Possibilities of transcranial color-coded sonography in pathology of deep brain veins in children

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Abstract
A study in children with headaches associated mainly with venous hemodynamic disturbances has been performed. The role of cerebral venous disturbances has been defined in children with structural cerebral abnormalities: craniovertebral junction anomalies (Chiari abnormalities I) and hypoplasia of cerebral venous sinuses. Disturbances of cerebral hemodynamics revealed by ultrasonic methods determine the management of patients with different cerebral venous abnormalities.

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Introduction
The estimation of cerebral venous hemodynamic disturbances in literature is described mainly in adults. Diagnosis of such disturbances in children is not detected in time, though they often turn out to be one of the main evidence of cerebrovascular pathology. Venous outflow in deep brain veins (straight sinus, cavernous sinus, great cerebral vein of Galen) was registered by ultrasonic Doppler and duplex methods. Cavernous sinus is described in literature basically in case of craniocerebral trauma with formation of carotid-cavernous fistulas. Cavernous sinus actively participates in regulation of venous brain outflow from a cranial cavity. The internal carotid artery is located in the center of the cavernous sinus which changes the volume of sinus by its pulse fluctuations. Thus a venous outflow is stimulated and makes influence on intracranial venous circulation. Therefore, the cavernous sinus is often designated as a "venous heart". Hemodynamic disturbances in the cavernous sinus are "markers" of cerebral venous hemodynamic dysfunction. Thus research of cavernous sinus hemodynamics presents new possibilities for revealing the disturbances of cerebral venous blood circulation in the complex investigation of deep brain veins.

It is difficult to assess the cavernous sinus in children by standard (transorbital) approach. We worked out a new approach of transcranial duplex scanning to visualize the cavernous sinus, with determination of structures and features of venous blood flow for subsequent elaboration of diagnosis algorithm and possibility of conservative care of children, who have disturbances of venous cerebral hemodynamics.

Purpose
Cerebral hemodynamic features and the role of venous hemodynamic disturbances under structural cerebral abnormalities in children have been studied.
Materials and methods

1200 patients aged from 3 to 17 years who complained of headache have been examined. The control group consisted of 95 healthy children.

The examination of children has been performed by transcranial Doppler analyzer (TCD) "ANDIOGIN", "SONOMED-500" of "BIOSS" and "SPECTROMED" companies (Russia) equipped with a standard transducer (2 MHz). Transcranial color-coded duplex (TCCD) scanning of brain vessels has been carried out by "Logic P-5" device (Japan) with a sectoral transducer (5 MHz) in triplex mode (B + CF + PW; B + PDI + PW). Blood flow velocity and structure features of the cavernous sinus, carotid arteries, ophthalmic arteries and veins, the extracranial part of the internal jugular vein, the straight venous sinus and the great cerebral vein of Galen have been registered. We proposed a new technique of transcranial duplex scanning of the cavernous sinus. This approach provides a good overview of forms and peculiarities of the hemodynamics of the cavernous sinus. Magnetic resonance imaging (MRI) has been performed as well.

Results

All children with headaches were separated into several groups according to the clinical and ultrasound findings: migraine headache (30%), tension type of headache (26%), headache with increase or reduction of arterial pressure (17%), headache caused by cerebral venous dysfunction (27%) (Fig. 1).

It is noted that children with different types of headache (migraine, tension headache, one with changing arterial pressure) had also cerebral venous hemodynamic disturbances with different intensity. This fact is usually not mentioned in literature regarding headache research (Fig. 2).
In a group of children with headaches caused by cerebral venous dysfunction, 88 children had different structural abnormalities (confirmed by MRI): 46 of them had abnormalities of craniovertebral junction (Chiari abnormalities I). 42 children had abnormalities of deep brain veins. Hypoplasia of transverse sinuses combined with hypoplasia of sigmoid sinuses was revealed in 36 children, hypoplasia of the superior sagittal sinus in 3 children, and Chiari abnormality in 5 children (Fig. 3).

The clinical picture of children with structural abnormalities was characterized by headaches (100%), nasal bleeding (60%), sickness and vomiting (40%), noise in ears (35%), dizziness (30%), vegetative dysfunction, 1% of children had relative deafness, and 8% of children had tics (mostly of face muscles). All examined children complained of headaches localized in cervical and parietal regions, that arised while or after night/day sleeping. Increase of headaches occurred after physical exercises, and lessons at school. 60% of children had typical nasal bleeding, mostly abundant and spontaneous as a “fountain” (Fig. 4).

As a result of the research we revealed an increase of velocity in deep brain veins (peak systolic velocity—VPS): in the straight sinus 56 ± 5.6 cm/s, and in the great cerebral vein of Galen 57 ± 9.4 cm/s (our normal values were 26 and 22 cm/s, respectively). An increase of blood flow velocity in vertebral venous plexus was also registered (not registered regularly) (Fig. 5).

Considering the difficulties of localizing the cavernous sinus using the transorbital access in children (especially in younger ones), we applied a new technology of evaluating the cavernous sinus by transcranial duplex scanning. This allows to determine the structure and features of the cavernous sinus and blood flow in eye veins. Disturbances of venous outflow in the cavernous sinus have been revealed in 68% of children by TCCD (Fig. 6).

Ultrasonic data in children with structural cerebral abnormalities was in accordance with MRI findings (Fig. 7).

The conservative treatment which has been performed under ultrasonographic control (TCD, TCCD) in children with disturbances of cerebral hemodynamics, led to subjective and objective improvement in 85% of children. We recommend ultrasonic methods not only for diagnostics of cerebral venous disturbances, but also for follow-up of the therapy. Clinically, the frequency and intensity of headache, nasal bleeding, dizziness, nausea and vomiting were reduced after the treatment (up to total disappearance of symptoms) (Fig. 8).
Discussion

Features of cerebral hemodynamics causing disturbances of venous outflow are described in cases of abnormalities of craniovertebral junction and deep brain veins. These venous outflow disturbances are probably caused by obstacles to venous outflow (anomaly of craniovertebral junction, hypoplasia of cerebral venous sinuses) and increase of intracranial pressure. These disturbances are of great importance in clinical manifestations, especially in children. Nevertheless, there is a lack of sufficient information in literature concerning possibilities and necessity of carrying out TCD and TCCD investigations for diagnostics and therapy.

Conclusion

Clinical and ultrasound investigation of children with different types of headaches shows various dysfunctions in deep brain veins: great vein of Galen, cavernous and straight venous sinuses.

Venous disturbances most frequently occurred in children with Arnold-Chiari I and deep brain vein abnormalities.

Hemodynamic findings in sinus cavernous revealed by TCD and TCCD in our patients were “markers” of disturbances in cerebral venous hemodynamics. An agreement between TCD, TCCD and MRI data was found.

The ultrasonographic examination of venous hemodynamics is necessary in complex diagnostics in children with cerebral abnormalities for prevention and treatment.