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# Оценка когнитивного и биохимического статуса головного мозга у пациентов после проведения каротидной эндартерэктомии

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***АННОТАЦИЯ***

***Введение.*** В таких крупных исследованиях, как NASCET, ESCT, VACS, ACAS и ACST-1, не определена роль изменения когнитивных функций пациента в раннем и отдаленном послеоперационном периоде.

***Цель.*** Оценить биохимические параметры церебральных функций, когнитивный статус пациентов, а также их взаимосвязь после каротидной эндартерэктомии.

***Материалы и методы.*** В исследование было включено 60 пациентов, разделенных на две группы. Средний возраст составлял 67,3 ± 7,9 года, мужчин было 49 (81%), женщин — 19 (19%). Группа А — «*симптомные*» больные (n = 30), которым выполнялась каротидная эндартерэктомия, и они в анамнезе имели перенесенное острое нарушение мозгового кровообращения. Группа Б — «*асимптомные*» больные (n = 30), которым выполнялась каротидная эндартерэктомия, и они не имели в анамнезе церебральных сосудистых событий. В рамках исследования в срок до 6 месяцев были оценены когнитивный статус (по шкалам MMSE, FAB, MoCA-test, NIHSS), биохимические показатели (белок S100b, нейрон-специфичная энолаза (NSE), мозговой нейротрофический фактор роста (BDNF)) и данные ультразвукового исследования сонных артерий.

***Результаты.*** Установлено, что у пациентов группы А имеет место улучшение когнитивного статуса к 6 месяцам по шкале MMSE (p = 0,001) и MoCA-test (p = 0,09) относительно исходных показателей; по шкале FAB относительно данных — через 1 месяц (p = 0,01); отмечено снижение уровня неврологического дефицита по шкале NIHSS (p = 0,01). В группе А выявлена обратная корреляция между оценкой по шкале MMSE и индексом резистентности (r = -0,675; p = 0,005) и прямая — между шкалой FAB и конечным диастолическим давлением во внутренней сонной артерии (r = +0,912; p = 0,005), по данным ультразвукового исследования. В группе Б были получены данные, отражающие улучшение когнитивного статуса к 6 месяцам только по шкале MoCA-тест на 2 балла (p = 0,03) относительно исходных показателей. Также в данной группе через 6 месяцев после операции произошло повышение маркера S100b (p = 0,01) и белка NSE (p = 0,02) в 2 раза, а протеина BDNF в 1,5 раза по сравнению с исходными значениями (p = 0,005).

***Выводы.*** Каротидная эндартерэктомия ведет к улучшению когнитивного статуса, оцененного по шкалам (MMSE, FAB, MoCA, NIHSS) в отдаленном послеоперационном периоде у симптомных пациентов. Степень улучшения нейропсихического статуса зависит от уровня конечного диастолического давления и индекса резистентности во внутренней сонной артерии на стороне вмешательства.

**Ключевые слова:** *атеросклероз сонных артерий; каротидная эндартерэктомия; когнитивные функции; биохимические маркеры церебрального повреждения*

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# Evaluation of Cognitive and Biochemical Brain Status in Patients after Carotid Endarterectomy

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***ABSTRACT***

***INTRODUCTION:*** In the large studies such as NASCET, ESCT, VACS, ACAS and ACST-1, the role of alteration of the cognitive functions of a patient in the early and long-term postoperative periods have not been determined.

***AIM:*** To evaluate the biochemical parameters of cerebral functions, the cognitive status of patients, and their interrelation after carotid endarterectomy.

***MATERIALS AND METHODS:*** The study involved 60 patients divided into two groups. The mean age was 67.3 ± 7.9 years, there were 49 (81%) men and 19 (19%) women. Group A included 'symptomatic' patients (n = 30) who underwent carotid endarterectomy and had a history of an acute cerebrovascular event. Group B included 'asymptomatic' patients (n = 30) who underwent carotid endarterectomy but had no history of cerebrovascular events. As part of the study, the following data were evaluated within a 6-month period: cognitive status (on MMSE, FAB, MoCA-test, NIHSS scales), biochemical parameters (S100b protein, neuron specific enolase (NSE), brain derived neurotrophic growth factor (BDNF)) and the ultrasound data of the carotid arteries.

