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Research Article

Transcranial Doppler Assessment of Cerebral Venous Hemodynamics in Hemispheric Ischemic Stroke and Transient Ischemic Attack

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Abstract

Introduction: Cerebral circulation receives about 20% of the cardiac output. The volume of blood flow to the brain directly depends on the degree of stenosis of the vessels of the circle of Willis. At the same time, the severity of clinical symptoms depends not only on the degree of violation of arterial hemodynamics, but also on the state of venous outflow of blood from the brain. The arterial and venous systems of the brain are a highly organized single system that ensures the adequacy of cerebral blood flow. Transcranial Doppler is a non-invasive method for obtaining quantitative parameters of blood flow from arterial and venous vessels of the brain.

Objective: To comparatively study the hemodynamics in main cerebral veins in patients with hemispheric ischemic stroke (HIS) and transient ischemic attack (TIA) using transcranial Doppler.

Material and Methods: A retrospective analysis of the results of transcranial dopplerography (TD) of the cerebral vessels was performed in 95 patients with hemispheric ischemic stroke (HIS) and in 31 patients with transient ischemic attack (TIA) caused by atherosclerosis of the internal carotid (IC) and middle cerebral arteries (MCA). The average age of the subjects was 63,7 ± 3,2 and 51.6 ± 5.2 years, respectively. The control group consisted of 56 health individuals (HIS-CG), the average age - 59,3 ± 4,9 years. The visualization frequency and systolic blood flow velocity (Vs) of the main cerebral veins - the basal vein of the brain (Rosenthal's vein), the deep middle cerebral vein (MCV), the large vein of the brain (Galena's vein), and Straight sinus (SS) were studied. Doppler ultrasound was conducted on a Philips HD 11XE device using a linear sector (2 - 4 MHz) transducer.

Results: Among the patient with the Hemispheric ischemic stroke Galen's vena was visualized in 91 (95,8%) cases, the Rosenthal's vein - in 89 (93,7%), the median cerebral vein (MCV) - in 81 (85,3%) and the Straight sinus - in 87 (91,6%) cases, respectively. In a patient with transient ischemic attack this data was: 29 (93,5%); 26 (83,8%); 22 (71,0%) and 23 (74,2%) cases, respectively. In healthy individuals the Galen's vena was visualized in 51 (91,1%) cases, the Rosenthal's vein - in 46 (82,1%), the median cerebral vein (MCV) - in 33 (58,9%) and the Straight sinus - in 35 (62,5%) cases, respectively. The frequency of imaging of Rosental's vein ($P < 0,05$), the median cerebral vein ($P < 0,001$) and the straight sinus ($P < 0,001$) in patients with HIS was significantly higher than among HI. In addition, a SS in HIS was visualized more often than in a patient with TIA ($P < 0,05$).

Based on the clinical symptoms and the level of neurological deficit, according to the state of severity, all patients were divided into three groups: group I included 21 patients with severe; group of II - 49 patients with moderate and group of III - 25 patients with mild course of HIS. In all the cerebral veins of the I group of patients, the Vs exceeded the corresponding parameters of the other groups: in SS - 34,5 ± 2,7 cm/c, in MCV - 30,1 ± 2,6 cm/c and in Galen's vena - 29,1 ± 2,1 cm/c, respectively (Figure 1). However, a significant difference between the groups was found only in the MCV - 30.1 ± 2.6 cm/c in the I group; 23.2 ± 2.1 cm/c in the II group and 22.4 ± 2.3 cm/c in the III group, respectively ($P < 0.05$). In the group of patients with severe HIS, magnetic resonance imaging revealed a lesion larger than 2 cm in size.

Conclusion: Transcranial dopplerography revealed the increased blood flow velocity in the main cerebral veins in ischemic stroke.

There is established a link between the velocity parameters of venous blood flow and the severity of ischemic stroke: the more severe the disease was, the higher systolic velocity of venous blood flow were recorded.

The increase in venous blood flow in patients with transient ischemic attack was recorded to a lesser extent than in patients with acute hemispheric ischemic stroke.

