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Postoperative cognitive dysfunction and cerebral microembolization during coronary artery bypass surgery under conditions of artificial circulation

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Abstract

Damage to the brain is one of the first places in the list of postoperative complications in cardiosurgical operations. In modern scientific literature, many mechanisms of damage to the brain in cardiosurgical patients, operated under the conditions of artificial circulation, are discussed. The lack of a common opinion in this issue justifies the need for additional research.

The aim of the study was to analyze the volume of cerebral microembolization in the basin of the middle cerebral arteries (MCA) during coronary artery bypass grafting (CABG) in conditions of artificial circulation (AC), and to investigate the relationship between cerebral microembolization and the development of postoperative cognitive disorders.

The study included 34 patients (19 men and 15 women) who underwent CABG using AC.

Monitoring of cerebral blood flow during the operation was carried out on the apparatus "Angiodin 2K" (Bios, Russia).

Assessment of the cognitive status of patients was carried out using verbal and nonverbal tests. Evaluation was carried out twice, before surgery and on the fifth day after the operation. Criteria for diagnosis of postoperative cognitive dysfunction (POCD) showed a decrease in the results of testing by 10% or more with a full study in two tests and more, and a decrease of 2 points or more in the tests of MOS and MMSE.

These data indicate that in all patients after aortocoronary shunting under the conditions of artificial circulation, microembolization of the cerebral blood flow is determined, and in the amount of more than 800 microemboli, results in a clinically pronounced impairment of brain function in the early postoperative period ($r = 0.78$ $p < 0.05$).

The understanding of regularities of the emergence of postoperative cognitive dysfunctions is a powerful resource for obtaining positive results when performing CABG operations under the conditions of the AC.

Key words: microembolization, cerebral blood flow, coronary artery bypass grafting, artificial circulation.

Introduction. Coronary heart disease (CHD) is one of the leading causes of disability and mortality worldwide [1, 2]. Despite significant progress in the field of pharmacotherapy of ischemic heart disease, it is not always able to achieve the desired effect [3, 4], which serves as the basis for the use of surgical methods of revascularization.

The operation of coronary artery bypass grafting (CABG) is one of the most widespread surgical methods for the treatment of CHD, traditionally performed under conditions of artificial circulation (AC).

However, the conduct of such operations is associated with the risk of damage to the central nervous system (CNS), the development of neurological and neuropsychological disorders of varying severity, associated with features of surgical and perfusion techniques [5]. A special place among these disorders is postoperative cognitive dysfunction (POCD) [6; 7], which, in turn, is a marker of poor quality of life, financial dependence of the patient on relatives, and the state and unfavourable prognosis for life [8; 9; 10, 11; 12].

In the recommendations of the American Heart Association (AHA) and the American College of Cardiology (ACC) in 2004, cerebral complications of cardiosurgical interventions are divided into 2 types: [13].

Cerebral lesions of the 1st type are associated with death as a result of a stroke, fatal stroke or transient ischemic attack, whereas delirium and postoperative cognitive dysfunction (POCD) are classified as type 2 cerebral lesions [6].

The two most significant clinical neurological complications of CABG are stroke and POCD. The incidence of stroke in patients with CABG is 1.6% [6]. However, the quantification of POCD is more complicated to obtain. According to various authors, the incidence of encephalopathy in the postoperative period reaches 40-90% [6,14,15,16,17].

POCD is a reduction in cognitive function after surgery and anesthesia compared to the preoperative baseline [18]. POCD can manifest itself in various cognitive domains, such as attention, memory, learning, visual spatial, motor skills and executive functions. Can also be accompanied by behavioral changes.

The modern concept of POCD is the development of violations of higher cortical functions in the early and retention in the late postoperative periods [19; 20].

Clinically, POCD can be confirmed by neuropsychological testing performed immediately after surgery and in a remote postoperative period, compared to baseline studies that were performed before surgery. However, at the present time there is no international agreement, there is no generally accepted criteria for the diagnosis of POCD, its structure is unclear, and there are no unified approaches to conducting neuropsychological testing [21].

Numerous studies indicate that the pathogenesis of POCD is multifaceted [6; 22; 23; 24]. At the same time, discussions and searches of the most important factors in the development of POCD in cardiac surgical patients are still ongoing.

The problems of prevention of brain function disorders in cardiac surgical interventions in conditions of artificial circulation are still not fully understood and largely unresolved [25]

In the current scientific literature, the following mechanisms of brain damage in cardiac surgical patients operated under conditions of artificial circulation (AC) are discussed [26, 27, 28, 29; 30; 31]:

• intraoperative microembolization of cerebral arteries;

• systemic hypoperfusion in conditions of AC with violation of autoregulation of cerebral blood flow;

• systemic and cerebral inflammatory response;

• cerebral edema;

• dysfunction of the blood-brain barrier;

• contact activation of blood cells during AC;

• metabolic disorders;

• pharmacological effects of anesthetics;

• other surgical and individual factors.

