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Emergency Extra-Intracranial Microanastomosis After Carotid Endarterectomy Complicated With Thrombosis of the Internal Carotid Artery

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ABSTRACT We report a case of emergency extra- intracranial microanastomosis in a patient with acute thrombosis of the internal carotid artery, formed on the first day after classical carotid endarterectomy using a temporary by-pass under conditions of contralateral occlusion. The causes of the complication are analyzed. A set of instrumental examinations was demonstrated, including multispiral computed tomography with angiography of the brain and extracranial arteries, as well as multispiral computed tomography with the study of parameters of cerebral perfusion after acetazolamide. The main stages of surgical correction, the dynamics of clinical indicators are presented. The conclusion was made about the effectiveness and safety of the chosen revascularization strategy.

Keywords: carotid endarterectomy, thrombosis of the internal carotid artery, temporary bypass, dissection of the internal carotid artery, emergency extra-intracranial microanastomosis, acute posterior ischemic optic neuropathy, endovascular aspiration of thrombus, thrombextraction, thrombolysis, EICMA

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BP - blood pressure
BCA - brachiocephalic arteries
ICA - internal carotid artery
CW - circle of Willis
ISh - intraluminal shunt
CEE - carotid endaterectomy
MSCT AG - multispiral computed tomography with angiography
NLF - nasolabial fold
ACVA - acute cerebrovascular accident
STA - superficial temporal artery
RCA - right coronary artery
ACA - anterior cerebral artery
MCA - middle cerebral artery
TLT - thrombolytic therapy
DM - dura mater
FC - functional class
CDS - color duplex scanning
PCI - percutaneous coronary intervention
CN - cranial nerves
HR - heart rate
EIKMA - extra-intracranial microanastomosis
CBF — Cerebral Blood Flow
CBV — Cerebral Blood Volume
ATT — Average Transit Time

INTRODUCTION

Carotid endarterectomy (CEE) has become a routine vascular surgery [1–5]. The main nuances of the intervention are well known and widely demonstrated in the modern literature [6–10]. Complications of CEE are rare [1, 3, 5, 9, 11]. Their main mass is represented by such cardiovascular events as acute cerebrovascular accident (ACVA) and myocardial infarction. [2, 3, 6, 8, 11]. So, the clinic in which CEE is performed cannot exceed the "stroke + mortality from stroke" indicator, equal to 3% for patients with transient ischemic attack and 5% for patients with stroke [1].

Among the more rare complications of CEE is thrombosis of the internal carotid artery (ICA) [1, 3, 5, 9, 11]. The main causes of this condition are intimal detachment distal to the reconstruction zone or dissection of an artery as a result of mechanical trauma to the vessel by a temporary intraluminal shunt (TS). [1, 3, 5, 9, 11]. The main indications for the installation of the latter are: low retrograde pressure (less than 60% of the systemic pressure), contralateral occlusion of the ICA, an open circle of Willis (WC) [1, 4, 5, 11]. However, the frequency of using IS does not exceed 5% of the total volume of all CEE. [1, 3, 5, 10]. In this regard, insufficient experience in correct calibration of the balloon, which limits the displacement of the IS within the vessel, can lead to rupture of the artery wall or dissection with the formation of further consequences (thrombosis and / or bleeding). [1, 2, 5, 7]. But if the variant of a defect in the integrity of the vessel is still easy to establish intraoperatively on the basis of signs of developing bleeding after removal of the IS, thrombosis of the ICA is most often differentiated in the early postoperative period after the patient comes out of anesthesia on the basis of signs of developing stroke and using instrumental approaches that confirm this complication. [3, 5, 6, 9, 11].

Emergency revascularization methods under these conditions are similar to the situation of primary ICA thrombosis and include open thrombectomy, endovascular thromboaspiration, thrombextraction, thrombolytic therapy (TLT) [12–16]. However, in addition to the fact that there are no randomized studies examining the use of each of these methods in the correction of ICA thrombosis after CEE, there are no modern recommendations establishing a strict framework for the implementation of the mechanisms of emergency revascularization of this postoperative state [1, 12, 15–17]. Thus, the most problematic thrombosis, differentiated after such a period of time, which forms the conditions for the impossibility of the implementation of the above methods, makes the problem difficult for modern vascular surgery [12–17]. The lack of solutions to the problem, information in the world literature and various recommendations creates the need for emergency improvisational solutions aimed at preventing and regressing the clinical condition, which may be more promising than conservative treatment tactics.