Keywords: *Transcranial Dopplerography (TD); Hemispheric Ischemic Stroke (HIS); Transient Ischemic Attack (TIA); Cerebral Venous Hemodynamics*

Introduction

Brain stroke is one of the most common causes of death and a major cause of disability worldwide [1]. Every year 610,000 individuals suffer an ischemic stroke and 185,000 a hemorrhagic stroke in the United States [2]. Cerebral circulation receives about 20% of the cardiac output. The volume of blood flow to the brain directly depends on the degree of stenosis of the vessels of the circle of Willis. At the same time, the severity of clinical symptoms depends not only on the degree of violation of arterial hemodynamics, but also on the state of venous blood flow from the brain. It is known that the venous blood flow from the vascular plexuses and deep sections occurs through a large cerebral vein flowing into a straight sine. Superficial veins of the brain that collect blood from the cerebral cortex flow into the upper sagittal sinus, cavernous, upper stony, etc. Through the sinuses of the dura mater, the blood flows into the internal jugular veins [3,4].

Spiral computed tomography (SCTA) and magnetic resonance angiography (MRA) are the main diagnostic methods for cerebrovascular diseases [5,6]. However, the need to use contrast agents limits the widespread use of these methods.

In the last 2 decades, along with CT and MRI in the diagnosis of ischemic stroke, transcranial dopplerography is used to determine the site of stenosis of the main arteries of the brain [7,8].

Objective of the Study

To comparatively study the hemodynamics in main cerebral veins in patients with hemispheric ischemic stroke (HIS) and transient ischemic attack (TIA) using transcranial Doppler.

Material and Methods

A retrospective analysis of the results of transcranial dopplerography (TD) of the main cerebral vessels was performed in 95 patients with hemispheric ischemic stroke (HIS) and in 31 patients with transient ischemic attack (TIA) caused by atherosclerosis of the internal carotid (IC) and middle cerebral arteries (MCA). The average age of the subjects was 63,7 ± 3,2 and 51.6 ± 5.2 years, respectively. The control group consisted of 56 health individuals, the average age - 59,3 ± 4,9 years. The visualization frequency and systolic blood flow velocity of the main cerebral veins - the basal vein of the brain (Rosenthal's vein), the deep middle cerebral vein (MCV), the large vein of the brain (Galena's vein), and Straight sinus (SS) were studied. Doppler ultrasound was conducted on a Philips HD 11XE device using a linear sector (2 - 4 MHz) transducer.

Results

Among the patient with the Hemispheric ischemic stroke Galen's vena was visualized in 91 (95,8 ± 2,1%) cases, the Rosenthal's vein - in 89 (93,7 ± 2,5%), the median cerebral vein (MCV) - in 81 (85,3 ± 3,6%) and the Straight sinus - in 87 (91,6 ± 2,8%) cases, respectively. In patients with transient ischemic attack this data was: 29 (93,5 ± 4,4%); 26 (83,8 ± 6,6%); 22 (71,0 ± 8,1%) and 23 (74,2 ± 7,9%) cases, respectively. In healthy individuals the Galen's vena was visualized in 51 (91,1 ± 3,7%) cases, the Rosenthal's vein - in 46 (82,1 ± 5,1%), the median cerebral vein (MCV) - in 33 (58,9 ± 6,6%) and the Straight sinus - in 35 (62,5 ± 6,5%) cases, respectively (Table 1).

The frequency of visualization of the main brain veins, %	HIS (n = 95)	TIA (n = 31)	CG (n = 56)
	1	2	3
Galen's vena	91 (95,8 ± 2,1)	29 (93,5 ± 4,4)	51 (91,1 ± 3,7)
Rosenthal's vein	89 (93,7 ± 2,5) P1-3< 0,05	26 (83,8 ± 6,6)	46 (82,1 ± 5,1
Median cerebral vein	81 (85,3 ± 3,6) P1-3< 0,001	22 (71,0 ± 8,1)	33 (58,9 ± 6,6)
Straight sinus	87 (91,6 ± 2,8) P1-2 < 0,05 P1-3 < 0,001	23 (74,2 ± 7,9)	35 (62,5 ± 6,5)

Table 1: *The frequency of visualization of the main brain veins in patients with hemispheric ischemic stroke and transient ischemic attack.*

The table shows that the frequency of imaging of Rosental's vein (P < 0,05), the median cerebral vein (P < 0,001) and the straight sinus (P < 0,001) in patients with ischemic stroke was significantly higher than among healthy individuals. In addition, the Straight sinus in ischemic stroke was visualized more often than in a transient ischemic attack (P < 0,05).