***RESULTS:*** Patients of group A showed improvement of the cognitive status by the 6$^{th}$ month on MMSE scale (p = 0.001) and in MoCA-test (p = 0.09) relative to the initial parameters; on FAB scale relative to the data after 1 month (p = 0.01); a decline of the level of neurological deficit on NIHSS scale (p = 0.01). In group A, an inverse correlation was found between the results on MMSE scale and resistance index (r = -0.675; p = 0.005), and a direct correlation between the results on FAB scale and the end diastolic pressure in the internal carotid artery (r = +0.912; p = 0.005) according to the ultrasound data. The data obtained in group B, reflected improvement of the cognitive status by the 6$^{th}$ month only by 2 points on MoCA test (p = 0. 03) relative to the initial data. Besides, in 6 months after the surgery, there was a 2-fold increase in S100b marker (p = 0.01) and NSE protein (p = 0.02) and a 1.5-fold increase in BDNF protein as compared to the initial values (p = 0.005).

***CONCLUSIONS:*** Carotid endarterectomy leads to improvement of the cognitive status evaluated on MMSE, FAB, MoCA, NIHSS scales in the long-term postoperative period in symptomatic patients. The extent of improvement of neuropsychological status depends on the level of the end diastolic pressure and resistance index in the internal carotid artery on the operated side.

**Keywords:** *atherosclerosis of carotid arteries; carotid endarterectomy; cognitive functions; biochemical markers of brain damage*

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ECO•VECTOR

## LIST OF ABBREVIATIONS

ACAS — asymptomatic carotid atherosclerosis study
ACST-1 — asymptomatic carotid surgery trial
BDNF — brain derived neurotrophic factor
CEA — carotid endarterectomy
EDP — end diastolic pressure
ECST — European Carotid Surgery Trial
FAB — frontal assessment battery
ICA — internal carotid artery
MMSE — Mini Mental State Examination
MoCA-test — Montreal Cognitive Assessment
NASCET — North American Symptomatic Carotid Endarterectomy Trial
NIHSS — National Institutes of Health Stroke Scale
NSE — neuron specific enolase
RI — resistance index
TILB — temporary intraluminal bypass
VACS — Veterans Affairs Cooperative Study

## INTRODUCTION

At the moment, surgical revascularization of the carotid system (carotid endarterectomy (CEA) or stenting of the carotid arteries)), if indicated, is the main method of both primary and secondary prevention of undesirable cerebral ischemic events associated with the degradation of an atherosclerotic plaque. Large studies, such as the North American Symptomatic Carotid Endarterectomy Trial (NASCET), the European Carotid Surgery Trial (ECST), the Veterans Affairs Cooperative Study (VACS), the Asymptomatic Carotid Atherosclerosis Study (ACAS) and the Asymptomatic Carotid Surgery Trial (ACST-1), show the leading role of CEA in the prevention of cerebrovascular catastrophes [1–5]. Nevertheless, in these studies, the role of changes in the cognitive status of the patient in the early and long-term postoperative period have not been investigated. Also of great importance is evaluation of predictors of changes in neuropsychic functions in this group of patients [6]. Taking into account a significant number of strokes occurring in the group patients of the working age, this is increasingly important for the socialization and return of the patient to work. Early cognitive and psychoemotional changes have been studied, although not widely, but, nevertheless, they are described in the literature as a postoperative cognitive dysfunction, and reflect short-term processes of restructuring cerebral hemodynamics in response to an increase in the cerebral blood flow [7–9].

The data about the long-term postoperative period and the status of the cerebral functions are ambiguous [10]. In a large meta-analysis including 31 studies and 2059 patients, it is stated that 64% of patients had no changes in the cognitive functions in the long-term period after carotid interventions, 24% of patients had improvements in several tests, 1.8% had impairment in all domains, and 1.5% had improvement [11].

Biochemical markers of cerebral damage are also of great importance for an objective assessment of the degree of ischemic and reperfusion damage to both neurons and glia [12–14].

Among the basic markers, of importance are 3 brain proteins [15–17]:

1. *S100b protein* is considered specific to cerebral tissue, as it is a component of different cells (Schwann cells, astrocytes). Since this protein is present in a large number of nerve cells, it should also be considered as an indirect sign of damage to the blood-brain barrier, because in this case it appears in the peripheral blood.

2. *Neuron specific enolase* (NSE) is present in almost all cells including granular cells, Purkinje cells, projection, sensory and autonomic neurons, etc. Appearance of NSE in the systemic circulation evidences damage to neurons and increase in the permeability of the blood-brain barrier.

3. *Brain derived neurotrophic factor* (BDNF) is widely expressed in the central nervous system and can have a strong influence on the development, morphology, synaptic plasticity and cerebral functions. Besides, it plays a role in the processes, such as neuronal maturation, synapse formation and synaptic plasticity. Its increase reflects the processes of restoring functions of nervous tissue in damages of different genesis.

The **aim** of this study to evaluate biochemical cerebral parameters, cognitive status of patients and their interrelation in the early and long-term periods after carotid endarterectomy.

