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Cerebral Hemodynamics in Chronic Disorders of Cerebral Circulation

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The experience of using different methods of magnetic resonance study of the arterial and venous parts of the vascular bed of the head and neck is analyzed, and the feasibility and possibility of simultaneous assessment of the state of the brain and the study of the anatomy of the cerebral bed are shown. 87 patients with chronic cerebral ischemia (CCI) on the background of hypertension (GB) were examined, of the 36 women and 51 men aged from 46 to 72 years. All patients underwent standard neurological examination, MRI of the brain with venography (MRV) of the brachiocephalic veins and venous sinuses of the brain, duplex scanning (DS) in the modes of color Doppler mapping and pulsed Doppler of extra- and intracranial vessels. Comparative assessment of brain MRI results in patients with CCI revealed diffuse changes in the signal intensity from the white matter of the brain (periventricular, subcortical leucoarea, LA), single or multiple ischemic foci of 115 mm, external and internal cerebral atrophy (CA). the feasibility and the possibility of a one-stage assessment of the state of the brain and the study of the anatomy of the cerebral bed are substantiated. The need for an extended magnetic resonance study of the vascular system in the defeat of the arterial bed of the brain is due to certain anatomical and functional relationships between the arterial and venous sections.

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1. INTRODUCTION

Disorders of cerebral circulation because of arterial hypertension (AH) are one of the most pressing problems of modern cardiology and neurology, remaining the subject of discussion to date. It is known that in the reactions of cerebral autoregulation of cerebral circulation plays significant role violations of the venous circulation [1,2].

Thus, with increased blood pressure, there is an increase in the diameter of the veins and an increase in the permeability of the blood-brain barrier [3,4]. According to some authors, when using MRI techniques focused on the study of the venous bed, patients with hypertension revealed the following changes: expansion of the superficial cerebral veins, lack of a signal from the blood flow or reduction in the size of the transverse and sigmoid sinus, combined with expansion of the sizes of like sinuses from the opposite side [5,6,7]. Further research in this direction may allow developing new approaches to the prevention and treatment of hypertensive encephalopathy.

The advantages of MRI are not limited to the visualization of anatomical structures. The functional MRI created on the basis of angiographic techniques allows estimating the change in the velocity of the venous flow. At the same time, the change in the intensity of the signal on the angiograms obtained at rest and under conditions leading to the activation of a certain part or region of the cerebral cortex is compared [6,7].

Interest in studying the features of the cerebral venous circulation and attempts to assess its significance in the violation of cerebral circulation are determined, on the one hand, by the existing trend of increasing the number of patients suffering from vascular diseases, on the other - by the active development and introduction of modern visualization technologies [8,9,10,11].

In the available specialized literature, we were not able to find systematic data on the value of magnetic resonance angiography in assessing the arterial and venous circulation of the brain, which served as the basis for this study.

1.1 The Purpose of the Study

The purpose of the study is to substantiate the possibility of conducting and determine the features of the magnetic resonance venography in connection with cerebral arterial blood flow.

2. MATERIALS AND METHODS

87 patients with chronic cerebral ischemia (CCI) on the background of hypertension (GB) were examined, of them 36 women and 51 men aged from 46 to 72 years (mean age 57.2±11.3 years). The patients were divided into 2 groups: CCI stage I – 33 patients, CCI stage II – 54. In the examined patients, the mean systolic blood pressure was 181.7±9.3 mmHg; the mean diastolic blood pressure was 112.3±17.6 mmHg. The average duration of hypertension was 9.2±8.2 years (0.7–25 year). The control group consisted of 20 healthy individuals aged from 36 to 64 years old (mean age 49.1±9.7 years).

All patients underwent standard neurological examination, MRI of the brain with venography (MRV) of the brachiocephalic veins and venous sinuses of the brain, duplex scanning (DS) in the modes of color Doppler mapping and pulsed Doppler of extra- and intracranial vessels.

