity (LBFV), measured in cm/s, as well as the pulsatility index (PI) were assessed. Cerebral hemodynamic disorders in TBI are characterized by various changes and depend on the severity, localization of the lesion, and the extent of the lesion.

To more accurately determine the state of hemodynamics, we divided patients with mild (comparison group) and moderate (main group) TBI into 2 groups depending on age: the first 1-6 years, the second 7-14 years, taking into account the side of the lesion.

Table 3.1.

Dynamics of cerebral blood flow indicators in patients with mild TBI 1-7 years old.

Indicator (n=26)	Defeated side			The healthy side		
	Upon admission	7-8 days	14th day	Upon admission	7-8 days	14th day
Max V	98.8±6	112.1±6.1	96.0±6.1	95.1±4.6	101.3±5.3	98.3±5.4
LSC	64.2±4.3	76.1±5.1	63.5±4.6	63.2±3	69.3±4.3	62.0±3.6
PI	0.76±4.1	0.69±5	0.75±4.6	0.78±3.9	0.75±3.6	0.76±4

Max V - maximum blood flow velocity, LBCV - linear blood flow velocity (cm/sec), PI - pulsatility index.

Results of the study of cerebral hemodynamics. We took into account some biomechanical features of the side of the head injury in TBI. Thus, a direct blow to the head with a heavy object with a small striking surface damages the integuments and bones, pressing bone fragments into the cranial cavity. In case of a fall and a blow to the occipital region, a brain contusion or intracranial hemorrhage in the anterior parts of the hemispheres is suspected. Foci of brain contusion-crushing are also formed on the side opposite to the place of the blow in the parietal-temporal region [3,5].

First, let's look at the results of the first group. When studying the state of hemodynamics in the MCA, violations were detected in all cases. Both with local and diffuse trauma, they were observed for 2 weeks.

In patients of the comparison group with mild TBI, a slight increase in the velocity indices on the affected side was noted on the 7-8th day after the injury. At the same time, there was a decrease in the pulsatility index (PI) on the injured side also within 7-8 days, which may indicate activation of collateral blood flow. Here, it is necessary to take into account the functional immaturity of not only the brain, but also autoregulation. On the healthy side, hemodynamics did not change (Table 3.1).

In patients of the same age group, but with a moderate degree of TBI severity, as follows from Table 3.2, an increase in speed indicators is observed, more pronounced on the affected side. This indicates the development of cerebral spasm. These changes were expressed during the first week after receiving TBI and were practically leveled by the end of 14 days. The healthy side was less susceptible to these changes.

Table 2.

Dynamics of cerebral blood flow indicators in patients with moderate TBI aged 1-7 years.

Indicator (n=45)	Defeated side			The healthy side		
	Upon admission	7-8 days	14th day	Upon admission	7-8 days	14th day
Max V	98.1±6	118.1±6.9	102.2±5.1	95.2±4.6	104.2±5.6	99.1±4.4
LSC	64.7±4.3	81.5±5.3	66.3±4.3	63.4±3	74.1±4.8	65.2±3.8
PI	0.76±4.1	0.69±5	0.75±4.6	0.78±3.9	0.75±3.6	0.76±4

Max V - maximum blood flow velocity, LBCV - linear blood flow velocity (cm/sec), PI - pulsatility index.

If we look at the localization of traumatic foci, then in patients with convexital foci, the changes were less pronounced and manifested themselves mainly on the affected side. In patients with basal foci, the changes were more often bilateral and lasted longer.

Now let's move on to an older age group. In 11 (22%) cases in patients of the main group with moderate TBI over the age of 7 years, an increase in the PI index by more than 30% of the initial value was registered, which may serve as an indirect indication of the development of intracranial hypertension.

No significant changes were observed on either the healthy or the affected side (Table 3). However, in 12 cases (23.5%) with foci localized in the basal sections, an increase in speed indicators was noted on both sides, more so on the affected side.

Table 3.

Dynamics of cerebral blood flow parameters in patients with mild TBI aged 7-14 years

Show-tel (n=51)	Defeated side			The healthy side		
	At the time of receipt	7-8 days	14th day	At the time of receipt	7-8 days	14th day
Max V	85.1±5.9	88.4±5.2	84.6±4.2	84.1±7.8	85.2±6.0	80.4±5.7
LSC	59.2±6.2	59±4.2	57±5.8	58±6.3	61.1±5.2	60±3.3
PI	0.83±0.06	0.81±0.03	0.84±0.04	0.78±0.2	0.82±0.04	0.81±0.03

Max V - maximum blood flow velocity, LBCV - linear blood flow velocity (cm/sec), PI - pulsatility index.

In moderate TBI, cerebral hemodynamic disturbances were observed in almost all victims (Table 4). If in mild TBI we saw an increase in speed indicators only on the affected side, then in moderate TBI they were also observed on the contralateral side.

Table 4

Dynamics of cerebral blood flow parameters in patients with moderate TBI aged 7-14 years

Show-tel (n=58)	Defeated side			The healthy side		
	At the time of receipt	7-8 days	14th day	At the time of receipt	7-8 days	14th day
Max V	85.5±6.1	122.0±4.8	89.1±3.2	84.1±7.8	110.4±4.1	72.5±4.7
LSC	59.6±6	82.4±6.8	57.2±4.8	58.6±6.3	76.4±5	63.7±4.2
PI	0.83±0.06	0.76±0.03	0.86±0.04	0.78±0.1	0.77±0.02	0.82±0.03

Max V - maximum blood flow velocity, LBCV - linear blood flow velocity (cm/sec), PI - pulsatility index.

