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Original report

PECULIARITIES OF CEREBRAL BLOOD FLOW AND VASCULAR REACTIVITY IN PATIENTS WITH LARGE AND GIANT TUMORS OF THE CEREBELLO-PONTINE ANGLE

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Background. Vestibular schwannomas and posterior fossa meningiomas are one of the most difficult tumors for surgical treatment. The mortality rate after their removal reaches 13,5 %. The main causes of death are hemorrhagic and ischemic complications. There are no studies in the literature on tissue perfusion of brainstem structures and cerebellum and reactivity of vertebral and basilar arteries in patients with extraaxial tumors of the posterior cranial fossa. Therefore, the study of the blood supply of the brainstem structures and cerebellum, as well as the functional characteristics of the vertebral and basilar arteries in these patients is of considerable interest.

Aim. To evaluate tissue perfusion of the pons and cerebellum, as well as the reactivity of the vertebral and basilar arteries in patients with large and giant vestibular schwannomas and posterior fossa meningiomas.

Materials and methods. Eighty-two patients with large and giant extraaxial tumors of the base of the posterior cranial fossa were examined. The median age was 54 [44; 61] years. Vestibular schwannomas were diagnosed in 52.4 % of patients, and meningiomas of the posterior cranial fossa were diagnosed in 47.6 %. All patients underwent duplex scanning of the basilar and vertebral arteries. We evaluated linear blood flow and coefficients of reactivity and index of vasomotor reactivity. We investigated the metabolic reactivity of cerebral blood flow by conducting hyper- and hypocapnic tests. Computed tomography perfusion imaging was performed in 18 patients. We detected cerebral blood volume, cerebral blood flow, mean transit time of contrast agent and time to peak of contrast agent. Measurements were carried out in six regions of interest located symmetrically on the pons and in the white matter of the cerebellar hemispheres on the side of the tumor and on the opposite side.

Results. Linear blood flow rates in the intracranial segments of the vertebral and the basilar arteries in patients with tumors were higher than in the comparison group (p <0.05). These patients are characterized by a decrease of reactivity coefficients in the vertebral and basilar arteries, especially when performing hypercapnic tests (p <0.05). Paradoxical reactivity and areactivity were diagnosed in 34.9 % of patients with vestibular schwannomas and 25.6 % with meningiomas. In the pons on the side of the tumor in patients with vestibular schwannomas, a decrease in cerebral blood flow by 19.3 %, an increase in cerebral blood volume by 33.3 % and an increase in mean transit time of contrast agent and in time to peak of contrast agent by 48.1 % and 71.1 % (p <0.05) were found. In patients with meningiomas in the pons on the side of the tumor, all perfusion parameters were higher (p <0.05). In the deep regions of the cerebellar hemisphere on the side of the tumor in patients with tumors, all perfusion parameters were higher compared to the opposite side.

Conclusion. The results of the study made it possible to quantify cerebral blood flow in patients with large and giant vestibular schwannomas and meningiomas of the posterior cranial fossa base. The revealed changes indicate the risk of developing pathological vascular reactions and disorders of cerebral blood flow in the postoperative period.

Keywords: vestibular schwannoma, meningioma of the base of posterior cranial fossa, reactivity of the vertebral and the basilar arteries, perfusion of the pons and cerebellum

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BACKGROUND

Vestibular schwannomas (VS) and posterior fossa meningiomas (PFM) are considered one of the most complex neoplasms in the context of surgical treatment [1, 2]. While in cases of small tumors mortality rate is close to zero, for large and giant tumors mortality is 13.5 % [3], and clinically significant neurologic deficit is observed in 70 % of patients even in the long term [4]. The main causes of deaths are hemorrhagic and ischemic complications [5–8].

It is established that the effect of a benign slowly growing tumor on the brain is multifactorial and is not limited to direct compression. Dramatically expanded tumor vessels without the structural and functional features of normal capillaries cause a decrease in peripheral resistance and serve as a morphologic substrate for arteriovenous bypass due to increased blood flow through the tumor tissue which leads to the "steal syndrome" in the surrounding part of the brain with focal cerebral hypoxia and ischemia [9–11]. Additionally, abnormalities of vascular innervation, morphological changes in walls of the vessels and affected permeability, as well as compression and infiltration of the vascular walls with possible occlusion of arteries of various sizes, should be noted [12]. Dysgemia disorders, venous congestion and edema leading to hypoxia and subsequent dystrophic changes in the neural cells also develop [13].