Within the framework of this work, a case of performing an emergency extra-intracranial microanastomosis (EICMA) in a patient with acute ICA thrombosis, acute posterior ischemic optic neuropathy, formed on the first day after classical CEE using IS.

Clinical example

A 55-year-old man, 11/13/2018 underwent ischemic stroke in the area of the right middle cerebral artery (MCA). At the same time, ICA occlusion on the left and hemodynamically insignificant stenosis on the right were differentiated. In June 2019 marked the emergence of a clinic for angina pectoris of the II functional class (FC) was detected. According to coronary angiography, 90% of stenosis of the right coronary artery (RCA) was verified, for which percutaneous coronary intervention (PCI) was performed. Upon further examination of the patient, according to the results of color duplex scanning (CDS) and multislice computed tomography with angiography (MSCT AG) of the brachiocephalic arteries (BCA), 76% stenosis of the ICA on the right was visualized, occlusion was contralateral (Fig. 1). The patient was diagnosed with atherosclerosis. ICA stenosis on the right – 76%. Left ICA occlusion. The residual period of stroke by ischemic type in the

basin of the right MCA 11/13/2018 Left-sided spastic hemiparesis up to 2 points in the hand and 4 points in the leg. Central paresis of the 7th pair of cranial nerves on the left. Coronary heart disease. PCI with RCA stenting 06/26/2019 Chronic heart failure I, FC II. Essential hypertension III, risk 4. Concomitant diseases: penetrating corneal injury of the left eye, 2003 Corneal opacity on the left.

Objective status: general condition is satisfactory. Skin: physiological color, clean. Respiratory rate: 16 / min. Breathing is vesicular. Wheezing: no. Heart sounds: clear, rhythmic. Heart rate (HR): 66 beats / min. Blood pressure (BP): 120/70 mm Hg. Abdomen: painless. Diuresis: independent. Local status: no noise is heard during auscultation of the carotid arteries. The pupil on the left is closed with a thorn, vision is reduced on the left.

Neurological status: consciousness 15 points on the Glasgow coma scale. Contact is available. Orientation: fully oriented in place, himrself, time. Pupil change on the left. The right eye slit is the norm. The left eye slit is the norm. Nystagmus is the norm. Diplopia: no. Language: straight. Swallowing disorders: no. Tendon reflexes: D less than S in the upper limb, D less than S in the lower limb. Limb tone: high in the left limbs. Pathological signs: Babinsky symptom on the left. Strength in the upper limbs S 2 points. Strength in the upper limbs D 5 points. Strength in the lower limbs S 4 points. Strength in the lower extremities D 5 points. Sensitive disorders: no. In the Romberg position with wiggle. Meningeal signs: negative. Gait is hemiparetic. Intellect is reduced. Emotional sphere: excited. Increased tone in the left extremities according to the pyramidal type. Pose Wernicke-Mann when walking. The hand can compress, cannot unclench, the force is reduced proximally to 3b in the left upper limb and to 2b in the hand, in the lower limb to the left to 4b. Slight smoothness of the left nasolabial fold (NLF).

The patient underwent CEE on the right using the IS. Intraoperatively – no peculiarities. Intervention time was 50 minutes. The early postoperative period was uneventful. The next morning after the operation (≈ 20 hours after the operation), the patient noted a complete loss of vision. Multispiral computed tomography with angiography (MSCT AG) of the brain and BCA was conducted: CT picture of cerebral microangiopathy. Post-stroke zone of cystic-gliosis transformation of the right fronto-parietal region. Communicating expansion of cerebrospinal fluid spaces according to the substitutive type. Occlusion of the right and left ICA. Hypoplasia of A1 segment of the right anterior cerebral artery (ACA). The closed circle of Willis (fig. 1).

