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Emergency Glomus-Sparing Carotid Endarterectomy According to A.N. Kazantsev

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AIM OF STUDY Analysis of the results of a new method of emergency glomus-sparing carotid endarterectomy (CEE) according to A.N. Kazantsev in the the most acute period of ischemic stroke.

MATERIAL AND METHODS This cohort comparative prospective open-label study included 517 patients operated on for occlusive stenotic lesions of the internal carotid arteries (ICA) in the acute period of ischemic stroke (within 24 hours after the development of ischemic stroke) from January 2017 to April 2020. Depending on the implemented revascularization strategy, all patients were divided into three groups: group 1 — 214 patients (41.4%) — glomus-sparing CEE according to A.N. Kazantsev; 2nd group — 145 (28%) — classical CEE with plasty of the reconstruction zone with a patch; 3rd group — 158 (30.6%) — eversion CEE. The observation period was 35.2±9.6 months.

Glomus-saving CE according to A.N. Kazantsev was carried out as follows. Arteriotomy with transition to the common carotid artery (CCA) was performed along the inner edge of the external carotid artery (ECA) adjacent to the carotid sinus, 2–3 cm above the ostium, depending on the spread of atherosclerotic plaque (ASP), the ICA was cut off at the site formed by the sections of the wall of the ECA and CCA. Then endarterectomy from the ICA using the eversion technique was performed. The next step was open endarterectomy from ECA and CCA. Then the ICA was implanted in the same position on the saved site.

RESULTS In the hospital follow-up period, there were no significant intergroup differences in the number of complications. However, it should be noted that in the CEE group according to A.N. Kazantsev had no adverse cardiovascular events. In the long-term follow-up period, the smallest number of cardiovascular accidents after CEE according to A.N. Kazantsev was detected. However, intergroup differences were found only in the combined endpoint and the incidence of thrombosis, which were the highest in the 2nd and 3rd groups ($p = 0.01$). When analyzing the survival curves, it was revealed that the greatest number of cardiovascular accidents in the group of classical and eversion CEE occurred either during the hospital observation period or during the first months after surgery, and after CEE according to A.N. Kazantsev - in a year or more.

When analyzing the graph of the dynamics of systolic blood pressure (BP), it was revealed that after glomus-sparing CEE according to A.N. Kazantsev, stable numbers were maintained while receiving preoperative antihypertensive therapy and did not rise above 140 mm Hg. In turn, after classical and eversion CEE, critical hypertension persisted in the first three days, which was difficult to treat. In the future, blood pressure figures are unstable and fluctuate in the range from 140 to 160 mm Hg. All cases of myocardial infarction and ischemic stroke were recorded against the background of critical numbers of systolic blood pressure, reaching 180-200 mm Hg.

CONCLUSION The presented glomus-sparing carotid endarterectomy according to A.N. Kazantsev meets the modern standards of carotid surgery, combined with the minimum permissible risks of developing adverse cardiovascular events, both in hospital and in the long-term follow-up. The confident effect of the developed revascularization is based on the precise removal of plaque from the common, external and internal carotid arteries, as well as maintaining the stability of hemodynamic parameters.

Keywords: carotid endarterectomy, classical carotid endarterectomy, eversion carotid endarterectomy, carotid endarterectomy according to A.N. Kazantsev, glomus-sparing carotid endarterectomy, carotid glomus, DeBakey carotid endarterectomy, emergency carotid endarterectomy, acute phase of acute cerebrovascular accident, SYNTAX Score, Prolene

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BP – blood pressure
ASP – atherosclerotic plaque
CCA – common carotid artery
ICA – internal carotid artery
ECA – external carotid artery
MI – myocardial infarction
CABG – coronary artery bypass grafting
CEE – carotid endarterectomy
LV – left ventricle
EF – ejection fraction
FC – functional class
MSCT AG – multispiral computed tomography with angiography
MFA – multifocal atherosclerosis
ACVA — acute cerebrovascular accident
ADCC – acute disturbance of cerebral circulation
TIA – transient ischemic attack
CDS – color duplex scanning
PCI – percutaneous coronary intervention