Search queries in the PubMed and eLIBRARY. RU databased for the years 2000–2022 showed the absence of studies on tissue perfusion of the brainstem and cerebellar structures and reactivity of the vertebral and basilar arteries in patients with extracerebral neoplasms of the posterior fossa. Considering the above stated, investigation of blood supply of the brainstem and cerebellar structures, as well as functional characteristics of vertebral and basilar arteries in patients with VS and PFM is of significant interest in the context of identification of possible predictors of vascular complications.

Aim. to evaluate tissue perfusion of the pons and cerebellum, as well as reactivity of the vertebral and basilar arteries, in patients with large and giant VS and PFM.

MATERIALS AND METHODS

At the Krasnoyarsk Regional Clinical hospital, analysis of examination of 82 patients with large and giant extracerebral tumors of the posterior fossa was performed. Diagnosis was established based on clinical and anamnesis data and results of magnetic resonance imaging, as well as histological examination of the tumor. The sample consisted of 22 (26.8 %) men, 60 (73.2 %) women. Median age was 54 [44; 61] years. Inclusion criteria were VS of size >3 cm or PFM of size >2.5 cm; exclusion criteria were the presence of decompensated concomitant pathology, extracranial pathology of the vertebral arteries, history of the use of stereotactic radiosurgical methods.

In 43 (52.4 %) patients, VS was diagnosed; in 39 (47.6 %), meningiomas of the petrous part of the temporal bone. Median tumor diameter was 36 [26; 45] mm. In 49 (59.7 %) patients, large neoplasms were diagnosed; in 33 (40.3 %), giant. Median Karnofsky Performance Status score at hospitalization was 70.0 [60.0; 80.0].

In the preoperative period, all patients underwent duplex scan of the basilar and intracranial segments of the vertebral arteries through the suboccipital window using the Acuson 128XP/10c device and color Doppler in combination with B-mode and pulsed wave Doppler. Averaged maximal linear blood flow velocities (LBFV) were evaluated based of the intracranial segments of the vertebral and basilar arteries at rest.

Metabolic reactivity of cerebral blood flow was studied using hyper- and hypocapnia tests (voluntary breath holding and hyperventilation tests). Reactivity tests were performed at second 20 of breath holding or rapid breathing irrespective of heart rate after completion of the test.

Reactivity indices (RI) for hypercapnia load (RI^+) were calculated using the K.F. Lindegaard (1986) formula:

$$RI^+ = (V^+/V^0 - 1) \times 100,$$

where V^0 – mean maximal LBFV at rest in cm/s, V^+ – mean maximal LBFV during hyperventilation in cm/s.
Reactivity coefficients for hypocapnia load (RI^-) were calculated using the K.F. Lindegaard (1986) formula:

$$RI^- = (1 - V^-/V^0) \times 100,$$

where V^0 – mean maximal LBFV at rest in cm/s, V^- – mean maximal LBFV during hypoventilation in cm/s.

Vasomotor reactivity index (VMRI) was calculated using the E.B. Ringelstein et al. (1988) formula:

$$VMRI = ((V^+ - V^-)/V^0) \times 100,$$

where V^0 – mean maximal LBFV at rest in cm/s, V^+ – mean maximal LBFV during hyperventilation in cm/s, V^- – mean maximal LBFV during hypoventilation in cm/s [14].

The obtained results were compared to parameters measured in 50 individuals without cerebral pathology (comparison group). The comparison group consisted of patients with osteochondrosis of the cervical spine, mean age was 46.24 ± 1.51 years.

Perfusion computed tomography was performed in 18 patients. The examination was performed using the 64-slice Siemens Definition AS scanner with the standard protocol (80 kV, 120 mAs) and subsequent postprocessing standard reconstruction algorithm.