## MATERIALS AND METHODS

An open perspective study was conducted in the period from October 2021 to December 2022 on the base of the cardiovascular surgery department of Ryazan Regional Clinical Hospital. The study was approved by the Local Ethics Committee of Ryazan State Medical University (Protocol No. 3 of October 11, 2021). All the patients signed the informed consent to participate in the study.

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Sixty patients were included and divided into two groups:

- ***Group A*** — 30 'symptomatic' patients with a hemodynamically significant lesion of the internal carotid artery (ICA) and a history of an acute cerebrovascular accident (ischemic stroke, transient ischemic attack, retinal embolism), who underwent CEA.

- ***Group B*** — 30 'asymptomatic' patients with a hemodynamically significant lesion of the ICA, but with no history of cerebral vascular accidents, who underwent CEA.

Both groups of patents were comparable in age and comorbid pathology, as well as in the technique of intervention. All the patients underwent CEA.

***Inclusion criterion:*** hemodynamically significant lesion of the ICA. For verification, all the patients underwent preoperative US of brachiocephalic arteries. For the patients of group A, the indication for the intervention was ICA stenosis from 50% (with unstable atherosclerotic plaque), or 60% (with no signs of instability) to 99% (NASCET criterion), for group B patients — stenosis from 70% to 99%. Three patients of group A (10%) and 2 patients of group B (6%) had contralateral stenosis of the ICA more than 70%.

***Exclusion criteria:*** acute cerebrovascular accident (stroke or transient ischemic attack) in the early postoperative period, refusal of the patients from participation in further examination, identification of oncological disease irrespective of localization, and death of a patient.

**Table 1.** Clinical and Demographic Characteristics of Studied Groups

| Parameters | Group A, 'symptomatic' patients | Group B, 'asymptomatic' patients | p |
|---|---|---|---|
| n | 30 | 30 | – |
| Age, M ± m, years | 66.7 ± 8.2 | 68.2 ± 7.1 | – |
| Number of men, n (%) | 21 (70) | 20 (66) | – |
| Essential hypertension, n (%) | 28 (93) | 26 (86) | *0.424* |
| Coronary heart disease, n (%) | 11 (36) | 15 (50) | *0.123* |
| Postinfarction cardiosclerosis, n (%) | 4 (13) | 6 (20) | *0.302* |
| Type 2 diabetes mellitus, n (%) | 7 (23) | 6 (20) | *0.155* |

*Note:* p — significance level in comparison between groups A and B

A standard protocol of preoperative examination included general clinical examination and laboratory tests, examination by a therapist, neurologist, ophthalmologist, ultrasound examination of the extracranial sections of the brachiocephalic arteries (linear sensor 7 MHz–13 MHz; GE Vivid S5, USA), magnetic resonance imaging of the brain (SIEMENS MAGNETOM Symphony, Germany), in some cases, CT angiography of the aortic arch arteries to clarify the treatment tactics (Siemens Somatom Go Up, Germany).

The CEA technique (classic or eversion) was chosen based on the preferences of the operating surgeon, the extension of the atherosclerotic plaque to the internal and common carotid arteries, as well as the level of the carotid bifurcation. The types of surgical interventions and the angiological status are presented in Table 2.

A temporary intraluminal bypass (TILB) was used in patients whose cerebral reserve did not permit surgical intervention with prolonged clamping of the carotid arteries. Retrograde pressure was measured in the ICA, the criterion for installing TILB was retrograde pressure in the ICA below 45 mm Hg. Also, in some clinical situations, surgeons used an intraluminal bypass preventatively.

All patients were given a standard anesthetic support. Premedication included sedatives, antihistamines and M-cholinolytic drugs. Intraoperatively, total combined anesthesia was applied with use of fentanyl, inhalation anesthetic (nitric oxide), and oxygen.

The overall follow-up period was 6 months. All the patients underwent ***control examinations*** in the following periods:

- Before intervention;
- 1 day after intervention;
- 1 month after intervention;
- 6 months after intervention.

On the examination, the patients underwent:

1. Testing using cognitive status assessment scales:

- *Mini Mental State Examination* (MMSE) in five basic positions: orientation, memory, perception,

**Table 2.** General Characteristics of Performed Interventions

| Intervention | Group A, 'symptomatic' patients | Group B, 'asymptomatic patients' | p |
|---|---|---|---|
| n | 30 | 30 | – |
| Carotid endarterectomy, n (%) | Classic — 14 (46)<br>Eversion — 16 (54) | Classic — 14 (46)<br>Eversion — 16 (54) | *0.519*<br>*0.457* |
| Transient intraluminal bypass, n (%) | 6 (20) | 7 (23%) | *0.378* |

attention, speech. Periods: before the intervention, after 1 day, 1 month, 6 months;