It is noteworthy that with convexital foci - frontal, parietal and occipital regions of the brain by the end of the second week from the moment of injury, the speed indicators practically returned to normal values, while with localization of the focus in the basal regions of the brain they were increased during the entire observation period.

In the main group of moderate TBI, cerebral hemodynamic disorders were observed in almost all patients. How did they manifest themselves?

Firstly, by the increase of the velocity indices both on the affected and healthy sides practically without asymmetry during the whole observation period. Secondly, in some patients the predominant increase of the diastolic blood flow velocity with the decrease of the pulsatility index was noted, which together can be regarded as the tendency to vasodilation. During the dynamic observation by the end of the second week the restoration of the blood flow was noted in the persons with convexital foci, while in the presence of the foci in the basal sections the BPV remained elevated. Thirdly, in the majority of the patients (>70%) the PI index was elevated regardless of whether the foci were single or multiple. At the same time the correlation with the clinical signs of intracranial hypertension was noted.

Of particular interest, in our opinion, is the dynamics of the overshoot coefficient (OC). This is the ratio of the average linear velocity of the first two MCA Dopplergrams after blood flow restoration to the average linear velocity in the MCA before compression during the Giller test. The main mechanism in the pathogenesis of microcirculation disorders in TBI is a violation of the autoregulation of cerebral blood flow, the main indicator of which is a decrease in OC. Autoregulation disorders occur to varying degrees in all forms of TBI, and their severity is associated with the severity of TBI [6,9].

The dynamics of changes in CE are presented in Tables 5 and 6. In patients of the younger age group with mild TBI, a decrease in cerebrovascular reactivity occurred in 18 (35%) of those examined, and it was more often observed in the presence of multiple foci of brain damage.

Table-5

Overshoot coefficient values in patients with TBI aged 1-7 years

Day	Mild degree (comparison group) n=26		Average degree (main group) n=45		R
	Defeated side	The healthy side	Defeated side	The healthy side	
Upon admission	1.36±0.04	1.38±0.03	1.34±0.04	1.36±0.02	P<0.05
7-8 days	1.32±0.02	1.36±0.03	1.29±0.03	1.34±0.04	P<0.05
14th day	1.35±0.03	1.36±0.03	1.32±0.04	1.36±0.03	P<0.05

The decrease in autoregulation in some patients with mild TBI may be explained by previous hemodynamic instability, expressed in neurocirculatory dystonia, as well as a history of perinatal trauma. In other cases of mild TBI, the KO did not undergo significant changes. In patients with moderate TBI, a decrease in KO on one side was observed more often and was recorded in 26 (44.8%) patients. In these cases, CT/MRI showed multiple foci of brain contusions and their more basal location.

Table-6

Overshoot coefficient values in patients with TBI aged 7-14 years

Day	Mild degree (comparison group) n=51		Average degree (main group) n=58		R
	Defeated side	The healthy side	Defeated side	The healthy side	
Upon admission	1.34±0.03	1.36±0.04	1.33±0.04	1.34±0.02	P<0.05
7-8 days	1.32±0.02	1.35±0.04	1.26±0.03	1.32±0.03	P<0.05
14th day	1.34±0.02	1.36±0.02	1.3±0.03	1.35±0.04	P<0.05

Autoregulation disorders occur in most patients with TBI. In patients with moderate TBI, autoregulation disorders were more common - in 33 (56.9%) patients and were manifested by a more pronounced decrease in KO compared to mild TBI. This was most clearly noticeable on days 8-13.

It should be noted that in case of a single hemispheric contusion, by the end of hospitalization, a clear restoration of the CC was observed, while in most patients with multiple foci it was reduced during the entire period of treatment in the hospital. It is also important that the asymmetry of the autoregulation disorder in patients with single foci was detected in only 22% of cases, which indicates the universality of the mechanisms that ensure the autoregulation of cerebral blood flow.

It should be noted separately that we had 8 patients with a progressive course of moderate SAH under observation for comparison. It is known that blood flow asymmetry in the MCA should not normally exceed 20%. We noted that in 37% of patients it was observed on the 8-10th day, which may be due to the dynamics of cerebral edema. The PI index significantly increased by the 8-10th day from the moment of injury, which may also reflect the presence of cerebral edema. Within 2 weeks after injury, the LBFV on the affected side is increased, while on the opposite side, an increase in speeds was noted during the first week, and then in ½ they returned to normal values. Thus, we can note the asymmetry of the LBFV.

Summary

To summarize the above, it can be said that cerebral hemodynamic disorders in different forms of TBI are most pronounced during the second week of observation. An increase in the pulsatility index (PI) was noted in 22% of patients in the main group with a moderate TBI, which can be explained by the development of intracranial hypertension. Autoregulation disorders are observed in different degrees of TBI severity. In patients in the main group with a moderate TBI aged 7-14 years, autoregulation disorders of cerebral blood flow were noted in 56.9% of observations. The duration and severity of these changes depend on the clinical course.

The disturbance of cerebral hemodynamics and autoregulation of cerebral blood flow that we have identified explains the cause of the disturbance of cerebrospinal fluid circulation, which results in increased permeability of the blood-brain barrier. A large amount of fluid can accumulate in neurons and the intercellular space, which leads to swelling of the brain.

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