During the examination, cerebral blood flow characteristics were evaluated: cerebral blood volume (CBV) (mL/100 g), cerebral blood flow (CBF) (mL/100 g/min), mean transit time (MTT) (s), time to peak (TTP) (s). The measurements were performed in 6 regions of interest located symmetrically in the pons, crebellar white matter at

3 cm depth (they are referred to as deep parts of the brain) and white matter of the subcortical matter of the cerebellum (convexity parts) at the tumor side and contralateral side. The obtained results were compared to each other.

Statistical analysis of the results was performed using descriptive statistics and correlation analysis (Statistica 8 software). to test distribution normality, Shapiro–Wilk test was used. Since most of the data was not distributed normally, parameters were described using median, 25th and 75th percentiles. Statistical significance of the differences in comparison of 2 independent groups was calculated using Mann–Whitney test; 2 dependent groups, using Wilcoxon's test. The threshold significance level (p) for testing of statistical hypotheses was set as 0.05.

RESULTS

Linear blood flow velocities in the intracranial segments of the vertebral arteries in patients with VS were higher than in individuals of the comparison group, and the difference from the healthy side was significant (Table 1).

The decrease in RI^+ in the vertebral arteries in patients with VS on both the affected and healthy sides should be noted (p <0.05). However, RI^- and VMRI had a tendency to decrease but without statistical significance.

In the basilar artery, LBFV was higher, VMRI was lower in patients with VS compared to comparison group (p <0.05) (Table 2). RIs also showed a tendency to be lower.

In 8 (18.6 %) patients with VS, unreactivity of one of the vertebral or basilar arteries was observed, while LBFV did not change during testing. In 7 (16.3 %) observations, paradoxical reactivity was observed where LBFV increased during testing when it should have been decreasing and vice versa. Therefore, in total unreactivity and paradoxical reactivity were observed in (34.9 %) patients with large and giant VS.

Doppler ultrasound results presented in Fig. 1, 2 demonstrate severe abnormalities in reactivity in a female patient with giant VS on the right.

In patients with PFM, LBFV in the intracranial segments of the vertebral arteries was even higher, and these

Table 1. *Linear blood flow rates and coefficients of reactivity in vertebral arteries (VA) in the group of patients with vestibular schwannomas and in the comparison group, Me [Q_1; Q_3]*

Parameter	Main group (VA on the side of the tumor)	Main group (VA on the opposite side)	Comparison group (VA)	Validity of differences
	1	2	3	
LBFR, cm/sec	40.0 [34.0; 45.0]	40.0 [35.5;47.5]	35.0 [29.2; 42.4]	$p_{1-3} = 0.052$ $p_{2-3} = 0.01$*
KR^+, %	15.0 [8.3; 28.5]	22.5 [14.2; 33.3]	37.0 [23.5; 43.6]	$p_{1-3} = 0.002$* $p_{1-2} = 0.011$*
KR^-, %	23.0 [14.2; 31.4]	23.6 [15.2; 35.0]	32.0 [22.4; 39.0]	$p_{1-3} = 0.457$ $p_{2-3} = 0.829$
IVMR, %	35.1 [25.0; 59.0]	44.8 [29.4; 65.2]	70.4 [56.7; 78.2]	$p_{1-3} = 0.077$ $p_{1-2} = 0.091$

**Differences are statistically significant (p <0.05).*
Note. *Here and in tables 2–4: Me [Q_1; Q_3] – median, lower and upper quartiles; LBFR – linear blood flow rate; KR^+ – coefficient of reactivity when performing hypercapnic test; KR^- – coefficient of reactivity when performing hypocapnic test; IVMR – index of vasomotor reactivity.*

Table 2. *Linear blood flow rates and coefficients of reactivity in basilar artery (BA) in the group of patients with vestibular schwannomas and in the comparison group, Me [Q_1; Q_3]*

Parameter	Main group (BA)	Comparison group (BA)	Validity of differences
	1	2	
LBFR, cm/sec	56.0 [46.0; 70.0]	48.8 [39.2; 60.0]	$p_{1-2} = 0.021$*
KR^+, %	15.6 [7.6; 30.4]	34.0 [24.6; 42.0]	$p_{1-2} = 0.101$
KR^-, %	23.0 [11.5; 27.5]	30.2 [22.8; 42.4]	$p_{1-2} = 0.119$
IVMR, %	35.0 [19.3; 56.0]	64.3 [46.2; 72.6]	$p_{1-2} = 0.047$*