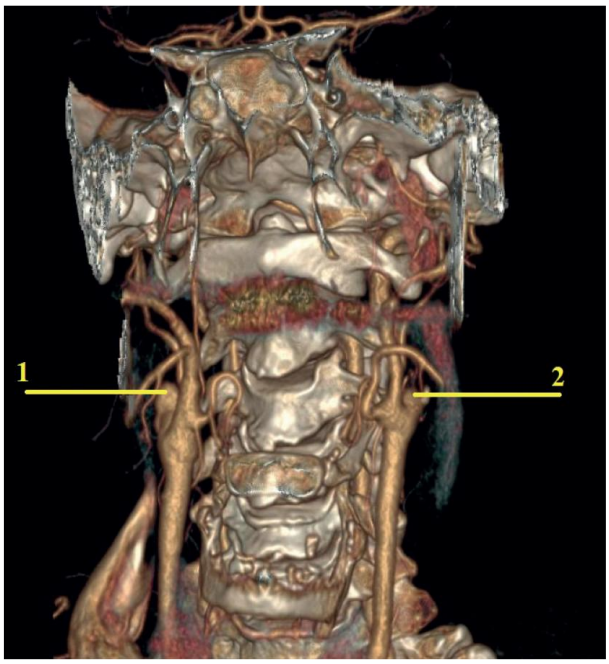

Fig. 1. Multispiral computed tomography with angiography of the brachiocephalic arteries after the development of thrombosis of the internal carotid artery. 1 – thrombosis of the internal carotid artery on the right; 2 – occlusion of the internal carotid artery on the left

The probable cause of thrombosis was ICA dissection with intimal detachment during the insertion of the ICA.

When examined by a neurologist, no dynamics in the neurological status was noted. According to the results of consultation with an ophthalmologist, acute posterior ischemic optic neuropathy of the right eye with complete loss of vision was discovered.

Due to the presence of a time interval from the formation of thrombosis after CEE to the onset of the above symptoms, exceeding 20 hours, open thrombectomy, endovascular thrombaspiration, thrombextraction and TLT are regarded as unpromising. A multidisciplinary council consisting of a vascular surgeon, neurosurgeon, endovascular surgeon, cardiologist, neurologist, ophthalmologist, due to complete loss of vision and the absence of signs of stroke, decided to conduct an additional examination (MSCT AG with the study of parameters of cerebral perfusion after taking acetazolamide) to consider the possibility of conducting EICMA. According to the results of the study: signs of fresh (acute and subacute) ischemic infarction / edema of the brain substance are not determined. The zone of hypoperfusion in the right fronto-parietal region corresponds to the previous areas of postischemic encephalomalacia (cystic-glial changes). Insignificant changes in perfusion indicators after taking acetazolamide were revealed (packing and measurement zones are not identical): average transit time (MTT) up to 115 (previously 87); cerebral blood flow (CBF) up to 81 (previously 100); volumetric cerebral blood flow (CBF) up to 93 (previously 98) (Fig. 2).

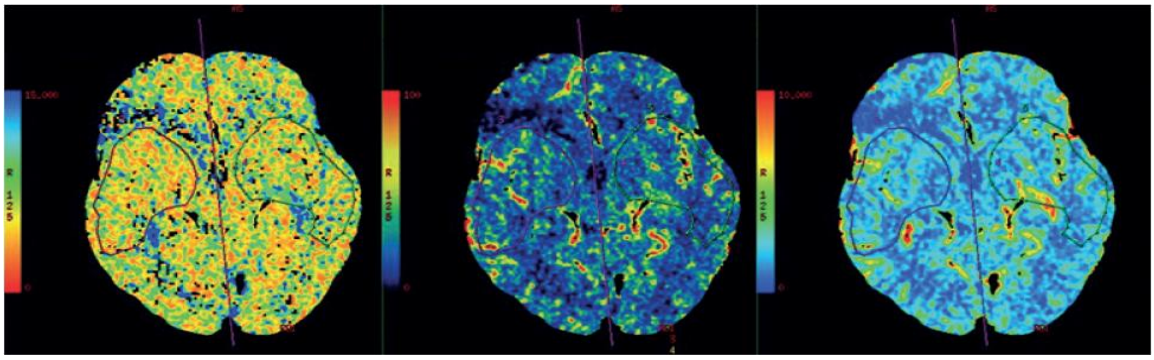

Fig. 2. Multispiral computed tomography with angiography with the study of indicators of cerebral perfusion after taking acetazolamide. Areas of insignificant changes in perfusion parameters are highlighted

