

NEUROPHYSIOLOGIC FEATURES OF CEREBRAL HEMODYNAMICS IN PATIENTS WITH VERTEBRO-BASILAR INSUFFICIENCY

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<https://doi.org/10.5281/zenodo.11551752>

Abstract. *The article presents the results of own research of cerebral (arterial and venous) hemodynamics state at duplex scanning of neck vessels, transcranial Dopplerography of cerebral vessels in patients with VBI. The increase in the diameter of the internal jugular vein, increase in the blood flow velocity and decrease in the pulsatility index of the basal Rosenthal vein, increase in the LBFV and diameter of the vertebral vein were found in the venous circulation characteristic of patients with venous encephalopathy.*

Keywords: *vertebro-basilar insufficiency, cerebral venous dyscirculation, cerebral hemodynamics.*

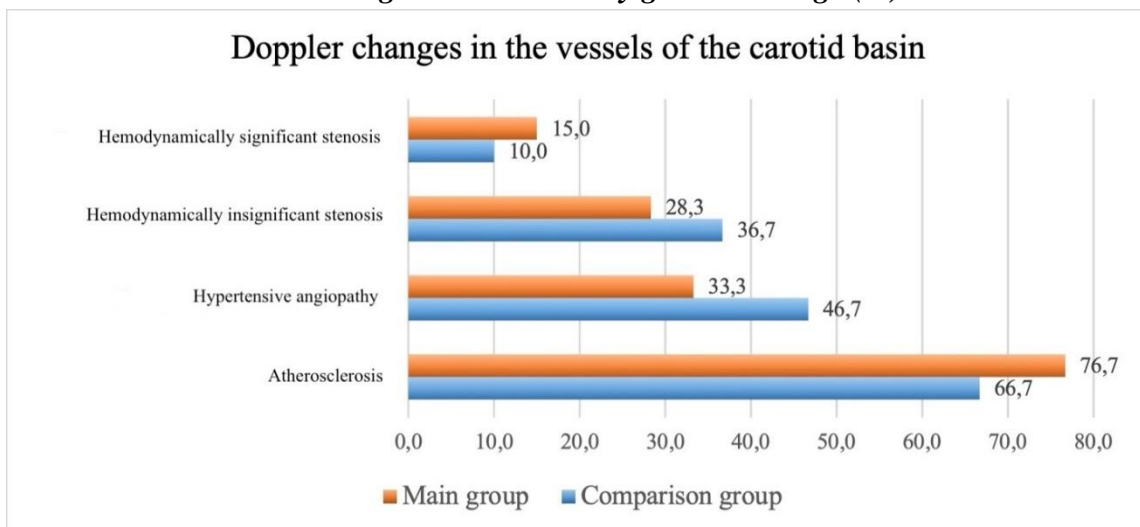
Introduction. For many years, when studying the pathogenesis of chronic cerebral ischemia, venous dyscirculation was given secondary importance. The lack of reliable knowledge, the difficulty of diagnosis, and the absence of objective methods for studying venous circulatory dysfunction prevented us from fully investigating the influence of venous disorders on cerebral ischemia [1, 2]. Examining the studies related to cerebral ischemia, only about 10% of them are works related to venous blood flow disorders, and most of the works are related to arterial blood flow disorders. Considering the interconnected system of arterial blood supply and venous blood flow work, and the fact that the venous section makes up 85% of the cerebral vascular bed [3] ignoring one of the factors leads to an incomplete assessment of the problem.

In the pathogenesis of chronic cerebral ischemia there are disorders of arterial and venous blood flow, often both of these factors are involved. Disturbances of cerebral venous circulation are one of the important pathogenetic mechanisms of development of cerebral vascular diseases and can be an independent cause of CCI. Recent publications have shown a high degree of dependence of CCI on venous stasis. Functional venous dystonia reflexively causes constriction of intracerebral arteries, thereby reducing blood flow to the brain [2, 5]. These two processes are closely interconnected. As a result of decreased blood circulation in CCI, structural organic changes and dystrophic processes develop, against which the outflow through the superficial venous network becomes difficult as a result of sclerosis of the lacunae of the superior sagittal sinus. Blood deposition in the venous microcirculatory bed occurs. To reduce venous stasis, additional outflow pathways in the deep venous system are included, which begin to work with overload. At venous stasis metabolic changes and hypoxia of the brain occur, venous and intracranial pressure increases, in acute cases cerebral edema is possible [4].