**Differences are statistically significant (p <0.05).*

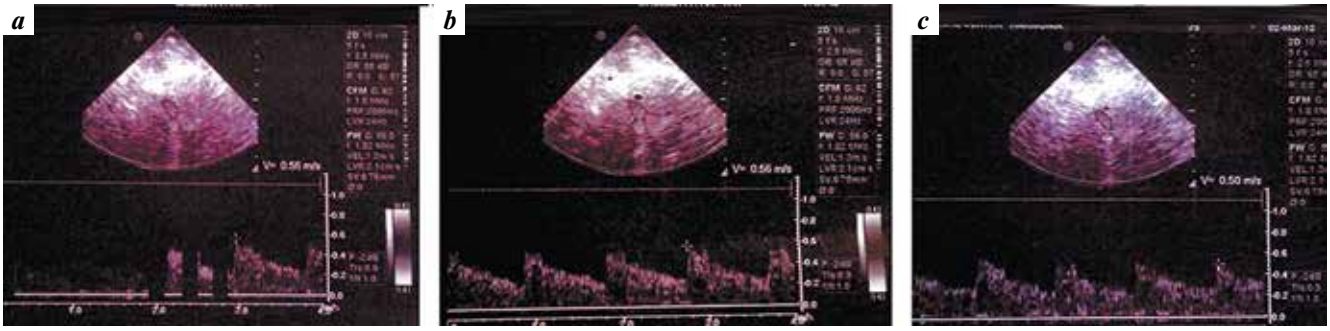

Fig. 1. *The dopplerography images of intracranial segment of right vertebral artery on the side of the tumor in patient with giant vestibular schwannoma: a – linear blood flow (LBF) at rest is 40 sm/sec; b – LBF during performing hypercapnic test is 38 sm/sec. It is paradoxical reactivity; c – LBF during performing hypocapnic test is 27 sm/sec. Reactivity coefficient – 32.5 % (normal reactivity)*

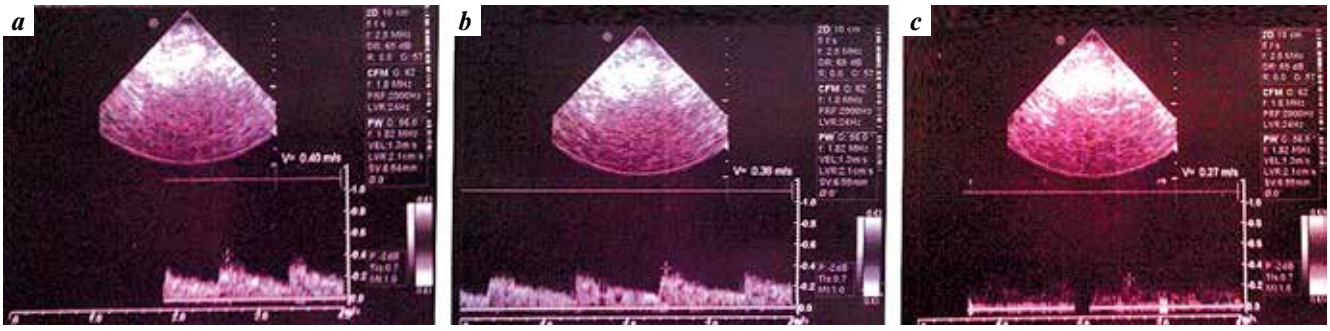

Fig. 2. *The dopplerography images of basilar artery in patient with giant vestibular schwannoma: a – linear blood flow (LBF) at rest is 56 sm/sec; b – LBF during performing hypercapnic test is 56 sm/sec. It is absence of reactivity; c – LBF during performing hypocapnic test is 50 sm/sec. Reactivity coefficient – 11.2 % (low reactivity)*

Table 3. *Linear blood flow rates and coefficients of reactivity in vertebral arteries (VA) in the group of patients with posterior fossa meningiomas and in the comparison group, Me [Q_1; Q_3]*