Taking into account the results of the study, it was decided (2 hours after the onset of symptoms of vision loss) to conduct an emergency EICMA. The course of the operation: under endotracheal anesthesia, in the position of the patient lying on his back with the head turning to the right, after processing and isolation of the operating field, a horseshoe-shaped skin incision was made in the frontotemporal region on the left. The skin flap was folded back to the ear. Dissection of the superficial temporal artery (STA) from the subcutaneous fat was performed for 10 cm. The temporalis muscle was transsected longitudinally, pulled apart and taken on the holders. The bone was skeletonized. Bone flap measuring 5x2 cm was sawed out. The dura mater (DM) was dissected in an arcuate manner. The arachnoid membrane was transsected, the cortical branch of the left MBA was prepared in the Sylvian fissure (M4 segment, about 2 mm in diameter). The STA blood flow was blocked with a temporary clip, the lumen of the artery is flushed with a heparin solution. With the help of two temporary microclips, blood flow was blocked in 1 cm segment M4 of the left MCA. A hole was formed in the wall of the artery through which the lumen of the artery is washed with a heparin solution. Using a 10-0 polyester suture, interrupted sutures, a microvascular end-to-side anastomosis was applied between the donor artery (STA) and the recipient artery (MCA). The blood flow through the arteries has started. The pulsation of the anastomotic zone was noted. Leakage of blood through the anastomotic sutures was stopped with the help of hemostatic “Surgicel”. The temporary clamping was 32 min. The dura mater was sutured and sealed using a layer of hemostatic sponge "Tachocomb». The bone flap was placed in its position, leaving a defect in the flap for the donor artery, fixed by plates and screws. Layer-by-layer wound suturing with a thread "Polysorb 2-0" was made (Fig. 3).

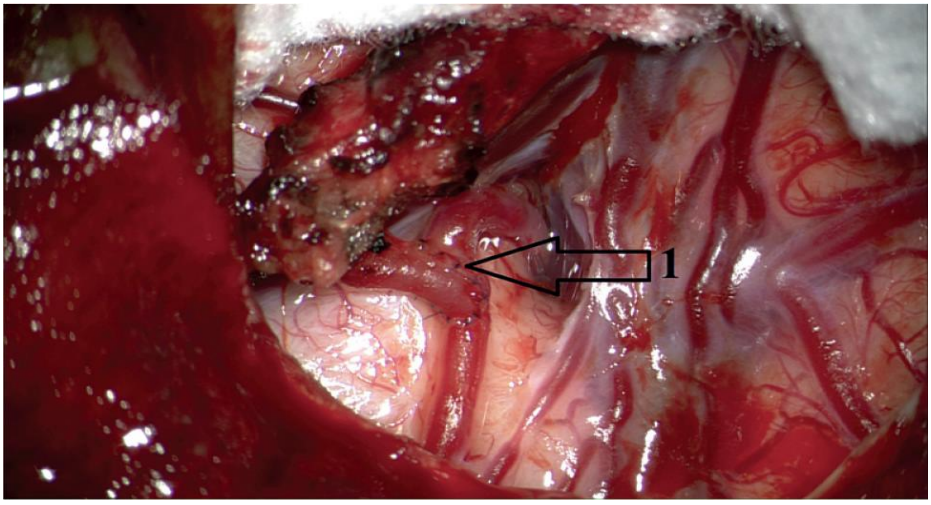

Fig. 3. Extra-intracranial anastomosis: the area of anastomosis between the superficial temporal and middle cerebral arteries. 1 — anastomosis between the superficial temporal and middle cerebral arteries

In the postoperative period, anticoagulant therapy was carried out (intravenously with an infusomat, dose change under the control of activated partial thromboplastin time – target values 2–2.5 times the initial 33.6), double antiplatelet therapy (acetylsalicylic acid 100 mg at lunchtime; clopidogrel 75 mg at lunchtime), infusion therapy (10.0 ml of pentoxifylline + 200.0 ml of saline intravenous drip), vitamin therapy (1.0 ml of pyridoxine intramuscularly; 1.0 ml of thiamine intramuscularly), nootropic therapy (citicoline 1000 mg intravenous drip).

On the 10th day after performing EICMA the patient began to distinguish the outlines of large objects with the right eye. Control MSCT with brain angiography was performed: condition after creating an extra-intracranial anastomosis between the STA and MCA. It was contrasted along the entire length, the patency was preserved (Fig. 4).