The maximum systolic blood flow velocity (Vs) in the main veins of the brain in patients with hemispheric ischemic stroke, transient ischemic attack and in healthy individuals is presented in table 2. Among the patient with the ischemic stroke Vs in the Galen's vena was 27,3 ± 1,9 cm/c, in the Rosenthal's vein - 22,1 ± 2,3 cm/c; in the median cerebral vein - 25,2 ± 2,4 cm/c and in the Straight sinus - 32,4 ± 2,6 cm/c, respectively. In a group of patients with TIA this data was: 22,4 ± 2,3cm/c; 19,1 ± 2,4 cm/c; 16,7 ± 2,9 cm/c and 25,1 ± 2,7 cm/c, respectively. The Vs of the venous blood flow in healthy individuals statistically did not differ from the results of patients with TIA and were: 19,5 ± 2,1 cm/c; 15,8 ± 2,3 cm/c; 13,1 ± 2,7 cm/c and 24,1 ± 2,5, respectively.

The systolic blood flow velocity, cm/c	HIS (n = 95)	TIA (n = 31)	CG (n = 56)
	1	2	3
Galen's vena	27,3 ± 1,9 P1-3 < 0,01	22,4 ± 2,3	19,5 ± 2,1
Rosenthal's vein	22,1 ± 2,3 P1-3 < 0,05	19,1 ± 2,4	15,8 ± 2,3
Median cerebral vein	25,2 ± 2,4 P1-2 < 0,05 P1-3 < 0,001	16,7 ± 2,9	13,1 ± 2,7
Straight sinus	32,4 ± 2,6 P1-2 < 0,05 P1-3 < 0,05	25,1 ± 2,7	24,1 ± 2,5

Table 2: *The maximum blood flow velocity in the large brain veins in a patients with hemispheric ischemic stroke and transient ischemic attack.*

As can be seen from table 2, the systolic blood flow velocity in all studied brain veins in patients with HIS statistically significantly exceeded the parameters of healthy individuals (P < 0.05 - P < 0.001). A significant difference between the velocity parameters of patients with HIS and TIA was detected only by MCV and Straight sinus (P < 0.05). The highest Vs was recorded in Straight sinus.

Based on the clinical symptoms and the level of neurological deficit, according to the state of severity, all patients were divided into three groups: group I included 21 patients with severe; in II - 49 patients with moderate and in group III - 25 patients with mild course of ischemic stroke. A tendency was revealed about the presence of a direct connection between the speed indicators of venous blood flow and the severity of ischemic stroke: the more severe the ischemic stroke was, the greater the speed rates of venous blood flow were recorded (Table 3).

The average maximum blood flow velocity, cm/c	HIS	HIS	HIS
	Severe n = 21	Moderate n = 49	Mild n = 25
	1	2	3
Galen's vena	29,1 ± 2,1	27,4 ± 1,8	25,4 ± 1,9
Rosenthal's vein	23,2 ± 2,5	22,4 ± 1,9	20,7 ± 2,4
Median cerebral vein	30,1 ± 2,6 P1-3 < 0,05 P1-2 < 0,05	23,2 ± 2,1	22,4 ± 2,3
Straight sinus	34,5 ± 2,7	32,1 ± 2,4	30,6 ± 2,6

Table 3: *The parameters of the maximum systolic blood flow velocity in the veins of the brain, depending on the severity of ischemic stroke.*

As can be seen from the table in all the cerebral veins of the I group of patients, the systolic blood flow velocity exceeded the corresponding parameters of the other groups: in straight sinus - 34,5 ± 2,7 cm/c, in median cerebral vein - 30,1 ± 2,6 cm/c and in Galen's vena - 29,1 ± 2,1 cm/c, respectively (Figure 1). However, a significant difference between the groups was found only in the middle cerebral vein - 30.1 ± 2.6 cm/c in I group; 23.2 ± 2.1 cm/c in II group and 22.4 ± 2.3 cm/c in III group, respectively ($P < 0.05$). In the group of patients with severe ischemic stroke, magnetic resonance imaging revealed a lesion larger than 2 cm in size (Figure 2).