Parameter	Main group (VA on the side of the tumor)	Main group (VA on the opposite side)	Comparison group (VA)	Validity of differences
	1	2	3	
LBFR, cm/sec	44.0 [36.5; 55.0]	44.0 [38.0; 53.0]	35.0 [29.2; 42.4]	$p_{1-3} = 0.025$* $p_{2-3} = 0.018$*
KR^+, %	17.7 [4.7; 33.3]	21.9 [12.5; 34.0]	37.0 [23.5; 43.6]	$p_{1-3} = 0.022$* $p_{2-3} = 0.042$*
KR^-, %	20.9 [13.4; 31.9]	22.8 [15.2; 30.4]	32.0 [22.4; 39.0]	$p_{1-3} = 0.016$* $p_{2-3} = 0.052$
IVMR, %	44.0 [15.7; 65.7]	45.9 [26.4; 62.1]	70.4 [56.7; 78.2]	$p_{1-3} = 0.082$ $p_{2-3} = 0.094$

**Differences are statistically significant ($p < 0.05$).*

differences were statistically significant (Table 3). Analysis of reactivity showed decreased RI^+ in both vertebral arteries and decreased RI^- on the affected side ($p < 0.05$). VMRI also tended to be lower.

Similar data were obtained for LBFV and reactivity in the basilar artery in patients with meningiomas (Table 4). LBFV were higher, while RI^+ and VMRI were lower ($p < 0.05$).

Unreactivity of one of the vertebral or basilar arteries in patients with meningiomas was rarer than in patients with schwannomas: it was observed in 3 (7.7 %) cases, while paradoxical reactivity was more common: it was observed in 7 (17.9 %) cases.

Comparison of LBFV, RI in the vertebral and basilar arteries in patients with VS and meningiomas did not show any statistical differences.

Examination of perfusion characteristics (Table 5) in the pons at the schwannoma side compared to the contralateral side showed CBF decrease by 19.3 % with CBV increase by 33.3 % and statistically significant increases in MTT and TTP by 48.1 and 71.1 %, respectively.

Table 4. *Linear blood flow rates and coefficients of reactivity in basilar artery (BA) in the group of patients with posterior fossa meningiomas and in the comparison group, Me [Q_1; Q_3]*

Parameter	Main group (BA)	Comparison group (BA)	Validity of differences
	1	2	
LBFR, cm/sec	60.0 [47.5; 72.0]	48.8 [39.2; 60.0]	$p_{1-2} = 0.019$*
KR^+, %	17.8 [9.2; 26.9]	34.0 [24.6; 42.0]	$p_{1-2} = 0.092$
KR^-, %	20.0 [12.6; 31.6]	30.2 [22.8; 42.4]	$p_{1-2} = 0.042$*
IVMR, %	34.4 [21.5; 56.7]	64.3 [46.2; 72.6]	$p_{1-2} = 0.024$*

**Differences are statistically significant ($p < 0.05$).*

Table 5. *Results of computed tomography perfusion imaging in patients with vestibular schwannomas, Me [Q_1; Q_3]*

Parameter	Regions of interest	Side of the tumor	Opposite side	*p*
CBF, ml/100 g/min	Pons	39.2 [23.0; 49.2]	48.6 [29.6; 57.7]	0.682
	Deep part of cerebellar hemisphere	60.8 [42.0; 76.6]	41.0 [34.8; 78.7]	0.086
	Superficial part of cerebellar hemisphere	49.0 [32.2; 55.5]	48.4 [40.7; 55.5]	0.639
CBV, ml/100 g	Pons	4.8 [3.1; 7.0]	3.2 [1.7; 4.1]	0.056
	Deep part of cerebellar hemisphere	5.3 [4.1; 6.1]	3.6 [2.1; 3.9]	0.243
	Superficial part of cerebellar hemisphere	2.4 [2.1; 3.1]	2.8 [2.4; 3.3]	0.572
MTT, sec	Pons	7.9 [6.7; 9.5]	4.1 [3.2; 5.4]	0.044*
	Deep part of cerebellar hemisphere	4.3 [3.3; 5.7]	3.9 [3.0; 5.1]	0.824
	Superficial part of cerebellar hemisphere	3.1 [3.0; 4.7]	4.1 [3.8; 5.0]	0.560
TTP, sec	Pons	4.5 [2.8; 6.0]	1.3 [1.0; 4.4]	0.045*
	Deep part of cerebellar hemisphere	4.2 [3.0; 4.5]	3.9 [2.0; 4.2]	0.463
	Superficial part of cerebellar hemisphere	3.6 [2.7; 5.1]	3.8 [2.6; 5.2]	0.876