- *Frontal Assessment Battery* (FAB). Evaluation of the following parameters: conceptualization, verbal fluency, dynamic praxis, simple choice reaction, complicated choice reaction, and the study of grasping reflexes. Periods: before surgery, after 1 month, 6 months;

- *Montreal Cognitive Assessment* (MoCA). Evaluation of the following parameters: visual-constructive/ executive skills, naming, memory, attention, speech, abstraction, delayed reproduction, orientation. Periods: before surgery, after 1 month, 6 months;

- *National Institutes of Health Stroke Scale* (NIHSS) — for symptomatic patients in the period before the intervention and after 6 months;

2. Assessment of markers of cerebral cellular dysfunction in the peripheral blood:

- *S100b protein*;
- *neuron specific enolase* (NSE);
- *brain derived neurotrophic factor* (BDNF).

Blood was taken in fasting condition. Next, the blood was centrifuged at 3000 revolutions per minute for 10 minutes, the obtained serum was used to determine the level of biochemical parameters. S100b protein was determined using SEA567Hu ELISA Kit for S100 Calcium Binding Protein B (S100B) (Korea); NSE — using SEA537Hu ELISA Kit for Enolase, Neuron Specific (NSE) (Korea) kits; BDNF — using SEA011Hu ELISA Kit for Brain Derived Neurotrophic Factor (BDNF) (Korea). The enzyme immunoassay was used (Stat Fax 3200, USA) with two control measurements of one sample;

3. Ultrasound examination to evaluate:

- *the degree of ICA restenosis*;
- *end diastolic pressure (EDP) in ICA*;
- *resistance index in ICA*.

On the 1st day, testing was performed only on the MMSE scale to identify postoperative cognitive dysfunction, evaluate the predictivity of this scale, and also to avoid the effect of 'memorization' on other neuropsychic scales. All patients were tested in the daytime by the same specialist, the testing time did not exceed 30 minutes to reduce the risk of the exhaustion.

The statistical analysis was performed using Statistica 10.0 (Stat Soft Inc., USA), Excel (Microsoft, USA) program. The data distribution was performed using Shapiro–Wilk test (level: $p > 0.05$). In case of distribution of data different from normal, nonparametric statistical methods were used for further processing of the results obtained. Spearman's correlation coefficient was used to assess the interrelation of the studied parameters. Wilcoxon criterion was used to assess the statistical significance of intra-group differences (in symptomatic or asymptomatic patients in different follow-up periods). The intergroup differences (between groups A and B) were assessed using Mann–Whitney test. The critical significance level (p) was assumed to be $< 0.05$.

## RESULTS

***Cognitive and biochemical status in group A (symptomatic patients).*** Cognitive testing in different periods before and after surgery showed improvement of the cognitive status of this group of patients on MMSE scale ($p = 0.001$) and MoCA-test ($p = 0.09$) by the 6th month relative to the initial data; on FAB scale relative to the data after 1 month ($p = 0.01$, Figure 1). At the same time, a decrease in the level of neurological deficit on NIHSS was noted ($p = 0.01$). On the whole, the increment was 1 point on MMSE, 2.5 points on MoCA and 1 point on FAB, but there was 1.5 point reduction on NIHSS scale, which reflects improvement of the cognitive status in this group of patients after surgical intervention.

To note, there were no significant differences in the MMSE scores in patients on the first day after the intervention as a reflection of cerebral hyperperfusion syndrome or postoperative cognitive deficit. There was neither correlation between neuropsychic testing and ICA clamping time.

Comparing the parameters of cognitive status and the ultrasound data, it was noted that 6 months after surgery, the ultrasound data showed an inverse correlation between the MMSE score and the resistance index (RI; $r = -0.675$; $p = 0.005$; Figure 2A) and a direct