It is important to note that the role of each of the above pathogenic factors of perioperative brain damage is debated by modern researchers, and a unified concept of etiopathogenesis of neurologic function disorders in cardiac surgical patients in the postoperative period has not yet been formulated.

A number of studies have demonstrated a relationship between the volume of microembolization of cerebral arteries and the degree of brain damage in operations with artificial circulation [30; 32; 33]

Intraoperative microemboli are recorded in the vast majority of cardiac surgical patients. A significant relationship between the number of cerebral microemboli, on the one hand, and postoperative cognitive impairment, on the other hand, has been demonstrated in a significant number of neuropsychological studies [32; 33; 34]

Objective. To study the volume of cerebral microembolization in the basin of the middle cerebral arteries (MCA) while conducting CABG in conditions of artificial circulation, and to investigate the relationship between cerebral microembolization and the development of postoperative cognitive disorders.

Materials and methods. The study included 34 patients (19 men and 15 women) who underwent CABG using a AC.

The average age of the patients was 67.2 ± 5.1years. The average index of body mass index is 27.5 ± 5.1 kg / m^2. The average duration of the operation was 269.3 ± 7.9 minutes. The duration of the artificial circulation was 146 ± 4.6 min.

Depending on the functional capacity (FC) of angina, all patients were distributed as follows: II FC - 5 persons (14.7%), III FC - 24 persons (70.6%), IV FC and unstable angina pectoris - 5 persons (14.7%).

One myocardial infarction (MI) 22 (64.7%) patients had in the past, two MI - 2 (5.9%) patients. In 10 (29.4%) of the examined patients, ischemic heart disease (IHD) proceeded without MI in the anamnesis.

Left ventricular ejection fraction (EF) above 40% was registered in 26 (76.5%) patients, below 40% in 8 (23.5%) people.

At duplex scanning of the main vessels of the neck, at the preoperative stage, in all patients, hemodynamically significant stenosis in the region of the common carotid or internal carotid artery were not revealed.

All patients were operated under conditions of general anesthesia based on sevoflurane (1.5-2 MAC). Introductory anesthesia included propofol (1.6 ± 0.4 mg / kg) and fentanyl (1

μg / kg). Myorelaxation was provided with pipecuronium bromide (0.07-0.08 mg / kg), further analgesia with fentanyl (21.6 ± 3.3 μg / kg during the time of the surgery).

Artificial ventilation of the lungs in the examined patients was carried out with an air-oxygen mixture (FiO2 = 50%) under the control of ABG (mean pCO2 value of arterial blood was 35.4 ± 2.5 mmHg)

Artificial circulation was performed on a S3 apparatus (Stockert, Germany) in a laminar regime, using a disposable membrane oxygenator Affinity (Medtronic, USA) under moderate hypothermia (T = + 32 ° C).

Primary examination of patients was performed 3 days before the operation and, together with conventional methods, included transcranial doppler sonography with Siemens apparatus (Germany).

In the course of all operations, a standard protocol of anesthesia, surgical technique and artificial circulation was used.

Assessment of the cognitive status of patients was conducted using verbal and non-verbal tests.

1. MoCA- The Montreal Cognitive Evaluation Scale [35] is a battery of tests designed to quickly assess cognitive impairment. The test evaluates memory, "frontal" functions (visual-constructive skills, speech speed, abstraction, etc.), Nominal function of language, visual-spatial praxis. The duration of evaluation in elderly patients averaged 15-20 minutes. In the postoperative period, alternative variants of the test were used for MoCA scores (other words were used in the memory test, and another figure in the copy test)

2. MMSE - short scale of assessment of mental status [36] - the technique is widely used to diagnose dementia. Orientations, memory, attention, speech, executive functions and constructive praxis are studied. The duration of the survey in the elderly usually did not exceed 15 minutes.

3. A comprehensive study of various cognitive functions: Trail-making test, Grooved Pegboard test, a test for fine motor skills, learning 10 words of Luria, Wechsler test, Schulte tables.

The criterion for diagnosing POCD was a 10% or more reduction in test results with a full study in two tests or more and a decrease of 2 points or more in the tests of MoCA and MMSE.

Intraoperative monitoring of cerebral blood flow was carried out on the apparatus "Angiodin 2K" (Bios, Russia). The measurements were performed by transcranial access according to a standard procedure [37]. The baseline assessment of linear blood flow indices

was performed on the eve of the operation, and subsequently intraoperatively, beginning with the induction of anesthesia. In this case, ultrasonic sensors of linear format with a frequency range of 5-10 MHz were used.