**Differences are statistically significant ($p < 0.05$).*
Note. *Here and in table 6: Me [Q_1; Q_3] – median, lower and upper quartiles; CBF – cerebral blood flow; CBV – cerebral blood volume; MTT – mean transit time; TTP – time to peak.*

In the white matter of the cerebellar hemisphere at 3 cm depth at the tumor side, all perfusion parameters were higher compared to the contralateral hemisphere (by 33.0; 32.0; 9.3 and 7.1 %, respectively) but the differences were not significant. In the subcortical parts of the hemisphere, CBF was significantly higher while other parameters were significantly lower (by 16.6, 32.2 and 5.5 %, respectively).

In patients with PFM, in the pons at the tumor side all perfusion parameters were higher than on the contralateral side, and CBF and CBV were almost 2-fold higher, TTP – more than 3-fold higher ($p < 0.05$) (Table 6). At the 3 cm depth in the cerebellar white matter at the affected side, all perfusion parameters were also higher. CBF was statistically significantly higher: by 36.2 %, while CBV (by 44.4 %), MTT (by 15.7 %) and TTP (by 6.6 %) tended to be increased without statistical significance. In the subcortical parts of the cerebellar hemisphere at the meningioma side, CBF was higher by 24.8 %, CBV by 4.1 %, MTT by 2.3 %, while TTP was more than 2-fold lower. However, these changes were not statistically significant (see Table 6).

DISCUSSION

Abnormalities of the cerebral blood flow dynamics in patients with intracranial neoplasms are caused by intracranial hypertension. Location and histological structure of the tumor, characteristics of its vascularization and relation to the main arteries and venous collectors also significantly affect the condition of cerebral blood circulation [9].

The results of our study demonstrate statistically significant increase in the blood flow velocities in the main arteries of the posterior fossa in patients with large and giant VS and PFM compared to the control group. Additionally, LBFV was higher in patients with meningiomas. The observed changes can be explained by intracranial hypertension because blood flow intensity, level

Table 6. *Results of computed tomography perfusion imaging in patients with posterior fossa meningiomas Me [Q_1; Q_3]*

Parameter	Regions of interest	Side of the tumor	Opposite side	*p*
CBF, ml/100 g/min	Pons	104.9 [49.7; 162.5]	55.4 [53.4; 58.1]	0.042*
	Deep part of cerebellar hemisphere	83.5 [39.5; 113.2]	53.4 [23.8; 93.7]	0.039*
	Superficial part of cerebellar hemisphere	45.2 [24.4; 88.7]	34.0 [22.4; 111.0]	0.236
CBV, ml/100 g	Pons	5.3 [3.1; 11.9]	2.7 [2.3; 5.1]	0.021*
	Deep part of cerebellar hemisphere	4.5 [2.5; 5.8]	2.5 [1.5; 4.4]	0.176
	Конвекситальные отделы мозжечка Superficial part of cerebellar hemisphere	2.4 [1.9; 6.8]	2.3 [1.8; 11.4]	0.589
MTT, sec	Pons	4.7 [3.4; 4.9]	3.0 [3.0; 3.8]	0.016*
	Deep part of cerebellar hemisphere	3.8 [3.3; 4.5]	3.2 [3.0; 3.9]	0.441
	Superficial part of cerebellar hemisphere	4.2 [3.2; 4.9]	4.1 [3.1; 5.0]	0.790
TTP/sec	Pons	3.4 [1.9; 6.0]	1.0 [1.0; 2.4]	0.045*
	Deep part of cerebellar hemisphere	3.0 [2.0; 3.9]	2.8 [1.4; 3.9]	0.683
	Superficial part of cerebellar hemisphere	1.3 [1.2; 3.0]	2.8 [1.6; 4.4]	0.176