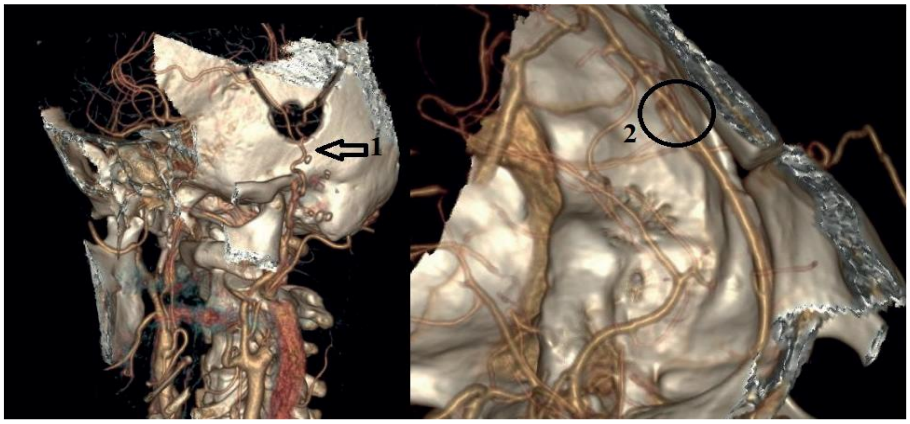

Fig. 4. Multispiral computed tomography with brain angiography in the postoperative period. 1 – area of anastomosis between the superficial temporal and middle cerebral arteries; 2 – intracranial anastomosis area

On the 12th day after the operation, the patient was discharged in a satisfactory condition with continued administration of anticoagulant (rivaroxaban 10 mg 2 times a day), antiplatelet (clopidogrel 75 mg at lunch, cilostazol 100 mg 2 times a day), nootropic therapy (citicoline 1 sachet 2 once a day orally). In this situation, the appointment of dual antiplatelet therapy was made due to the presence of coronary heart disease and PCI in the anamnesis. Anticoagulant therapy was required to prevent thrombotic complications in the reconstruction area.

The patient came to the clinic for a control examination 30 days after discharge. Complete restoration of vision of the right eye to the initial level (up to CEE) was noted. According to CDS EIKMA: the patency of the shunt was satisfactory.

DISCUSSION

The convincing clinical effect of EICMA does not require any discussion [16–20]. The performance of this operation in modern neurovascular surgery has found its recognition and application in patients with occlusive lesions of the ICA [1]. However, EICMA alone cannot be performed simply based on the presence of ICA occlusion / thrombosis (level of evidence A). Therefore, referring to current recommendations, we tried to prove hemodynamic insufficiency of cerebral circulation (level of evidence B) by performing MSCT with the study of parameters of cerebral perfusion (level of evidence C) on an emergency basis [1]. It should be noted that these postulates were created for planned patients and had a rather low level of evidence. Nevertheless, in the absence of international experience in the treatment of such a contingent of patients, this diagnostic approach in the framework of this clinical case was the only justified.

There are several studies investigating the efficacy of emergency EICMA in patients with symptomatic ICA occlusion. In the work of C.J. Rice et al. of 29 patients who underwent revascularization in the period up to 7 days after ischemic stroke, 31% (n = 9) received repeated perioperative stroke relative to 11.5% (n = 6) of the group of patients who underwent EICMA within a time interval exceeding 7 days (p=0,04). The authors concluded that emergency EICMA was unsafe and ineffective for patients with acute symptomatic ICA occlusion [16]. Another study led by T. Horiuchi obtained similar results with a positive outcome of revascularization in 60% of patients. The authors came to similar conclusions [17]. Despite the importance of the data provided, it should be noted that, within the framework of these studies, emergency EICMA was performed in patients in the most acute and acute periods of stroke, which already distinguishes them from our clinical case, where ischemic stroke was not recorded. Additionally, it should be noted that in our situation, the pathology developed as a complication of CEE. This condition qualitatively differs the presented example of solving the problem with world analogues.

When considering possible alternatives for correcting the condition, one should remember such an option for revascularization as TLT. However, the effectiveness of the method in patients with ICA thrombosis reaches only 35%, and with extended lesions it is reduced to zero. [21–23]. In the situation of a change in treatment tactics after an unsuccessful attempt at recanalization, limitations in the form of total hypocoagulation come to the fore. It is also worth noting that the effectiveness of the method has been proven only in the interval up to 6 hours after thrombosis with selective administration of the drug [21–23]. Within the framework of our clinical case, the time interval exceeded 20 hours, which became an additional argument in refusing this method.