Results and discussion. During the intraoperative study, microembolic signals in the projection of the middle cerebral artery were recorded in all the patients examined. At the same time, the average number of microemboli recorded in the MCA projection during the entire operation was 753.4 ± 15.7, the maximum was 842, and the minimum was 658.

It should be noted that in almost all patients episodes of group microembolism (from 2-3 to 10 or more signals over a period of 1 to 5 seconds) were noted in connection with surgical manipulations on the aorta, for example, during cannulation or at the time of application and removal aortic clamps. In many cases, group microembolization was observed at the onset of the artificial circulation, as well as in the restoration of effective cardiac activity. In some patients, a significant number of microembolic signals were recorded during the whole period of the heart failure. They appeared immediately after switching on the AC apparatus and disappeared immediately after it stopped regardless of the events in the operation field. Thus, in many patients the volume of intraoperative microembolism was determined directly by the functioning of the AC apparatus.

During the study, in none of the patients microembolization of MCA was accompanied by pupillary reactions and significant hemodynamic disturbances. The average velocity of blood flow in the MCA was small (Figure 1).

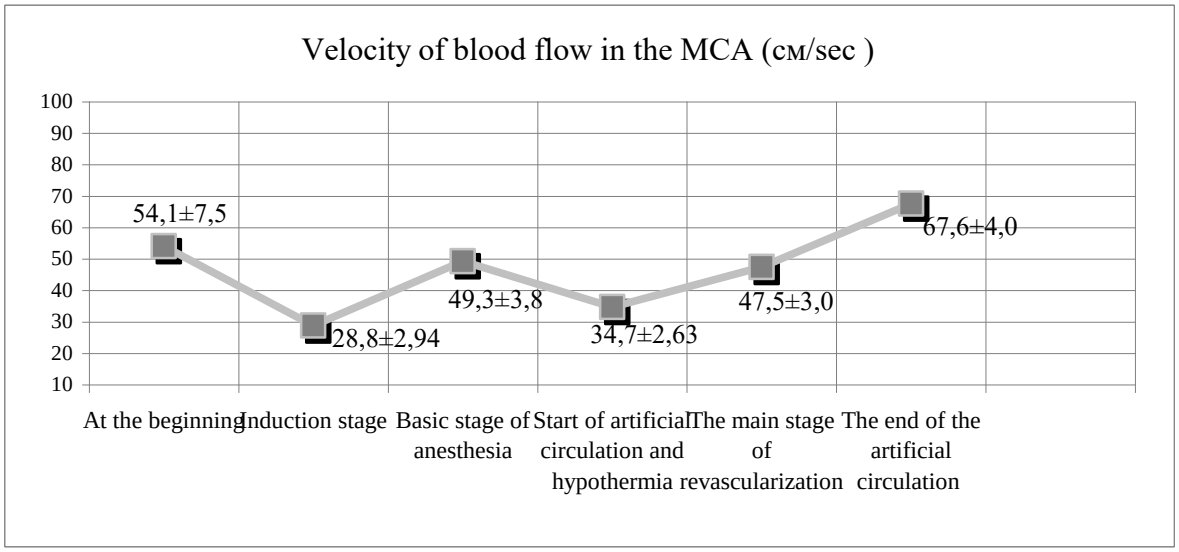

Fig.1. Dynamics of indices of linear velocity of blood flow in the basin of the middle cerebral artery (MCA) at different stages of the study

At the induction stage of anesthesia, an average depression of the mean linear velocity of blood flow in the MCA basin was observed, which was 28.8 ± 2.94 cm/sec (46.6 ± 2.4% relative to the initial value ($p = 0.0138$)).

Further observations showed that at the stage of maintenance of anesthesia, the cerebral blood flow indices stabilized and were close in their values to the initial values.

After connection of the device of artificial circulation and hypothermia, the rate of cerebral blood flow decreased, which averaged 34.7 ± 2.63 cm/sec (64.1 ± 3.8% of the initial value).

The main stage of myocardial revascularization under conditions of the calculated value of the volume perfusion rate was characterized by stabilization of the studied parameters. The mean linear velocity of blood flow in the MCA basin was fixed within 47.5 ± 3.0 cm/sec (78.5 ± 9.1% of the initial values).

After the end of the main stage of the operation, restoration of cardiac activity and attainment of normothermia, the linear velocity of blood flow in the MCA basin was stabilized and its progressive increase was 67.6 ± 4.0 cm/sec, which exceeded the previous values by an average of 29.6 ± 2, 0%, and the output indicators - by 19.8 ± 2.4%.