Purpose of the study. To study and compare the data of cerebral (arterial and venous) hemodynamics at duplex scanning of neck vessels and transcranial Dopplerography of cerebral vessels in patients with VBI.

Material and methods of research. The study was based on the data research of clinical picture of 90 patients diagnosed with vertebro-basilar insufficiency. All patients were divided into two groups. The main group consisted of 60 patients (39 female and 21 male patients) diagnosed with CCI vertebro-basilar insufficiency with clinical symptoms of cerebral venous circulatory disorders. The mean age of patients in the study group was 61.6 ± 5.68 years. Comparison group - 30 patients (21 women and 9 men) with the diagnosis of CCI vertebro-basilar insufficiency without clinical signs of cerebral venous circulation disorder. The mean age of patients in the comparison group was 59.03 ± 8.542 years. The age and sex distribution is shown in more detail in Figure 1. The control group consisted of 15 (11 women and 4 men) relatively healthy people without signs of cerebral circulation disorder.

Fig. 1 Distribution by gender and age (%)



To study cerebral hemodynamics, ultrasound examination of the cerebral circulatory system was performed in the groups of patients observed by us. Such methods as duplex scanning of BCV, transcranial Doppler method were used to assess the state of vessels. The features of arterial and venous cerebral blood flow, their peculiarities in functional and structural respects were revealed. At ultrasound examination of the arterial system, attention was paid to such parameters as vessel diameter, tortuosity, type of blood flow, presence of stenoses, atherosclerotic and thrombotic changes, asymmetry coefficient, and also such hemodynamic parameters as linear (average) blood flow velocity, resistance index (RI), pulsatility index (PI) were taken into account.

Results. As a result of the examination, the lesion was revealed not only in the vertebrobasilar system, but also in the system of carotid arteries (Fig. 5 and 6). Only in 11.1% of patients pathologic changes were detected in one vertebral artery. In other cases, the lesion of two arteries was observed in 56.6% of cases, and 3 arteries in 38.9%. As for bilateral lesions, according to ultrasound Doppler data, the most frequent lesion was the lesion of two vertebral arteries (56.7% of cases), combined lesion of common carotid arteries, slightly less frequently - in 22.2% of cases, and combined lesion of internal carotid arteries in 18.9% of cases.

In total, the predominant cause of carotid artery lesions was the presence of atherosclerosis, hypertension, and their combination. Atherosclerotic changes in the system of cerebral circulation were detected in 73.3% of the examined patients and were manifested by thickening of arterial walls, increase of vessel intima with its loosening and presence of atherosclerotic plaques. The above-mentioned changes in the main group occurred in 76.7% of the examined patients, and in the comparison group in 66.7%. Hypertensive angiopathy was found

less frequently in 37.8% of the examined patients, of which 33.3% in the main group and 46.7% in the comparison group.

Fig. 5 Doppler changes in vessels of the carotid basin (%)