MRI was performed on a Magnetom Verio 3 Tesla and Magnetom Avanto 1.5 Tesla from Siemens according to a generally accepted method. Brain scans were performed in axial, sagittal and coronary projections with slice thickness from 4 mm with T1 – TR programs – 450 ms, T2 – TR – 6000 ms, tirm TR – 600 ms, TI –110 ms, contrast enhancement occurred upon injection of 10 –20 ml of a 5% magnetism solution (Schering). For MRI with brain arteriography (MRA) and MRV, a 2-dimensional time-of-flight angiography (2DTOF) technique was used. Using fast T2-weighted programs, we evaluated the state of cerebrospinal fluid dynamics in the Sylvian aqueduct. To assess the cerebrospinal fluid dynamics, the signal intensity from the pulsation of the cerebrospinal fluid in the Sylvian aqueduct was compared with the signal intensity in the lateral ventricles at the same level.

3. RESULTS AND DISCUSSION

All patients complained of dull headaches, more pronounced in the morning. The pains were

mostly of a diffuse nature, occipital localization and, in most cases, combined with pain in the neck. In 49 (36%) patients, headaches were accompanied by a moderately pronounced “noise in the head”.

32 (36.8%) patients complained of pain in the cervical spine. Pain syndrome was more often characterized as chronic with periodic exacerbations. They noted the frequent connection of cervicalgia with headaches, a little less with dizziness.

Along with the headache, the subjects noted difficulty concentrating, confusion. 61 (70.1%) patients complained of sleep disturbance (superficial sleep, headaches on waking, a decrease in the level of daytime wakefulness) and dizziness. Dizziness were mostly non-systemic in nature, there was instability when walking, incoordination, which are especially clear when performing small movements.

During neurological examination, vestibulo-atactic disorders in the form of instability during walking, staggering in the Romberg position, elements of dysmetry, indistinctness when performing knee-heel and paltsenosova tests were most often encountered. The deficiency of oculomotor innervation, consisting in the weakening of convergence and accommodation, was observed less often. Visual disturbances in the form of cattle-resistant, photopsies were also observed. The signs of pyramidal insufficiency manifested themselves in the form of asymmetry of tendon and periosteal reflexes, pathological foot and hand symptoms.

The degree of cognitive disorders ranged from mild attention deficits to pronounced amnestic dysfunctions (Table 1).

DS and MRA revealed in patients the presence of occlusive processes in the form of tortuosity and stenosis. When CCI stage I crispiness was found in 31.4%; with CCI stage II. - in 38.2% of patients. Thus, the tortuosity of the carotid arteries was characteristic of all patients with hypertension, regardless of the stage of CCI. No statistically significant difference between the parties was obtained ($p>0.5$).

Atherosclerotic changes were detected in 27% of patients. At the same time, a seal of the artery wall was noted; atherosclerotic plaques, loosening and an increase in the intima of the blood vessels were detected. The scatter of indicators of the intima-media complex was significant and ranged from 0.6 to 2.7 mm with an average of 1.4+0.4. Patients with occlusion of common carotid arteries (CCA) in our studies were not.

Analysis of linear blood flow rate (LBFR) on the CCA at CCI stage I showed a slight decrease in the left CCA (26.5 cm/s; a 3.14) compared with the control group (30.9 cm/s; a 3.44; $p <0.05$). Hereinafter, the data are presented as the arithmetic mean (M) and standard deviation (a).

When CCI stage II in the left CCA, the mean (25.2 cm/s; a 4.43; in the control group – 30.9 cm/s; a 3.44), the maximum (84.0 cm/s; a 15.1; continued; in the control group – 105.1 cm/s; a 13.8) and minimum (26.0 cm/s; and 4.4; in the control group - 32.2 cm/s; and 5.2) linear blood flow rates ($p<0.01$), in the right CCA these changes were less pronounced.