It is worth mentioning other methods of possible revascularization of the brain in conditions of ICA thrombosis, such as endovascular thromboaspiration and thromboextraction using stents-retrievers. [13–15]. The essence of the first method consists in the use of a flexible wide-lumen catheter, which allows aspiration of a thrombus. And only in case of failure, the transition to thrombextraction is made [13–15]. It should be noted that simultaneous techniques of using both interventional instruments ("Solumbra") are gaining popularity, which not only allow achieving the set goal, but also reduce the risks of thrombus fragmentation. However, in spite of all the advantages of the presented strategies of brain reperfusion, their effect is confirmed only in the time interval up to 8 hours from the moment of thrombosis development [13–15]. Thus, endovascular correction of the state within the framework of the demonstrated clinical example turned out to be impossible.

CONCLUSION

The presented clinical case is distinguished by the extraordinary resolution of an acute condition in the form of thrombosis of the internal carotid artery, caused by intimal detachment after the installation of a temporary shunt during carotid endaterectomy. The implemented revascularization strategy has shown its effectiveness and safety in preventing the progression of further neurological deficits and irreversible vision loss in a patient with occlusion of the internal carotid artery contralaterally and diurnal ipsilateral thrombosis.

Emergency extra-intracranial microanastomosis may be the operation of choice in this difficult-to-manage cohort of patients with a confident optimal treatment outcome.