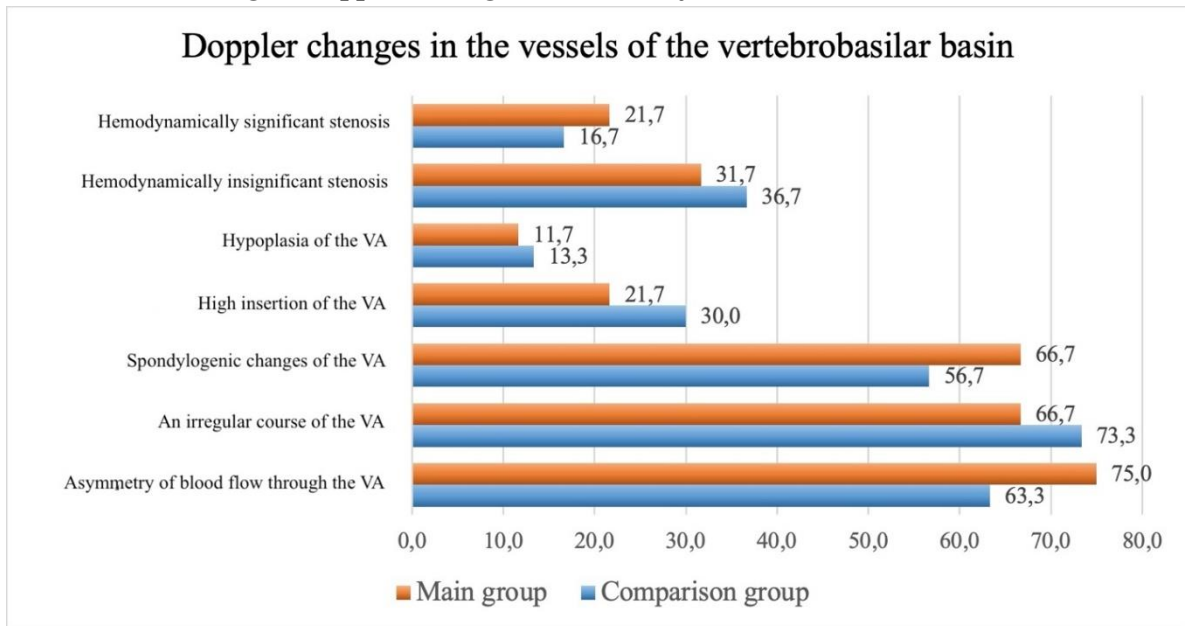
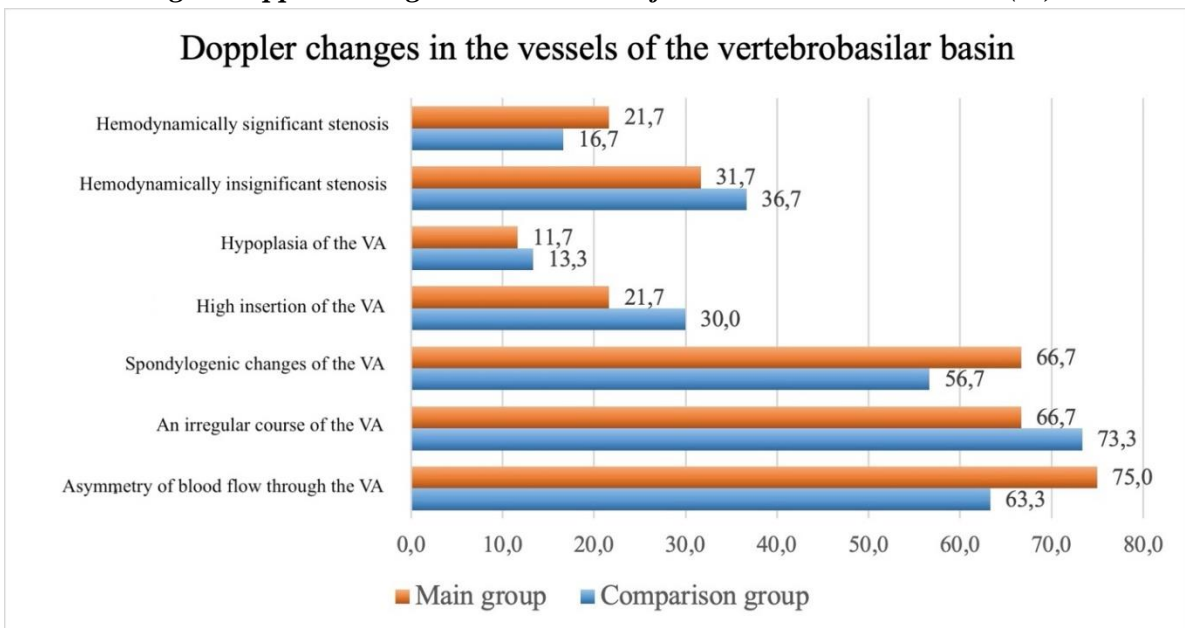


Fig. 6 Doppler changes in the vessels of the vertebrobasilar basin (%)



Stenotic lesions of the carotid arteries up to 50% of the vessel lumen occurred in 31.1% of patients, hemodynamically significant stenoses occurred in 13.3% of patients. There were no patients with arterial stenoses above 70% in the study; however, 2 patients in the main group underwent reconstructive surgery on CCA.