Evaluating LBFR, it can be stated that as the disease progresses, its decline occurs. Attention is drawn to the fact that for CCI stage I and II, these processes are more characteristic of the left CCA.

In order to assess hemodynamic changes in CCI, the volumetric blood flow rate Q (in ml/min) in SA and VA, as well as the total Qsumm (Table 2) was studied.

The study of the volumetric blood flow velocity in the main arteries of the head showed a significant decrease in the volumetric blood flow velocity in all extracranial vessels (CCA, VCA, BA), as well as the total volumetric velocity Qsumm as the severity increases. The decrease in the blood flow rate was associated with a significant decrease in the linear blood flow rate (LBFR) in the extracranial vessels compared with age norms.

In CCI stage I, there was only a tendency to a decrease in the volumetric blood flow velocity against the background of a moderate decrease in the blood flow velocity in the posterior circulation arteries. At stage II of the disease, there was a decrease in the linear and volumetric blood flow rates in the internal carotid arteries (ICA). In the arteries of the posterior circulation revealed a significant decrease in blood flow velocity. As for the encephalopathy (DE) III, there was a marked decrease in the linear and volumetric blood flow velocity, especially in the arteries supplying the back sections of the brain.

Considering the role of the common jugular vein as a collector of venous outflow from the cranial cavity, we analyzed the indicators of blood flow in it at different stages of CCI.

In all patients with CCI, the lumen of the internal jugular veins (IJV) was free. The valve was visualized in all cases in the mouth of the nuclear cell in all cases. In most cases, a bicuspid valve was detected.

To assess the viability of the IJV valvular apparatus, a respiratory load test was performed: in response to a deep breath, valve shut-offs were observed, accompanied by a significant reduction in blood flow to the IJV. In 59 (67.8%) cases with functional test, reversal of blood flow in valvar insufficiency was noted. No cases of valvar insufficiency were detected in the control group.

In all those examined in the control group and in the majority of patients with CCI, the blood flow in the IJV had a three- or four-phase character, synchronized with the act of breathing. In 1/3 of the cases, low-amplitude flow with reduced phasing was noted.

As can be seen from Table 3, patients with CCI determined higher values of the diameter of IJV and a comparative decrease in the intensity of the flow.

A particularly pronounced tendency to a decrease in the intensity of the flow, accompanied by a violation of its phasing, was observed in individuals with CCI II and a long history of hypertension (Fig. 1).

It is known that there is no outflow along the vertebral veins (VV) in the horizontal position of a person (Shakhnovich AR, Shakhnovich VA, 1996; Nikitin Yu.M. et al., 2001; Lelyuk V.G., Lelyuk S.E., 2000).

Examination of the vertebral veins (VT) was performed in the supine position, and the flow of the PT was determined in patients with CCI stage I, 26.4% of cases, CCI stage II – 42.7% (Fig. 2). During the transition to orthostatic- in 100.0% of cases in both groups. The failure of visualization of the vertebral veins was associated with the quality of visualization in general. Thus, more often, VV was inconsistent in patients with CCI stage II ($p<0.05$).

In all persons of the control group, the blood flow in the basal vein of Rosenthal from both sides and in the direct sinus had a monophasic character. Blood flow parameters are presented in Table 4.

Table 1. Main complaints and results of neurological examination of patients with CCI

Complains	n	%
Headache	87	100,0
Dizziness	67	77,0
Sleep disturbance	61	70,1
Memory disorder	73	83,9
Common weakness	59	67,8
Noise in the head	32	36,8
Dysphagia	6	6,9
Diplopia	7	8,0
Ataxia	22	25,3
Dysarthria	19	21,8

Table 2. Data of blood flow velocity (Q, ml/min) of extracranial arteries depending on the stage of CCI

Q	CCI stage I (n = 33)	CCI stage II (n = 54)	Control group(n=20)
CCA	495 ± 96 *	468 ± 91 *	523 ± 89
VCA	246 ± 39 *	213 ± 48 * ^	292 ± 68
BA	81 ± 29	54 ± 24 *	96 ± 35
Qsumm	634 ± 106 *	578 ± 78 *^	798 ± 84