**Differences are statistically significant (p <0.05).*

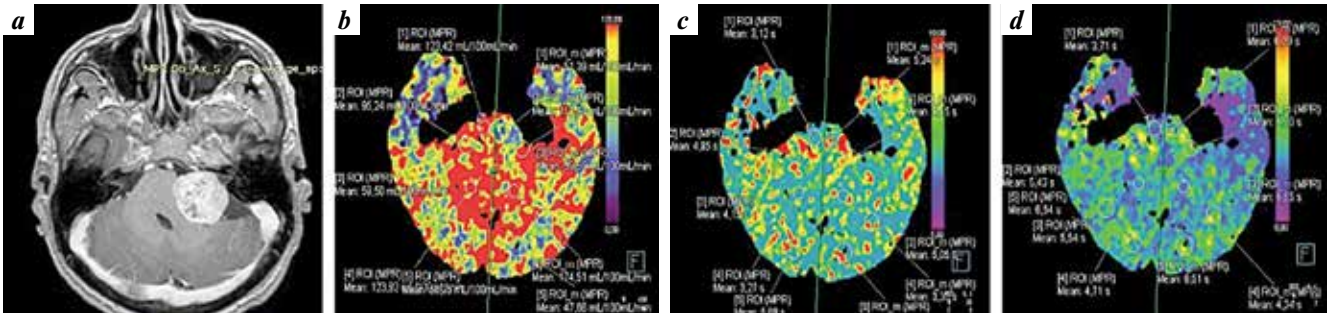

Fig. 3. *Results of magnetic resonance and computed tomography (CT) perfusion imaging in patient with big vestibular schwannoma: a – magnetic resonance imaging in T1 mode with paramagnetic; b – CT perfusion imaging: cerebral blood flow; c – CT perfusion imaging: mean transit time; d – CT perfusion imaging: time to peak*

of vascularization and relation of these neoplasms to the vessels are different.

Autoregulation is one of the fundamental features of cerebral circulation characterized by the ability of the vessels to preserve relatively constant volumetric blood flow velocity in cases of perfusion pressure changes [14, 15]. In the autoregulation range, intensity of cerebral blood flow remains relatively unchanging, and the integral characteristic of its adaptive ability is reactivity [9, 14]. Metabolic (photostimulation, hypo- and hyperventilation) and myogenic (nitroglycerin administration) tests are used in clinical practice for investigating reactivity [9].

A.Yu. Sboev et al. (2011) examined cerebral circulation in patients with gliomas, meningiomas and metastases of supratentorial location. The authors did not find statistically significant differences in LBFV parameters compared to healthy individuals. At the same time, statistically significant increase in the pulsatility index and decrease in RI^+ and RI^- were observed which, in the researchers' opinion, are caused by peritumoral edema, mass effect and increased intracranial pressure [16].

Doppler parameters of the middle cerebral artery in the distant postoperative period were studied by E.S. Rabinovich et al. (2016). It was shown that in patients with basilar meningiomas, decreased systolic blood flow velocity (67.96 ± 1.18 cm/s) and increased pulsatility index persist which is associated with increased peripheral resistance and local ischemia [17].

Analysis of the LBFV changes in the cerebral arteries after brainstem glioma resection was presented in the article by S.V. Madorsky et al. (2009). The authors showed that in 74 % of observations, LBFV in the basilar artery increased in the postoperative period, and in 32 % of cases it was considered to be a vasospasm. According to the researchers,

increased LBFV in the basilar artery, especially >90 cm/s, indicates elevated intracranial pressure and development of brainstem edema and ischemia [18].

In the majority of the studies, evaluation of cerebrovascular reactivity in the vertebrobasilar system is performed based on the analysis of changes in the basilar, in rare cases in the posterior, cerebral artery [9, 19]. Reactivity of the basilar artery and intracranial segments of the vertebral arteries in patients with neoplasms of the posterior fossa have not been sufficiently studied.

The results of our study showed a statistically significant decrease in RI^+ and RI^- of the vertebral and basilar arteries in patients with large and giant VS and PFM. Extreme abnormalities in the form of paradoxical reactivity and unreactivity were diagnosed in more than a third (34.9 %) of patients with VS and in every 4th patient (25.6 %) with PFM.