In 88.9% of patients, the study of the vessels of the vertebrobasilar system revealed signs of lesions of the VBS arteries at different levels, among which the most common was uneven course of the vertebral artery, which was detected in 62.2% of patients. High vertebral artery entry was detected in 24.4% of patients. Hypoplasia of the right vertebral artery was found in approximately 12.2% of cases. In 63.3% of the examined patients, spondylogenic changes of the vertebral artery were found.

The study of velocity parameters revealed peculiarities of cerebral blood flow disturbances characteristic of patients with VBI. In general, the patients examined by us were characterized by a decrease in linear blood flow velocity in the intracranial VA, in the PCA, on the side of the lesion. Peripheral vascular resistance indices in the cesarean section of vertebral arteries were elevated on both sides, which indirectly confirmed the increased resistance in the distal parts of the vertebro-basilar system.

Increased asymmetry coefficients of linear blood flow velocity in vertebral arteries, in common and internal carotid arteries, in posterior and anterior cerebral arteries indicate widespread damage of both extracranial and intracranial vessels in VBI patients. In our study, asymmetry of blood flow along the vertebral artery was found in 71.1% of patients.

During ultrasound examinations, we performed positional tests (turning the head in different directions), during which a decrease in blood flow in the basilar artery was observed. This sign indicates unstable hemodynamics and an important influence of vertebrogenic factors on the changes in blood flow velocity in the vertebral artery.

When studying the characteristics of the common carotid artery, we found the following changes. In 41.7% of the main group and 36.7% of the patients of the comparison group there was tortuosity of the common carotid artery. Atherosclerotic changes of the common carotid artery were revealed in 42% of the patients of the main group and 23.3% of the comparison group. The size of the intima-media complex, in the CCA, was 1.38 ± 0.403 mm in the main group and 1.26 ± 0.34 mm in the comparison group. Stenotic lesion more than 50% was detected in 30% of patients of the main group and 13.3% of patients of the comparison group.

When CCA velocity parameters were evaluated, LBFV in the main group was slightly lower (24.2 ± 3.6 cm/s) than in the comparison group (26.3 ± 3.39 cm/s) ($t=3.96$; $p<0.01$). Table 10 is presented in more detail.

Tab. 10 Ultrasound characterization of CCA

	Main group	Comparison group	Control group
Intima-media complex	1,49±0,26*#	1,26±0,11#	0,92±0,19
Linear blood flow velocity Vmed D	23,40±4,06*#	26,6±4,15#	31,61±4,43
Linear blood flow velocity Vmed S	25,03±2,89#	26,1±2,31#	32,44±3,61
Resistance index D	0,87 ± 0,06*#	0,82±0,03#	0,7±0,04
Resistance index S	0,77± 0,07*#	0,83± 0,04#	0,6±0,05

* Significantly with the comparison group ($p<0.05$)

- Significantly with the control group ($p<0.05$)

As we can see from the above data, the indices of the main group differed significantly from those of both the comparison group and the control group.

The results of the study of Doppler parameters of the internal carotid artery showed the following changes. In 36.7% of the main group and 20% of the comparison group patients there was tortuosity and uneven course of the ICA. Atherosclerotic changes of the common carotid artery were detected in 50% of patients of the main group and 33.3% of the comparison group.

Stenotic lesions of the internal carotid artery among the examined patients were mainly represented by hemodynamically insignificant stenoses, and in the main group this index amounted to 40% and in the comparison group 26.7%. Hemodynamically significant stenoses were detected in 20% of patients in the main group and 13.3% in the comparison group.