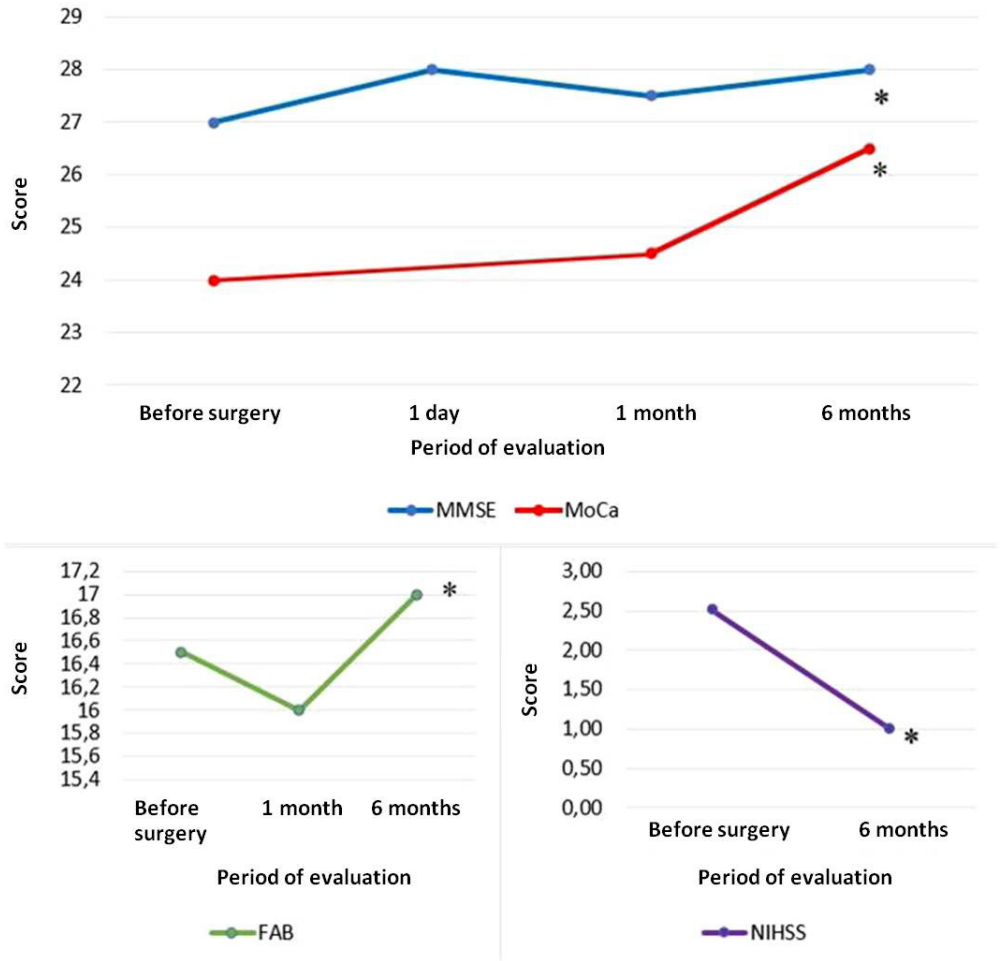


**Fig. 1.** Dynamics of cognitive testing on MMSE, MoCa, FAB and NIHSS scales in group A in different periods relative to the intervention.

*Notes:* FAB — frontal assessment battery, MoCA-test — Montreal Cognitive Assessment, MMSE — Mini Mental State Examination, NIHSS — National Institutes of Health Stroke Scale; * — $p < 0.05$ — statistically significant differences relative to the initial level.

correlation between the FAB score and EDP in ICA ($r = +0.912$; $p = 0.005$; Figure 2B). EDP parameters in ICA and RI reflect the state of intracerebral arteries and arterioles and, according to the data obtained, directly correlate with changes in the cognitive status of patients.

In the course of the study, we examined the dynamics of changes in biochemical parameters (BDNF, 100b, NSE; Figure 3). It was found that in patients of group A, 6 months after surgery, the BDNF neuro-adaptation marker increased ($p = 0.01$) against the background statistically insignificant change in the NSE ($p = 0.18$) and S100b ($p = 0.18$) cerebral damage parameters compared to the initial values. It is also necessary to note a 16-fold increase in BDNF from the 1st day to the 6th month ($p = 0.01$). During the restoration of cerebral perfusion with an increase in the blood flow in the intracranial region, the neurons located on the border with the infarction zone, undergo restructure and release neurotrophic factors that enhance interneuronal interactions. To this end, the markers of cerebral damage did not show any statistically significant changes, which reflects an insignificant reperfusion damage to the brain tissue in a sharp increase in the intracranial blood flow.

The correlation analysis revealed a direct relationship between the initial levels of S100b and NSE ($r = +0.834$, $p = 0.005$) and their values in 6 months ($r = +0.561$, $p = 0.005$) after surgical intervention. These proteins are markers of damage to the brain tissue and reflect the degree of breakage of the integrity of both white and gray matter cells as such and of the blood-brain barrier.