INTRODUCTION

Carotid endarterectomy (CEE) remains the main operation in the treatment of patients with hemodynamically significant stenosis of the internal carotid arteries (ICA) for a long time [1-3]. With the annual increase in the number of CEE, the requirements for its technical characteristics and the permissible incidence of postoperative complications grew [3]. Thus, the clinic in which CEE is performed, cannot exceed the "stroke + mortality from stroke" index, equal to 3% for patients with transient ischemic attack (TIA) and 5% for patients with acute cerebrovascular accident (ACVA) [3].

Despite the fact that the current recommendations clearly state that CEE can be performed within 2 weeks after the last stroke in case of minor stroke and 6-8 weeks after complete stroke, the debates on the effectiveness and safety of surgical intervention in the most acute period of stroke continue [3-6]. Among the causes of stroke after performing emergency CEE, not only thrombosis, embolism, but also unstable hemodynamics, which can lead to the development of both ischemic and hemorrhagic stroke, are distinguished [5–8]. Analyzing the possible causes of abnormal postoperative hypo- or hypertension, a number of authors have linked and proved its pathogenesis with damage to the carotid glomus. This led to the creation of glomus-saving CEE techniques [9, 10]. Thus, K.A. Antsupov et al. developed a complex S-shaped arteriosection, which makes it possible to routinely cut off the ICA and perform the already known course of the operation (Fig. 1). However, due to the fact that this technique did not provide complete visualization of the lumen of the common carotid artery (CCA) and the external carotid artery (ECA), it did not allow conclusively performing endarterectomy from them [9]. In 2017 R.A. Vinogradov et al. proposed a more advanced eversion CEE technique with performing a non-standard S-shaped incision with complete CCA cutoff (see Fig. 1). This approach made it possible to preserve the carotid glomus with a total eversion endarterectomy from all arteries of the carotid bifurcation [10]. However, the disadvantage of the listed glomus-sparing techniques is a significant complication of the operation in the case of an extended atherosclerotic plaque (ASP) in the ICA, descending to zero. This situation may cause the need to perform ICA autotransplantation according to E.V. Rosseikin [11]. However, the initial technical approach in the form of a specific S-shaped arteriotomy complicates the possibility of transforming the operation and most often ends with ICA prosthetics due to the formation of an unsatisfactory geometry of the reconstruction zone. Thus, there remains a need for the development of a new simplified method of glomus-sparing CEE, which makes it possible to visualize and remove ASB from CCA, ICA, ECA with the possibility of simple transformation into ICA autotransplantation according to E.V. Rosseikin with extended lesion.

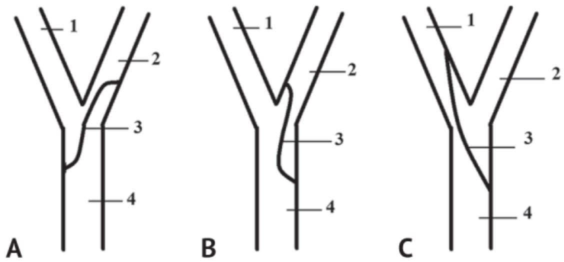

Fig. 1. Glomus-sparing carotid endarterectomy: A - carotid endarterectomy according to R.A. Vinogradov; B - carotid endarterectomy according to K.A. Antsupov; C - carotid endarterectomy according to A.N. Kazantsev; 1 - external carotid artery; 2 - internal carotid artery; 3 - arteriotomy line; 4 - common carotid artery

It should also be noted that there are no works devoted to the implementation of glomus-sparing CEE in the acute period of ADCC [9, 10]. Those individual studies that are devoted to urgent revascularization of the brain demonstrate promising results for emergency classical and eversion CEE [4–9]. However, the level of complications in the hospital postoperative period in this cohort of patients remains suboptimal [7, 8, 12, 13]. This can be largely due to damage to the carotid sinus during the implementation of the traditional CEE technique [9, 10, 14]. This damage causes uncontrolled hypertension, which can provoke both the development of hemorrhagic stroke and other cardiovascular events [9, 10, 14]. Under these conditions, it can be assumed that glomus-sparing CEE in the acute period of stroke is characterized by a lower risk of postoperative complications due to the stability of normal blood pressure (BP) parameters.