*Hereinafter. Note: * - reliability between groups and control; (p<0.01), ^ - reliability between groups (p <0.01)*

Table 3. The diameter and flow rate in the internal jugular vein depending on the stage of CCI

Parameters	CCI stage I	CCI stage II	Control group
Diameter, mm	15,8 ± 3,4*	17,6 ± 3,7*	10,4 ± 3,8
V_{max}, cm/s	16,3 ± 11,8*	14,3 ± 10,9*	21,5 ± 10,7

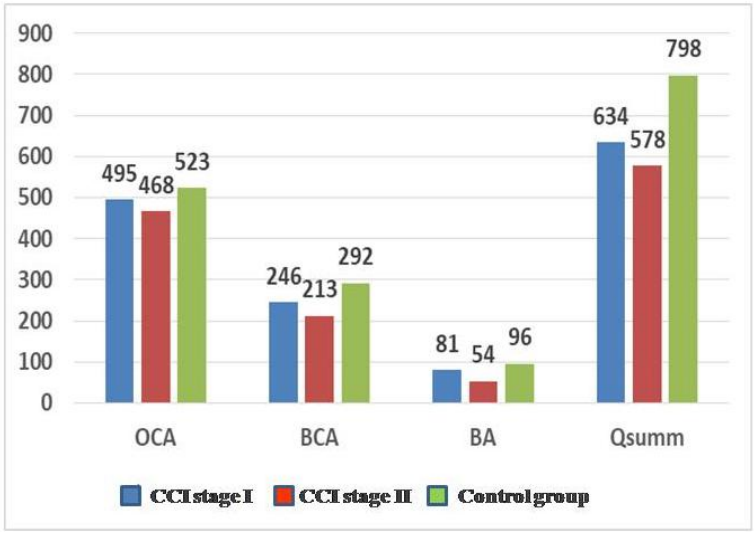

Fig. 1. Data of the blood flow rate (Q, ml/min) of extracranial arteries depending on the stage of CCI

Table 4. Blood flow parameters in the intracranial veins depending on the stage of CCI

Groups	Control group		CCI stage I		CCI stage II	
Parameters	**Vmax, cm/s**	**PI**	**Vmax, cm/s**	**PI**	**Vmax, cm/s**	**PI**
Basal vein of rosenthal	12,8 ± 5,4	0,41 ± 0,08	21,8 ± 7,2	0,28 ± 0,08	23,4 ± 7,2*	0,21 ± 0,07*
Straight sinus	20,1 ± 6,2	0,48 ± 0,07	29,6 ± 7,8	0,32 ± 0,07	31,2 ± 6,2*	0,24 ± 0,08*

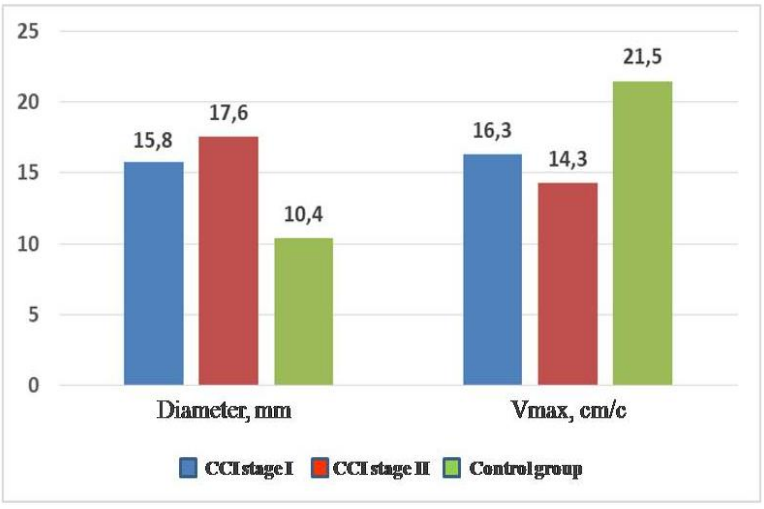

Fig. 2. The diameter and flow rate in the internal jugular vein depending on the stage of CCI

When assessing the quantitative parameters of the cerebral venous circulation in patients with CCI stage I, difficulty in the blood flow was found in the usual insolation of the intracranial veins. At the same time, a significant increase in LBFR was observed in the deep venous system against the background of a pronounced decrease in PI.