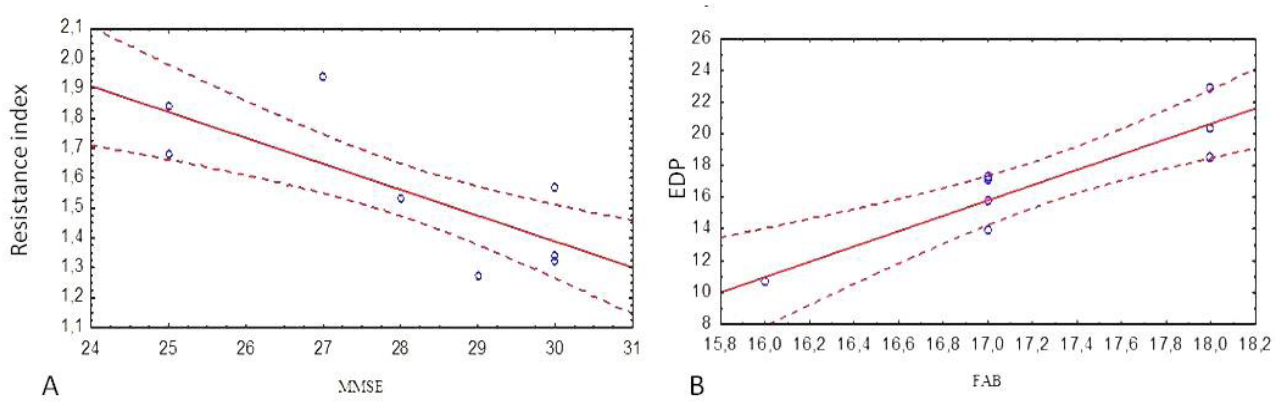


**Fig. 2.** Results of correlation analysis: A — correlation relationship between MMSE score and resistance index in the internal carotid artery in 6 months after the intervention, B — correlation relationship between FAB score and the end diastolic pressure in the internal carotid artery in 6 months after the intervention.
*Notes:* EDP — end diastolic pressure, FAB — frontal assessment battery, MMSE — Mini Mental State Examination.

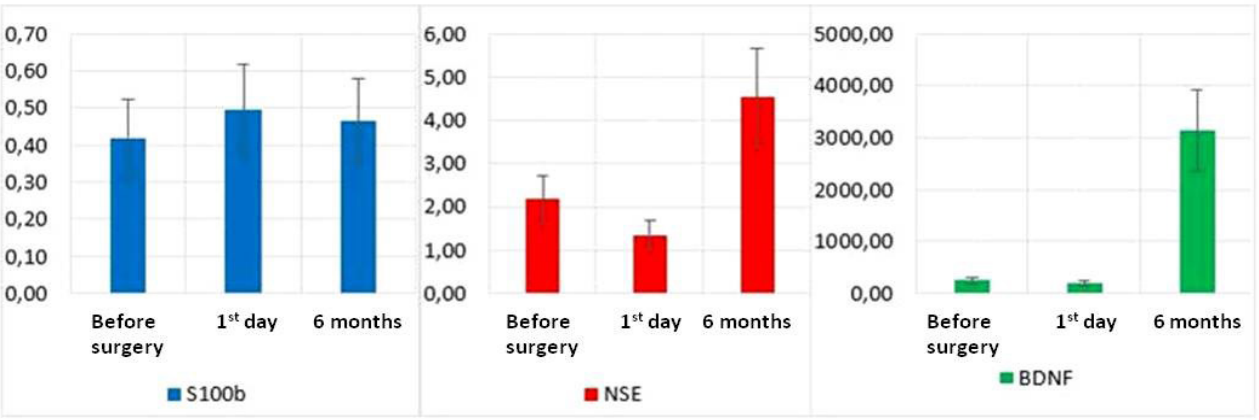


**Fig. 3.** Dynamics of biochemical parameters of the brain tissue (protein S100b, pg/ml; NSE, ng/ml; BDNF, pg/ml of plasma) within the first six months after the intervention in patients of group A.
*Notes:* BDNF — brain derived neurotrophic factor, NSE — neuron specific enolase.

The analysis of interrelations between the level of proteins associated with changes in the perfusion status of the brain and cognitive testing, did not reveal any statistical relationships.

***Cognitive and biochemical status in group B (asymptomatic patients).*** The data of the analysis of the studied parameters in asymptomatic patients are given in Figure 4. By the 6th month, no statistically significant improvement or worsening of the cognitive status were identified on the FAB, MMSE, NIHSS scales, MoCA test showed an improvement on average by 2 points ($p = 0.03$).

Correlation analysis revealed a direct relationship between FAB scale and MoCA test before the intervention ($r = +0.555$; $p = 0.005$) and 1 month after ($r = +0.566$; $p = 0.005$).

It is also important to note that, like in the group of asymptomatic patients, there were no reliable differences in the cognitive status of patients on the first day after the intervention as a reflection of reperfusion syndrome.