The aim of this study was to analyze the results of a new method of emergency glomus-sparing CEE according to A.N. Kazantsev in the most acute period of ADCC.

MATERIAL AND METHODS

This cohort comparative prospective open-label study for the period from January 2017 to April 2020 included 517 patients operated on for occlusive-stenotic lesions of the ICA in the acute period of ischemic stroke (within 24 hours after the development of stroke). Depending on the implemented revascularization strategy, all patients were divided into three groups: group 1 - 214 patients (41.4%) - glomus-sparing CEE according to A.N. Kazantsev (Fig. 1); 2nd group - 145 (28%) - classical CEE with plasty of the reconstruction zone with a xenopericardium patch; 3rd group - 158 (30.6%) - eversion CEE.

Glomus-saving SEE according to A.N. Kazantsev was performed as follows. Arteriotomy was performed along the inner edge of the ECA, adjacent to the carotid sinus, 2–3 cm above the orifice, depending on the spread of ASB, with the transition to CCA (also 2–3 cm below the orifice of the ECA). The ICA was cut off at the site formed by the sections of the wall of the ECA and the CCA. Then endarterectomy from the ICA was performed using the eversion technique. The next step was open endarterectomy from ECA and CCA. Then the ICA was implanted on the saved site in the previous position (Fig. 1C).

The choice of the revascularization strategy was carried out by a multidisciplinary commission (cardiovascular surgeon, neurosurgeon, endovascular surgeon, neurologist, cardiologist). The criteria for inclusion in the study were indications for CEE according to the current recommendations [3]. However, additional conditions for the SEE according to A.N. Kazantsev and eversion KEE steel: 1. closed circle of Willis; 2. lack of indications for the installation of a temporary shunt; 3. pronounced calcification of the ICA. If there were indications for the installation of a temporary shunt, ICA calcification, classical CEE was performed with plastic reconstruction of the reconstruction zone. However, additional conditions for the SEE according to A.N. Kazantsev and eversion KEE steel: 1.closed circle of Willis; 2nd group - 145 (28%) - classical CEE with plasty of the reconstruction zone with a xenopericardium patch; 3rd group - 158 (30.6%) - eversion CEE. A 6-0 Prolene suture was used as a suture material for the vascular anastomosis. Brain protection during CEE was carried out as follows. An invasive measurement of the retrograde pressure in the ICA was performed intraoperatively. After clamping the arteries, the blood pressure increased to 190/100 mm Hg, 5 thousand units of heparin were injected intravenously. The operation was performed under general anesthesia. Patient management in the hospital postoperative period was carried out according to the standard scheme, including obligatory consultations of a cardiologist, otorhinolaryngologist, neurologist, prescription of non-steroidal anti-inflammatory and nootropic drugs. Postoperative blood pressure measurements were performed 3 times a day during hospitalization. To plot the dynamics of blood pressure, the mean values of systolic blood pressure in the entire sample were selected during the day. The patient was discharged on the 7th day after CEE.