In patients with CCI stage II, the parameters of LSC in the basal veins of Rosenthal and the direct sinus did not significantly differ from CCI stage I, however, a tendency towards a progressive decrease in PI was observed. A significant difference in all four parameters was observed in patients of group 2 as compared with Control group.

Comparative assessment of brain MRI results in patients with CCI revealed diffuse changes in the signal intensity from the white matter of the brain (periventricular, subcortical leucoarea, LA), single or multiple ischemic foci of 115 mm, external and internal cerebral atrophy (CA). Large ischemic foci (cortical and subcortical heart attacks) in the examined patients were absent. Patients with CCI stage II differed more pronounced periventricular LA of all localizations compared with the group of patients with CCI stage II ($p<0.05$); symmetry of atrophic changes in the brain (the absence of significant differences in the index of the bodies of the lateral ventricles – IBLV, the linear dimensions of the anterior horns and the bodies of the lateral ventricles on the right and left); the prevalence of single and small (up to 5 mm) ischemic foci in the brain substance (43.4% with 10.7% CCI stage II, $p<0.05$). Compared to patients with CCI stage I, patients with CCI stage II were characterized by a greater ($p<0.05$-0.01) severity of asymmetric internal cerebral atrophy with predominant left hemisphere involvement (average values of Index of the bodies of the lateral ventricles (IBLV), linear dimensions of the anterior horns and bodies of the lateral ventricles were significantly higher left than right); a high representation of multiple ischemic foci of size>5 mm in the brain substance (39.3% with 10.4%, CCI stage II, $p<0.01$), especially in the deep sections of the white matter of the frontal lobes (50% and 23.1 respectively %), the head of the caudate nucleus (60.7% and 33.3%), the thalamus (60.7% and 30.8%), and the brain bridge (46.0% and 20.5%), i.e. in structures that are functionally significant for developed cognitive disorders (11).

According to MRI, the majority of patients were identified asymmetry of the main venous reservoirs; jugular veins and cerebral sinuses, mainly on the right side, were dilated in 53% of patients, on the left side – in 27%. Analysis of MRI data showed that in 58% of cases an abnormal development of the drainage system of the brain was detected. Thus, in 36% of cases, hypoplasia of one of the transverse sinuses was diagnosed (12 in the left, 6 in the right), and 14% of the patients showed aplasia in the transverse sinus. In 6 cases revealed hypoplasia of the sigmoid sinuses (right – 4, left – 2). In all cases, anomalies of development of the venous sinuses noted a compensatory expansion of the contralateral sinus, and in some cases, the upper and lower stony sinuses were visualized, the detection of which is normally difficult.

4. CONCLUSION

In chronic cerebrovascular disease along with changes in the arterial blood flow, changes in the regulation of the venous circulation are indicative. In chronic cerebral ischemia, both a comparative expansion of the IJV and a relative decrease in the intensity of blood flow in them is noted.

On the basis of the study, the feasibility and the possibility of a one-stage assessment of the state of the brain and the study of the anatomy of the cerebral bed are substantiated. The need for an extended magnetic resonance study of the vascular system in the defeat of the arterial bed of the brain is due to certain anatomical and functional relationships between the arterial and venous sections.

CONSENT

As per international standard written participant consent has been collected and preserved by the authors.

ETHICAL APPROVAL

As per international standard written ethical permission has been collected and preserved by the authors.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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