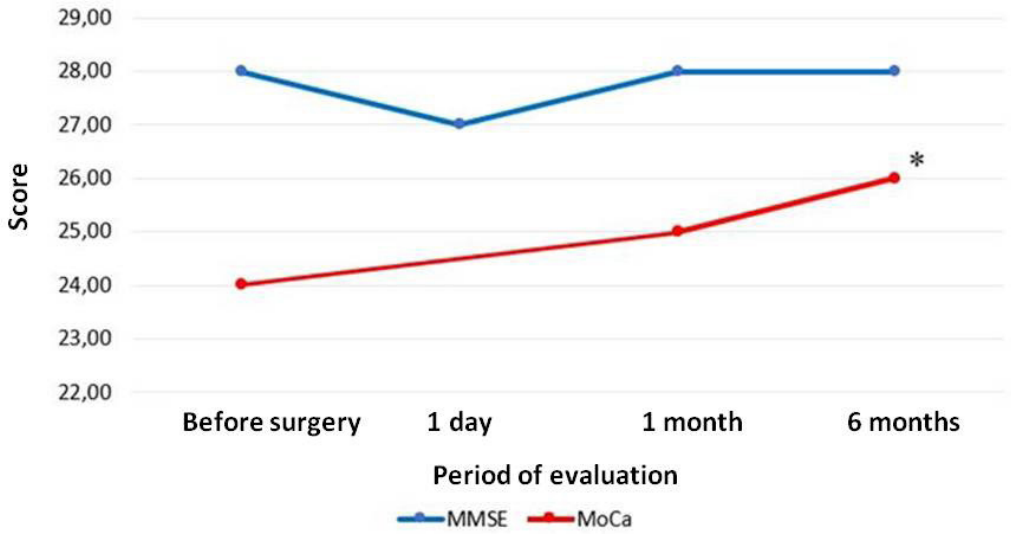


**Fig. 4.** Dynamics of cognitive testing on the MMSE, MoCa, FAB и NIHSS scales in group B in different periods relative to the surgical intervention.
*Notes:* : MoCA-test — Montreal Cognitive Assessment, MMSE — Mini Mental State Examination; * — $p < 0.05$ — statistically significant differences compared to the initial level.

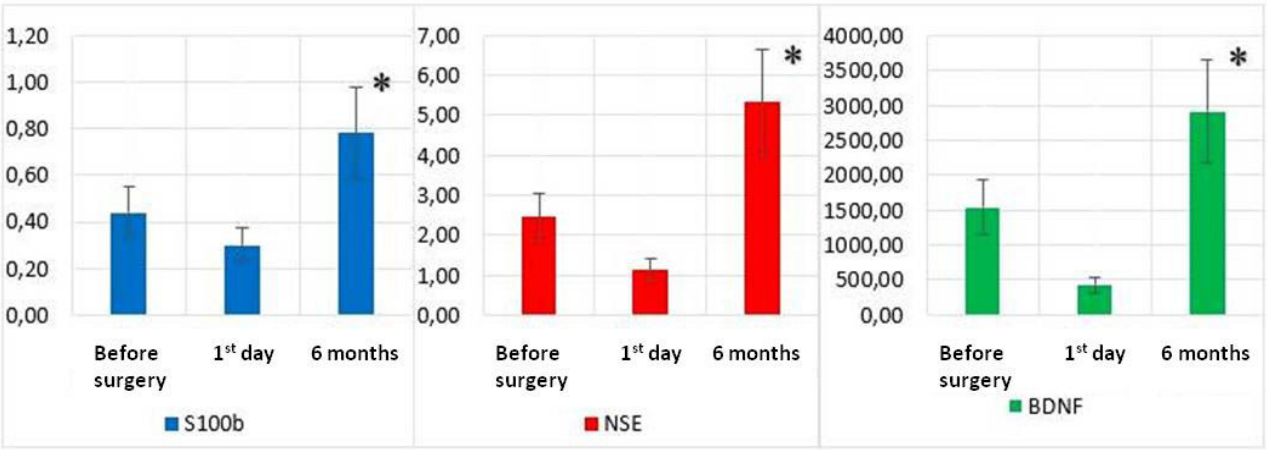


**Fig. 5.** Dynamics of biochemical parameters of the cerebral tissue (protein S100b, pg/ml; NSE, ng/ml; BDNF, pg/ml of plasma).
*Notes:* BDNF — brain derived neurotrophic factor, NSE — neuron specific enolase.

Considering the biochemical parameters, it was found that in 6 months after surgery, the S100b ($p = 0.01$) and NSE ($p = 0.02$) markers increased twice, and BDNF protein increased 1.5 times from the initial values ($p = 0.005$). As for NSE marker, it increased 4-fold by the 6th month relative to the values on the 1st day after the intervention ($p = 0.005$; Figure 5). These changes are rather ambiguous, S100b and NSE are markers of damage and appear in the peripheral blood only in case of disorders of the blood-brain barrier, which can be associated or not associated with damage to neurons. As for BDNF, it is a parameter of the restoration of the functions of neurons and glia. In our opinion, the detected changes should be considered as processes

occurring in parallel, including damage due to chronic cerebral ischemia and restoration with replacement of the lost functions of a number of nerve cells.