To conclude on the presence of multifocal atherosclerosis (MFA) at the preoperative stage, the patient underwent screening color duplex scanning (CDS) of the brachiocephalic bed, arteries of the lower extremities, aortic arch (using a linear transducer with a frequency of 7-7.5 MHz), heart (using a sector sensor with a frequency of 2.5–4 MHz) using the Acuson 128XP (Acuson, USA) and Sonos 2500 (Hewlett-Packard, USA) devices. To more accurately visualize the severity of carotid atherosclerosis and assess the viability of the circle of Willis, multispiral computed tomography with angiography (MSCT AG) of intra- and extracranial arteries was performed. To assess the lesion of the coronary bed, coronary angiography was performed (using an "Innova 2100" angiographic device (General Electric, USA)). The severity of coronary atherosclerosis was calculated using the SYNTAX Score interactive calculator (www.syntaxscore.com). According to the severity of the lesion, on the basis of this calculator, the following gradation is distinguished: low lesion level (≤22 points), intermediate (23–32 points) and severe (≥33 points).

Primary checkpoints mean the development of such unfavorable cardiovascular events as death, myocardial infarction (MI), acute cerebrovascular accident / transient ischemic attack (ACVA / TIA), thrombosis / restenosis in the reconstruction area, combined endpoint (death + ACVA / TIA + IM).

Monitoring the patient's condition is carried out by re-appearance of the patient in the clinic every six months. The observation period was 35.2 ± 9.6 months.

The type of distribution was determined using the Kolmogorov – Smirnov test. Comparison of groups was carried out using the Kruskal – Wallis test. Kaplan-Meier analysis was used to construct survival curves. To compare the curves, a Log-rank (Mantel-Cox) test was performed. Differences were assessed as significant at $p < 0.05$. The research results were processed using the Graph Pad Prism software package (www.graphpad.com).

In terms of clinical and demographic characteristics, the groups were completely comparable. Thus, in the total sample, the overwhelming majority belonged to the male sex, one third suffered from 1–2 functional class (FC) of angina pectoris, one in five had a history of myocardial revascularization. Also, for every fifth patient, a real stroke has become a recurrent one (Table 1).

Table 1

Clinical and demographic characteristics

Index	Group 1 (CEE according to A.N. Kazantsev)		Group 2 (classical CEE)		Group 3 (eversion CEE)		p
	n=214	%	n=145	%	n=158	%	
Age	64,7±4,9		65,5±6,0		63,8±5,3		0,38

Male gender	132	61,68	77	53,10	81	51,26	p2*1=0,3253 p3*1=0,1369 p3*2=0,9999
Angina pectoris 1–2 FC	62	28,97	46	31,72	50	31,64	p2*1=0,9999 p3*1=0,9999 p3*2=0,9999
PICS	25	11,68	18	12,41	23	14,55	p2*1=0,9999 p3*1=0,9999 p3*2=0,9999
DM	14	6,54	7	4,82	7	4,43	p2*1=0,9999 p3*1=0,9999 p3*2=0,9999
COPD	1	0,46	2	1,37	1	0,63	p2*1=0,9999 p3*1=0,9999 p3*2=0,9999
LV EF		61,4±4,1		61,0±5,2		59,8±5,5	0,56
Pulmonary hypertension	1	0,46	0	0	1	0,63	p2*1=0,9999 p3*1=0,9999 p3*2=0,9999
Postinfarction LV aneurysm	4	1,86	1	0,68	2	1,26	p2*1=0,9999 p3*1=0,9999 p3*2=0,9999
PCI in the past	37	17,28	24	16,55	26	16,45	p2*1=0,9999 p3*1=0,9999 p3*2=0,9999
CABG in the past	7	3,27	3	2,06	2	1,26	p2*1=0,9999 p3*1=0,6141 p3*2=0,9999
ADCC / ACVA TIA history	46	21,49	33	22,75	37	23,41	p2*1=0,9999 p3*1=0,9999 p3*2=0,9999

Notes: CABG – coronary artery bypass grafting; CEE – carotid endarterectomy; LV – left ventricle; EF – ejection fraction; ADCC – acute disturbance of cerebral circulation; ACVA – acute cerebrovascular accident; PICS – postinfarction cardiosclerosis; DM – diabetes mellitus; EF – ejection fraction; FC – functional class; COPD – chronic obstructive pulmonary disease; PCI – percutaneous coronary intervention; TIA – transient ischemic attack.