When assessing the velocity parameters of the ICA, the mean blood flow velocity in the main group was slightly lower (31.04 ± 8.56 cm/s) than in the comparison group (31.46 ± 5.25 cm/s), but the difference was statistically insignificant, whereas the resistance index was significantly higher in the main group. More detailed characterization of velocity indices of the internal carotid artery can be seen in Table 11.

Tab. 11 Ultrasound characterization of ICA

	Main group	Comparison group	Control group
Linear blood flow velocity Vmed D	31,64±8,96	32,13±5,27	41,03±8,1
Linear blood flow velocity Vmed S	30,43±8,16	30,79±5,24	42,65±7,9
Resistance index D	0,78±0,07*#	0,69±0,06	0,65±0,05
Resistance index S	0,77±0,08*#	0,68±0,05	0,63±0,05

* - Significantly with the comparison group ($p < 0.05$)
 # - Significantly with the control group ($p < 0.05$)

As we can see from the above data, the indicators of the main group slightly differed from those of the comparison group, but these differences were not reliable. There was a significant difference only in comparison with the control group.

When examining the characteristics of the vertebral artery, we found the following changes. The most frequent irregularity of the VA course was found in the patients we examined (66.7% of patients in the main group and 73.3% of patients in the comparison group).

In 28.3% of the main group and 36.7% of the comparison group, high vertebral artery entry was detected. Hypoplasia of the right vertebral artery was found in approximately 12.2% of both groups. Atherosclerotic changes of the vertebral artery were found in 47.8% of patients.

When assessing velocity parameters of the vertebral artery, we determined the presence of asymmetric blood flow in 71.1% of patients with predominance in the main group ($p < 0.05$). The mean LBFV in the main group (20.03 ± 4.1 cm/s) was significantly lower ($t = 4.41$, $p < 0.01$) than in the comparison group (22.76 ± 2.83 cm/s). More detailed characterization of velocity indices of the common carotid artery can be seen in Table 12.

Tab. 12 Ultrasonic characterization of the VA

	Main group	Comparison group	Control group
VA LBFV Vmed D	20,402±4,41*#	23,81±4,23#^	27.01±2,80
VA LBFV Vmed S	19,64±3,76*#	21,7±3,12#^	27,76±3,04
VA RI D	0,68±0,07*#	0,63±0,05#	0,59±0,06
VA RI S	0,7±0,06*#	0,64±0,04	0,61±0,06

* - Significantly with the comparison group ($p < 0.01$)
 # - Significantly with the control group ($p < 0.01$)
 ^ - Significant between parties ($p < 0.05$)

As can be seen from the table, in the main group there was a symmetrical decrease of LBFV in both VAs, whereas in the comparison group there was a significant decrease of LBFV in the right VA ($t = 2.20$, $p < 0.04$).

In order to clarify the peculiarities of hemodynamics in patients with VBI, ultrasound study of blood flow not only in the arterial but also in the venous system of the brain was performed. The size, diameter and maximum velocity of blood flow in these veins were evaluated.

One of the important parts of the venous circulation system is the internal jugular vein, as it is the collector of venous outflow from the cranial cavity.

Table 13 Ultrasonic characterization of IJV

	Main group	Comparison group	Control group
D right	22,04 ± 3,35*#^	11,48 ± 2,78	10,26 ± 3,22
D left	20,35 ± 3,23*#	10,72 ± 2,94	9,6 ± 2,91
Vmax right	16,77 ± 8,6*#	19,94 ± 7,85#	23,2± 6,03
Vmax left	14,71 ± 6,5*#	18,89 ± 6,37#	23,08± 4,61

* - Significantly with the comparison group (p<0.01)
 # - Significantly with the control group (p<0.01)
 ^ - Significant between parties (p<0.05)

During ultrasound examination of the IJV (Table 13), the increase in the diameter of the internal jugular vein up to 21.19±2.1 mm was characteristic for the main group, as well as indicating the presence of venous stasis in these patients, whereas in the comparison group this index amounted to 11.05±2.5 mm.