Subsequently, a direct correlation was established between the initial levels of the following proteins: S100b and NSE (r = +0.838; p = 0.005), S100b and BDNF (r = +0.592; p = 0.005), NSE and BDNF (r = +0.577; p = 0.005); on the 1st day after the intervention: NSE and BDNF (r = +0.620; p = 0.005); after 6 months: NSE and BDNF (r = +0.752; p = 0.005).

In group B patients, the ultrasound data 6 months after surgery were not associated with either neuropsychic status or biochemical parameters.

When analyzing the studied parameters in groups A and B, a difference was revealed only between the initial levels of BDNF marker. In group A patients, the level of this protein was three times lower than in group B patients (p = 0.04). This may probably be due to the depletion of the cerebral reserve aimed at restoring interneuronal interactions and replacing the lost functions of some neurons lost after a past cerebrovascular accident.

We also conducted an intra-group analysis of the studied parameters, depending on the type of surgical intervention performed. When comparing classic and eversion CEA, a difference on the FAB scale was revealed before surgery (p = 0.04), after 1 (p = 0.04) and 6 months (p = 0.01) in group B patients. At the same time, the average score with the classic method was lower and was 15 in all periods, and with eversion method — 17. In our opinion, these data are quite ambiguous due to a small sample size and the influence of the CEA type on only one scale of assessment of cognitive status.

In group A, neither type of CEA, nor the clamping time had any reliable effect on the cognitive and biochemical cerebral status.

## DISCUSSION

Considering a group of patients with a history of cerebrovascular accident, we found a reliable improvement of the cognitive status on all the studied scales (MMSE, FAB, MoCA-test, NIHSS) in the long-term period. It is difficult to say whether this is associated with the period of restoration of cerebral circulation after a cerebrovascular accident or with improvement of perfusion after CEA. Similar data were obtained by C. Baracchini, et al. (2012). They evidence improvement of the cognitive status in patients above 65 with an acute cerebrovascular accident in history and a significant lesion of the carotid artery, who underwent CEA. Patients with symptomatic stenoses showed a significant improvement of the average parameters of cognitive functions on MMSE and MoCA tests in 3 and 12 months, respectively [18]. Besides, in such patients, a relationship between neurophychic testing and ultrasound data should be noted: EDP and RI. Ultrasound parameters reflect a degree of brain perfusion directly related to the performed intervention. Similar data are reflected in the work of A. Nakamizo, et al. (2020), where the interrelation was shown between EDP and pulsation index in the common carotid artery and the level of neuropsychic status of patients after CEA [19].

In the group of patients without a previous acute cerebral ischemia, the neuropsychological testing data did not show much dynamics, only the MoCA scale scores significantly increased by the 6$^{th}$ month after the intervention. At the same time, the markers of cerebral damage (S100b and NSE protein) and of adaptation (BDNF protein) were higher by the 6$^{th}$ month. This cohort of patients had an inverse tendency compared to symptomatic patients. The noted changes may reflect restructure of the brain tissue in response to reperfusion with the intact white and gray matter.

In our study it was found that the groups of patients initially differed only in the level of BDNF protein, with the lower level in symptomatic patients. It is important to note the role of this protein in such processes as neuron maturation, synapse formation and synaptic plasticity [20]. Such changes may reflect the mechanisms of compensation and redistribution of functions between neurons due to formation of new interneuronal connections. Studies have shown that in chronic cerebral ischemia including that associated with stenoses of brachiocephalic arteries, the level of BDNF decreases, which correlates with impairment of cognitive functions, and in case of traumatic head injury it increases in the long-term period as a factor of regression of cognitive disorders [21, 22].

The limitations of the study include a small sample size, a short follow-up period after surgery, as well as the scales used (they are validated for assessing dementia, but not for determining postoperative cognitive deficits after CEA). In our opinion, it is necessary to continue this work and expand it by introducing a control group of patients and increasing the follow-up periods.

## CONCLUSIONS

1. In symptomatic patients, carotid endarterectomy leads to a comprehensive improvement of the cognitive status evaluated on the scales (MMSE, FAB, MoCA-test, NIHSS) in the long-term postoperative period, and in asymptomatic patients — only to a partial improvement (on MoCA scale).

2. The degree of improvement of the neuropsychic status of patients with a history of an acute cerebrovascular accident directly depends on the level

of the end diastolic pressure and resistance index in the internal carotid artery on the side of the intervention.

3. No reliable relationship was found between the biochemical status of the brain (the level of S100b, NSE and BDNF proteins) and cognitive functions.

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