In the analysis of angiographic characteristics, intergroup differences were not revealed. The severity of ICA stenosis varied within 80–95%. In half of the cases, unstable ASP was visualized, less often local ICA thrombosis with retrograde filling. The SYNTAX Score (taking into account the residual SYNTAX Score after a history of myocardial revascularization) corresponded to the low severity of coronary atherosclerosis (Table 2).

Table 2

Angiographic and perioperative characteristics

Index	Group 1 (CEE according to A.N. Kazantsev)		Group 2 (classical CEE)		Group 3 (eversion CEE)		p
	n=214	%	n=145	%	n=158	%	
Angiographic characteristics							
% ICA stenosis		90,3±4,9		91,5±4,2		90,6±4,7	0,35
Unstable ASP	122	57,00	76	52,41	86	54,43	p2*1=0,999 p3*1=0,999 p3*2=0,999
Local ICA thrombosis with retrograde filling	92	42,99	69	47,58	72	45,56	p2*1=0,999 p3*1=0,999 p3*2=0,999
SYNTAX Score, scores	10,5±4,4		12,5±3,7		12,1±4,1		0,72
Perioperative characteristics							
ICA clamping time, min	33,1±3,4		27,2±4,6		28,8±3,7		0,21

Notes: ASP — atherosclerotic plaque; ICA — internal carotid artery; ECA — external carotid artery; CEE — carotid endarterectomy

In the hospital follow-up period, there were no significant intergroup differences in the number of complications. However, it should be noted that in the SEE group according to A.N. Kazantsev had no adverse cardiovascular events.

In the long-term follow-up period, the smallest number of cardiovascular accidents was revealed after CEE according to A.N. Kazantsev. However, intergroup differences were found only in the combined endpoint and the incidence of thrombosis, which were the highest in groups 2 and 3 (Table 3).

Table 3

Hospital and long-term complications

Index	Group 1 (CEE according to A.N. Kazantsev)		Group 2 (classical CEE)		Group 3 (eversion CEE)		p
	n=214	%	n=145	%	n=158	%	
Hospital results							
Death	0	0	1	0,68	0	0	p2*1=0,4348 p3*1=0,9999 p3*2=0,5183
Myocardial infarction	0	0	2	1,37	1	0,63	p2*1=0,2752 p3*1=0,9999 p3*2=0,9999
ACVA / TIA	0	0	1	0,68	3	1,89	p2*1=0,9999 p3*1=0,1172 p3*2=0,6921
ICA thrombosis	0	0	0	0	0	0	p2*1=0,0 p3*1=0,0 p3*2=0,0
Combined end point	0	0	4	2,75	4	2,53	p2*1=0,1139 p3*1=0,1524 p3*2=0,9999
Long-term results							
Death from cardiovascular causes	1	0,46	2	1,37	2	1,26	p2*1=0,9999 p3*1=0,9999 p3*2=0,9999
Myocardial infarction (non-fatal)	1	0,46	4	2,75	5	3,16	p2*1=0,3671 p3*1=0,1866 p3*2=0,9999
ACVA / TIA (non-lethal)	1	0,46	3	2,06	5	3,16	p2*1=0,7662 p3*1=0,1487 p3*2=0,9999
Hemodynamically significant restenosis in the reconstruction area (more than 60%)	5	2,33	6	4,13	5	3,16	p2*1=0,9999 p3*1=0,9999 p3*2=0,9999
Thrombosis / occlusion of the ICA	0	0	0	0	0	0	—
Thrombosis / occlusion of the ECA	0	0	7	4,82	8	5,06	p2*1=0,0003 p3*1=0,9999 p3*2=0,0009
Combined end point	3	1,40	9	6,20	12	7,59	p2*1=0,1019 p3*1=0,0152 p3*2=0,9999

Notes: ICA — internal carotid artery; CEE — carotid endarterectomy; ECA — external carotid artery; ACVA — acute cerebrovascular accident; TIA — transient ischemic attack

When analyzing the survival graphs, significant intergroup differences were also obtained in the frequency of the combined endpoint (p = 0.01). However, analysis of the curves revealed that the greatest number of cardiovascular accidents in the group of classical and eversion CEE occurred either during the hospital observation period or during the first months after the operation. Moreover, all deaths developed over a period exceeding 7 months (Fig. 2–5).