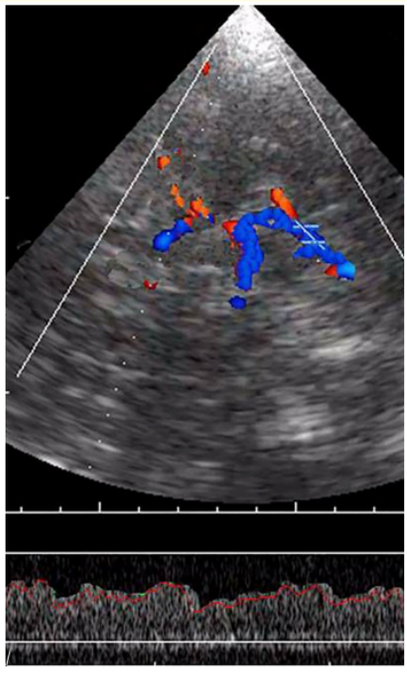

Figure 1: *Increased blood flow in the Galen's vein in a patient with ischemic stroke on the lesion side; Vs- 38 cm/s.*

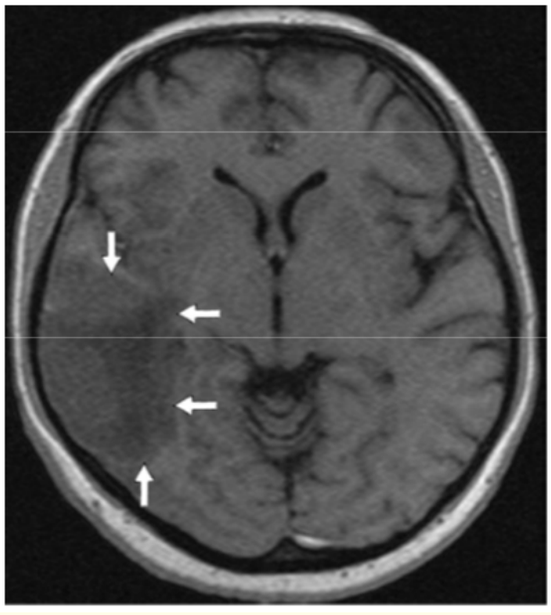

Figure 2: *MRI with ischemic stroke in the left MCR basin (left hypodence zone- arrows).*

Discussion

Transcranial Doppler is more often used to obtain quantitative parameters of arterial blood flow in cerebrovascular disease, in particular in ischemic stroke [9].

Transcranial dopplerography can be performed by a trained person at the patient's bedside within a few minutes. The role of transcranial dopplerography in the study of ischemic stroke is shown in previously published scientific papers. Studies by Siebert J., *et al.* (2012) show that the hemodynamic parameters correlate with long term prognosis in patients with ischemic brain stroke [10].

Simka M., *et al.* (2010) after examining the state of extracranial veins in patients with multiple sclerosis revealed a close correlation with the degree of cerebral venous insufficiency [11]. In the works of Iris Zavoreo., *et al.* (2013) is presented the possibilities of intracranial and extracranial ultrasound assessment of the venous circulation of the head and neck in chronic cerebrospinal venous insufficiency as one of the most common pathologies evaluated as part of the neurodegenerative processes in the central nervous system [12].

Cerebral venous pressure is governed by intracranial pressure, cerebral perfusion pressure, and venous outflow resistance. Therefore, changes in venous flow velocities are to be expected because of changes in intracranial pressure and brain tissue dislocation in patients with ischemic stroke and space-occupying brain edema. In contrast to the arterial blood flow, which tended to predominantly decrease with ischemic stroke, venous blood flow, according to our observations, tended to increase. In patients with ischemic stroke, there was a significant increase in speed indicators for the cerebral veins on the first day of the disease. That is, on the side of cerebral infarction, against the background of a decrease in arterial inflow, venous outflow was hindered up to the development of cerebral edema in severe cases. Due to the fact that the speed indicators increased in the veins under study, the quality of visualization of the veins themselves improved. This is explained by the fact that with Transcranial Doppler the registration of low velocity indicators of the blood flow is extremely difficult and with increasing velocity streams, the vessels are recorded much better. We have established a link between the velocity parameters of venous blood flow and the severity of ischemic stroke: the more severe the ischemic stroke was, the greater the maximum systolic velocity of venous blood flow were recorded. After analyzing a group of patients with TIA, we found that the increase in venous blood flow in it was recorded to a lesser extent than in patients with acute hemispheric ischemic stroke.

Conclusion

Transcranial dopplerography revealed the increased blood flow velocity in the main cerebral veins in ischemic stroke.

There is established a link between the velocity parameters of venous blood flow and the severity of ischemic stroke: the more severe the disease was, the higher systolic velocity of venous blood flow were recorded.

The increase in venous blood flow in patients with transient ischemic attack was recorded to a lesser extent than in patients with acute hemispheric ischemic stroke.

Conflict of Interest

The authors declared no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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