LBFV in the internal jugular vein in patients with VBI was significantly lower than in the control group. In the main group LBFV amounted to 15,21±6,5 cm/sec, and in the comparison group - 21,42±6,9 cm/sec.

Also, in the main group, we found asymmetry of venous blood flow, with a significant predominance of the right internal jugular vein diameter increase (22,04±3,34 mm) over the left one (20,35±3,23 mm).

The basal vein of Rosenthal has rather variable anatomical structure, as well as it is difficult to determine its location. During the study, the Rosenthal vein was detected in 51.1% of patients. In the main group there was a significant increase of LBFV up to 24.45±4.03 relative to the control group. In the comparison group, LBFV did not significantly differ from the control group and amounted to 18.82±4.18 cm/s. When studying the pulsatility index, we found that it was significantly lower in the main group and amounted to 0.2±0.06. In the comparison group, the pulsatility index was significantly lower than in the control group and averaged 0.33±0.06 and 0.4±0.03, respectively.

Tab.14 Ultrasound characterization of the Basal vein

	Main group	Comparison group	Control group
Vmax right	25.62± 6.06*#	19.7± 5.67#	15.06± 1.3
Vmax left	23.28 ± 5.32*#	17.95 ± 6.65#	14.56± 0.89
PI right	0.18± 0.08*#	0.33 ± 0.08#	0.41± 0.04
PI left	0.21± 0.08*#	0.34± 0.09#	0.39± 0.02

* - Significantly with the comparison group (p<0.01)
 # - Significantly with the control group (p<0.01)
 ^ - Significant between parties (p<0.05)

The patients were examined in the supine position, and as a result, the vertebral vein was not always detected (Table 15), since venous outflow from the skull in the horizontal position normally occurs through the internal jugular vein. At Doppler examination, the vertebral vein was detected in 47.8% of patients. In the main group this figure was 60%, and in the comparison group

- 23.3%. In the control group, only 10% had a VV. As it was mentioned above, among pathological changes of the VBB vessels, the most frequent was irregularity of the VA course, and when examining the VV, the signs of venous dysgemia were often found at the level where the VA straightness and its deformation were disturbed ($p < 0.05$).

The signs characteristic for venous dyscirculation were such changes in vertebral veins as increase in LBFV (40%) and vein diameter (35%), changes in the shape of the lumen (22%).

Tab. 15 Ultrasound characterization of the vertebral vein

	Main group	Comparison group	Control group
D right	3.7± 1,1*#	2,02 ± 0.35	1.65± 0.37
D left	3.9± 1.21*#	1.95 ± 0.34	1.64± 0.32
Vmax right	42.41± 8.28*#	21.7 ± 6.6	19.25± 1.75
Vmax left	40.72± 7.87*#	19.9± 8.3	18.47± 2.02

* - Significantly with the comparison group ($p < 0.01$)
- Significantly with the control group ($p < 0.01$)
^ - Significant between parties ($p < 0.05$)

The diameter of the VV in the groups studied differed, with a predominant increase in the main group to an average of 3.81 ± 1.1 mm, whereas in the comparison and control groups the diameter was 1.98 ± 0.32 and 1.64 ± 0.29 mm, respectively. As for hemodynamic parameters of vertebral veins, in the comparison group, in general, they did not differ from the control group, only the LBFV of the right VV was significantly higher than that of the left. In the main group, we found a statistically significant increase in the velocity indices of the VV of the patients of the main group relative to the comparison group. LBFV in the main group was 41.6 ± 6.2 cm/s on the right side, whereas in the comparison group this index was 20.8 ± 5.5 , which was also slightly higher than the control group (18.86 ± 1.48), but the indices were statistically insignificant.

Conclusions: The study of velocity parameters revealed peculiarities of cerebral blood flow disturbance characteristic of patients with VBI. They are characterized by decreased linear blood flow velocity in CCA, ICA and VA, increased peripheral vascular resistance indices. In the study of venous circulation characteristic for patients with VE, in these patients, there was an increase in the diameter of the internal jugular vein, increased blood flow velocity and decreased pulsatility index of the basal Rosenthal vein, increased LBFV and diameter of the vertebral vein.

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