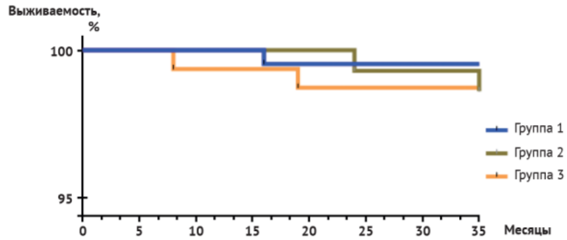

Fig. 2. Death-free survival, p=0.61

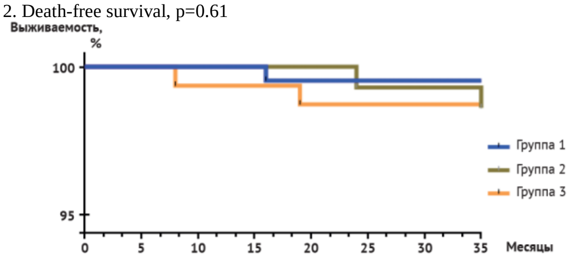

Fig. 3. Myocardial infarction free survival, p=0.11

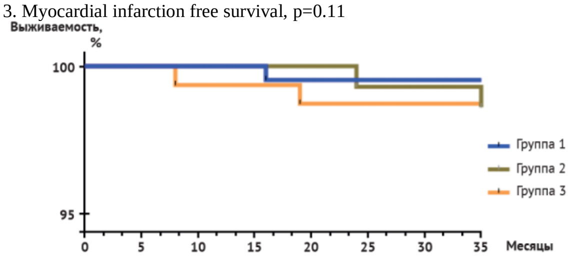

Fig. 4. Acute cerebrovascular event/transient ischemic attack free survival, p=0.12

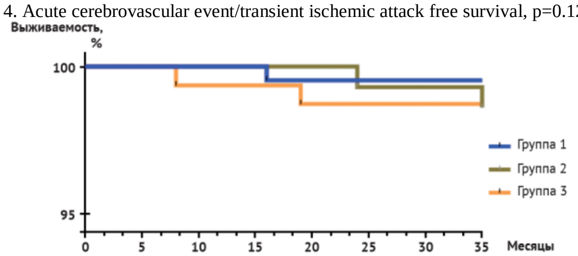

Fig. 5. Combined endpoint free survival, p=0.01

When analyzing the graph of the dynamics of systolic blood pressure, it was revealed that after glomus-sparing CEE according to A.N. Kazantsev, stable numbers are maintained while receiving preoperative antihypertensive therapy and do not rise above 140 mm Hg. In turn, after classical and eversion CEE, in the first 3 days, critical hypertension persists, which is difficult to treat. In the future, blood pressure figures are unstable and fluctuate in the range from 140 to 160 mm Hg. (Fig. 6).

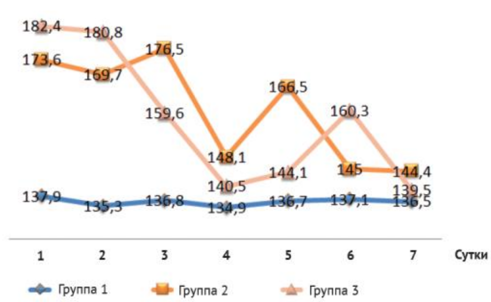

Fig. 6. Average indicators of systolic blood pressure in the postoperative period

The greatest number of unfavorable cardiovascular accidents in the groups of classical and eversion CEE occurred in the first 3 days after surgery. Against the background of standard management of patients in all groups in the postoperative period, comparable severity of comorbid pathology and MFA, unstable hemodynamics with a tendency towards uncontrolled hypertension became the most probable cause of adverse events. All cases of myocardial infarction and stroke were recorded against the background of critical numbers of systolic blood pressure, reaching 180–200 mm Hg.