Disorders of cerebral circulation autoregulation are associated with increased intracranial pressure [9]. This explains dramatic abnormalities in reactivity of the main arteries of the posterior fossa in patients with large and giant VS and PFM.

Perfusion computed tomography allows to non-invasively quantitatively evaluate capillary blood flow using the velocity and volume maps (CBF and CBV), as well as mean transit time (MTT) [20–23].

According to the studies, normal asymmetry in perfusion characteristics between the hemispheres can be as high as 12 %, and decrease to 15 % and lower is considered a criterion for hypoperfusion [23].

I. Sergides et al. (2009) investigated peritumoral area in patients with meningiomas. Compared to normal cerebral tissue, in the peritumoral area the authors observed a significant decrease in CBV, a small increase in MTT with close values of CBF. The researchers noted the similarity between perfusion characteristics of the peritumoral area with parameters of ischemic penumbra [24]. Similar data were obtained by A.M. Turkin et al. (2023). Changes in the area of perifocal edema in patients with supratentorial meningiomas showed decreased velocity and volume of local blood flow compared to the contralateral hemisphere but without statistical confirmation [25]. In their article, A.V. Yazvenko et al. (2009) showed that meningioma of size >3 cm is a statistically significant factor of cerebral blood flow destabilization with formation of intracerebral "stealing" and distant metabolic abnormalities [10].

We have found no studies on tissue perfusion in the cerebral structures of patients with VS and PFM in the available literature.

In patients with large and giant VS, we identified statistically significant increase in MTT and TTP, as well as a trend towards an increase in CBV and a decrease in CBF in the pons on the tumor side which can indicate hypoperfusion of the areas of the pons close to the tumor. Considering median MTT >6 s, it can also indicate marked hypoperfusion which can serve as a predictor of ischemic complications [23]. In patients with PFM in the pons at the side of tumor, all perfusion parameters were significantly higher than on the contralateral side which indicates hypoperfusion [23]. Our results in patients with meningiomas differ from the data obtained by I. Sergides et al. and A.M. Turkin et al. Possibly, this can be explained by participation of patients with supratentorial tumor location and smaller tumors in the previous studies, or small sample size in our series.

Differences in perfusion parameters in patients with VS and PFM in the pons are likely caused by different vascularization of these tumors with corresponding remodeling of blood flow in these cerebral structures. Different level of involvement of the pia mater of the pons also plays a role.

In patients with large and giant VS and PFM in the deep parts of the cerebellum at the affected side, a trend towards increased perfusion characteristics is observed. These changes can indicate hyperemia [23]. Earlier in the literature, simultaneous moderate increase in all perfusion parameters in the perifocal area of necrosis in patients with venous and arterial strokes was described in the literature [23]. The observed changes in patients with tumors require further study. In the subcortical areas of the cerebellar hemisphere at the affected side, no statistically significant differences from the healthy side were observed.

The obtained data indicate that in patients with VS, hypoperfusion changes in pons tissue blood flow and signs of hyperperfusion in the deep parts of cerebellar hemisphere at the affected side are present. They are caused both by direct compression by the tumor and secondary dysgemia. In patients with PFM, hyperperfusion both in the pons and in the deep parts of the cerebellar hemisphere at the affected side were observed which contradicts literature data. Differences in perfusion parameters in patients with VS and PFM in the pons are caused by different levels of tumor vascularization and secondary remodeling in the neighboring cerebral tissues. The identified changes indicate remodeling of blood flow in the tumor-adjacent cerebral structures and a risk of vascular complications in the postoperative period.

CONCLUSION

The results of the study allowed to quantitatively evaluate cerebral blood flow in the vertebrobasilar system and subtentorial cerebral structures in patients with large and giant VS and PFM. Metabolic tests have shown that in these patients hyporeactivity – and in some cases paradoxical reactivity and unreactivity – of the vertebral and basilar arteries are present. Analysis of perfusion parameters has demonstrated that in patients with VS, hypoperfusion of the pons and hyperemia of the deep parts of the cerebellum on the affected side are observed. On the other hand, meningiomas are characterized by hyperemia both in the pons and cerebellum. The identified changes indicate the risk of development of pathological vascular reactions and cerebral circulation anomalies in the postoperative period.

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