In the course of the study, a statistically significant positive correlation was found between the number of registered microemboli (more than 800) in the MCA projection and the adverse course of neurological status in the early postoperative period ($r = 0.78$ $p < 0.05$) (Fig. 2).

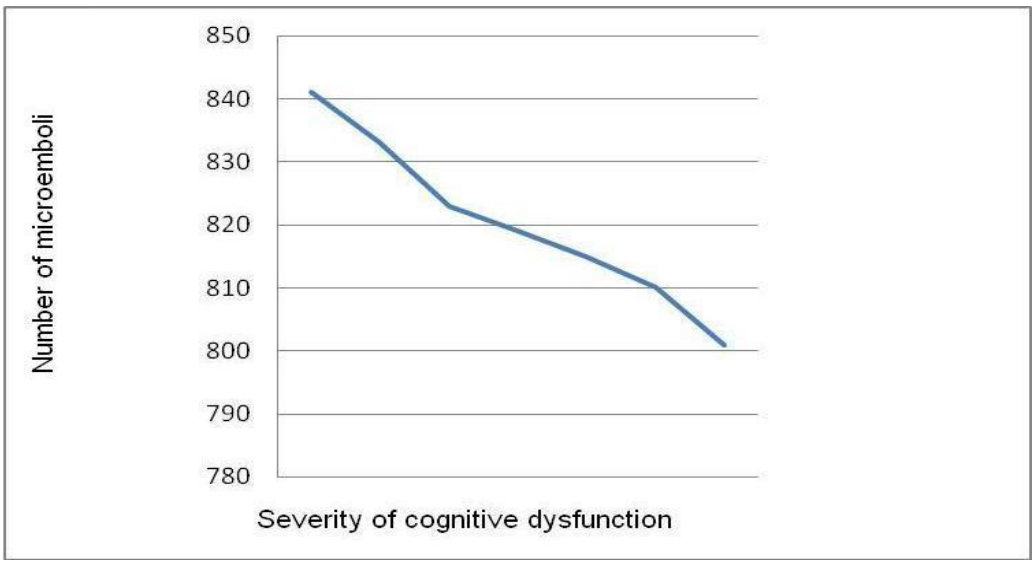

Fig. 2. Relationship between cognitive dysfunction and the number of microemboli.

In 6 (17.6%) cases after artificial circulation, cardiac weakness was observed, which was corrected by moderate doses of sympathomimetics.

A number of foreign studies have demonstrated a relationship between the volume of microembolization of the cerebral arteries and the degree of manifestation of POCD after operations with AC [22; 29; 33].

The average number of microemboli that we obtained in our study coincides with the analogous data of other authors. The vast majority of microemboli was recorded at the onset of the artificial circulation, at the time of application of the clamp on the aorta, as well as in the restoration of effective cardiac activity.

In addition to microemboli, hypoperfusion is also considered as a factor responsible for intraoperative ischemic brain damage [39; 40].

A number of authors in their studies indicate a reliable relationship [41; 42] between intraoperative disorders of brain perfusion and deterioration of cognitive status in the postoperative period.

L. Caplan et al. expressed the opinion that a decrease in cerebral perfusion limits the possibility of a blood flow for the washing of a microembolus from the microcirculatory bed and the zone of the borderline blood circulation is particularly sensitive to the embolic-hypoperfusion injury inflicted [43]

The results of measuring the average rate of cerebral blood flow, obtained in our study, coincide with the data of other authors [39].

In our study, the maximum decrease in the average rate of cerebral blood flow was recorded briefly at the stage of anesthesia, up to 46.6 ± 2.6% relative to the baseline value. And already at the stage of artificial circulation, the average speed was 64.3 - 78.7 ± 9.1% of the initial values, which was associated with the perfusion regimes.

This fact also can not but attract attention, as it is a factor contributing to the development of postoperative cognitive disorders.

Thus, the variety of approaches to assessing the etiopathogenetic role of these or other factors in the development of POCD in coronary artery bypass grafting in conditions of cardiovascular disease testifies to the lack of an optimal solution and confirms the need for further study of brain protection issues, determines the scientific and practical relevance of this study, its goals and objectives. The use of the revealed regularities of the emergence of postoperative cognitive dysfunctions is a powerful reserve for obtaining positive results when performing CABG operations in conditions of artificial circulation.

Conclusions

1. Microembolization of cerebral blood flow was determined in all patients under this study. The vast majority of microemboli was recorded at the onset of the artificial circulation, at the time of application of the clamp on the aorta, as well as in the restoration of effective cardiac activity.

2. The severity of POCD in the early postoperative period depends on the number of microemboli recorded in the middle cerebral artery during surgery. Clinically pronounced impairment of brain function was noted in patients with a microembolia number of more than 800.

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