DISCUSSION

As a rule, the benefit of cerebral revascularization after suffering from stroke depends on the balance between the long-term risk of vascular complications in conservative treatment and the perioperative risk of adverse cardiovascular events [12, 13, 15, 16]. A meta-analysis of two studies showed that the benefits of CEE are most pronounced for patients operated on within 2 weeks after stroke [17, 18]. Urgent CEE in the acute period of the disease is combined with a high operational risk [7, 8, 12, 17, 18]. However, according to a number of authors, for stable patients with minor stroke or TIA, surgery can be effective in the acute and early stages of the acute period of stroke, therefore, early CEE is considered justified [7, 8, 12, 17, 18]. In this context, it should be noted that there have been no previous studies devoted to emergency revascularization of the brain in the acute period of stroke with the use of glomus-sparing CEE. The relationship between damage to the carotid glomus and the development of ischemic complications in the early postoperative period of emergency CEE has never been demonstrated. Thus, the uniqueness of this work becomes beyond doubt.

The key protective aspect of CEE according to A.N. Kazantsev consists in preserving the integrity of the carotid glomus and baroreceptors. A number of authors have repeatedly confirmed the stability of postoperative blood pressure indicators when performing glomus-sparing interventions [9, 10, 14]. When performing standard eversion CEE, a significant difference was obtained with a tendency to difficult-to-control hypertension against the background of damage or excision of the carotid glomus [9, 10, 14]. This observation was confirmed by the results of our work (see Fig. 6). As a rule, patients heading for cerebral revascularization suffer from MFA with damage to the coronary and peripheral arteries [2, 5, 15, 19, 20]. Many of them, as a rule, have undergone some kind of reconstructive surgery on one of the arterial basins; some have yet to undergo revascularization [2, 5, 15, 19, 20]. Unstable hemodynamics in this cohort of patients increases the risks of developing stroke, TIA, MI, which is also associated with the likelihood of fatal complications [7, 8, 12, 13, 19]. Against this background, an additional risk of traditional emergency CEE is a fresh site of ischemic stroke, which, with unstable hemodynamics, can transform into a hemorrhagic one with subsequent undesirable outcome [7, 8]. Against this background, glomus-saving techniques are more preferable over the standard variants of eversion and classical CEE [9, 10, 14].

It should also be noted that high-quality endarterectomy not only from CCA and ICA, but also from ECA is important in terms of preserving additional collaterals that play a role in adequate cerebral hemodynamics [21–24]. From this point of view, our method is more preferable than the classical and eversional CEE, where the removal of ABP from the NSA occurs practically blindly [3, 20, 21, 23, 24]. The results of our study showed that in the long-term follow-up period, when performing CEE according to A.N. Kazantsev, no cases of ECA occlusion / thrombosis were observed, which confirms the protective role of the technique in maintaining adequate cerebral circulation.

CONCLUSION

Thus, the presented glomus-sparing carotid endarterectomy according to A.N. Kazantsev meets modern standards of carotid surgery, combined with the minimum permissible risks of developing adverse cardiovascular events, both in hospital and in the long-term follow-up periods. The confident effect of the developed revascularization is based on the precise removal of atherosclerotic plaques from the common, external and internal carotid arteries, as well as maintaining the stability of hemodynamic parameters. Thus, the presented type of glomus-sparing carotid endarterectomy according to A.N. Kazantsev may become one of the operations of choice in the treatment of patients with occlusive-stenotic lesions of the carotid arteries, especially in the acute period of acute cerebrovascular accident.

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