REFERENCES

1. Natsional'nye rekomendatsii po vedeniyu patsientov s zabolevaniyami brakhiotsefal'nykh arteriy. *Angiologiya i sosudistaya khirurgiya*. Moscow; 2013. (In Russ.)
2. Kazantsev AN, Sultanov RV, Burkov NN, Lider RYu, Yakhnis EYa, Bukhtoyarova VI, et al. Long-term results of surgical and conservative treatment of patients with occlusive-stenotic lesions of carotid arteries. *Pirogov Russian Journal of Surgery*. 2020;(1):67–73. (In Russ.) https://doi.org/10.17116/hirurgia202001167
3. Chechulov PV, Kostenykov AN, Belyaev DA, Stepanischev IV, Parfenov VE. Extracranial-Intracranial Bypass in Patients With Acute Symptomatic Occlusion of Internal Carotid Artery Doesn't Increase Hospital Morbidity or Mortality. Prospective Study. *Russian Neurosurgical Journal Named After Professor Polenov*. 2019;11(3):44–50. (In Russ.)
4. Vachev AN, Prozhoga MG, Dmitriev OV. Cerebral Protection from Ischaemia During Carotid Endarterectomy. *Angiology and Vascular Surgery*. 2020;26(1):96–101. (In Russ.) http://doi.org/10.33529/ANGI02020109
5. Lukshin VA, Usachev DYu, Shulgina AA, Shevchenko EV. Local cerebral hemodynamics following STA-MCA bypass in patients with symptomatic carotid occlusions. *Burdenko's Journal of Neurosurgery*. 2019;83(3):29–41. (In Russ.) https://doi.org/10.17116/neiro20198303129
6. Lukianchikov VA, Udodov EV, Dalibaldyan VA, Krilov VV. Surgical Treatment of the Patients With Brachiocephalic Arteries Pathology in Acute Stroke. *Russian Neurosurgical Journal Named After Professor Polenov*. 2017; 9(2):22–29. (In Russ.)
7. Gavrilenko AV, Kuklin AV, Al-Yousef NN, Wang Xiaochen, Bulatova LR, Li Rui. Meta-Analysis of the Results of Eversion Carotid Endarterectomy and Endarterectomy With Patch Plasty. *Angiology and Vascular Surgery*. 2020;26(1):176–183. (In Russ.) http://doi.org/10.33529/ANGIO2020121
8. Zakirzhanov NR, Komarov RN, Khalilov IG. Carotid endarterectomy in acute period of ischemic stroke. *Pirogov Russian Journal of Surgery*. 2020;(2):74–78. (In Russ.) https://doi.org/10.17116/hirurgia202002174
9. Ovsyannikov KS, Dubovoy AV, Galaktionov DM. Combined (direct and indirect) revascularization in adult patients with moyamoya disease. *Russian Journal of Neurosurgery*. 2018;20(3):57–66. (In Russ.) http://doi.org/10.17650/1683-3295-2018-20-3-57-66
10. Pokrovskiy AV, Golovyuk AL. Sostoyanie sosudistoy khirurgii v Rossiyskoy Federatsii v 2018 godu. *Angiology and Vascular Surgery*. 2019;25 Suppl 2:1–40. (In Russ.)
11. Kudryashova TA, Tokarev AS, Lukyanchikov VA, Polunina NA, Senko IV, Dalibaldyan VA, et al. Long-term results of surgical brain revascularization in patients with chronic cerebral insufficiency. *Russian Journal of Neurosurgery*. 2019;21(4):67–73. (In Russ.) https://doi.org/10.17650/1683-3295-2019-21-4-67-73
12. Kazantsev AN, Burkov NN, Tarasov RS, Anufriyev AI, Shabayev AR, Ruban EV, et al. Carotid endarterectomy in acute ischemic stroke. *Circulation Pathology and Cardiac Surgery*. 2018;22(1):66–72. (In Russ.). http://dx.doi.org/10.21688/1681-3472-2018-1-66-72
13. Lukyanchikov VA, Udodov EV, Polunina NA, Tokarev AS, Dalibaldyan VA, Nakhabin OY, et al. Possibilities of Surgical Correction of Internal Carotid Artery Thrombosis in Patients With Acute Ischemic Stroke. *Russian Sklifosovsky Journal Emergency Medical Care*. 2017;6(2):110–117. (In Russ.) https://doi.org/10.23934/2223-9022-2017-6-2-110-117
14. Nekrasov AS, Beliy AI, Volkolup OS, Tupikin PA. Successful Aspiration of Thrombotic Masses Out of the Left Internal Carotid Artery Lumen Using a Proximal Embolic Protection Device in the Conditions of Thrombolytic Therapy Performance. *Innovative Medicine of Kuban*. 2017;8(4):37–41. (In Russ.)
15. Cherednychenko YuV, Miroshnichenko AYu, Zorin MO. Endovascular Thrombextraction Combined With Selective Transarterial Thrombolysis in Acute Phase of Thrombosis of Vertebral and Basilar Arteries. *Endovaskuljarna nejrorentgenohirurgija*. 2016;2(16):77–84. (In Russ.)
16. Rice CJ, Cho SM, Taqui A, Moore NZ, Witek AM, Bain MD, et al. Early versus Delayed Extracranial-Intracranial Bypass Surgery in Symptomatic Atherosclerotic Occlusion. *Neurosurgery*. 2019;85(5):656–663. http://doi.org/10.1093/neuros/nyy411
17. Horiuchi T, Nitta J, Ishizaka S, Kanaya K, Yanagawa T, Hongo K, et al. Emergency EC-IC bypass for symptomatic atherosclerotic ischemic stroke. *Neurosurg Rev*. 2013;36(4):559–564; discussion 564-5. http://doi.org/10.1007/s10143-013-0487-5
18. Lukshin VA, Usachev DYu, Shulgina AA, Shevchenko EV. Local cerebral hemodynamics following STA-MCA bypass in patients with symptomatic carotid occlusions. *Burdenko's Journal of Neurosurgery*. 2019;83(3):29–41. (In Russ.) https://doi.org/10.17116/neiro20198303129
19. Dubovoy AV, Gulay YS, Ovsyannikov KS, Starikova OV. Conceptual and Technical Challenges in Intracranial-Intracranial Bypass Revascularization. *Russian Neurosurgical Journal Named After Professor Polenov*. 2018;10(2):25–35. (In Russ.)
20. Shabaev AR, Kazantsev AN, Tarasov RS, Ruban EV, Lider RYu, Yakhnis EYa, et al. Surgical Treatment of a Patient With Saccular Arterial Aneurysm of the Cavernous-Ophthalmic Segment. *Angiology and Vascular Surgery*. 2019;25(4):131–138. (In Russ.) http://doi.org/10.33529/ANGIO2019412
21. Cukurova LA, Timchenko LV, Golovko EN, Usachev AA, Fedorchenko AP, Porkhanov VA. The successful urgent operations on brachiocephalic arteries at two patients in acute period of ischemic stroke. *Russian Journal of Neurosurgery*. 2013;(4):70–72. (In Russ.)
22. Bazan HA, Zea N, Jennings B, Smith TA, Vidal G, Sternbergh WC. Urgent carotid intervention is safe after thrombolysis for minor to moderate acute ischemic stroke. *J Vasc Surg*. 2015;62(6):1529–1538. http://doi.org/10.1016/j.jvs.2015.07.082
23. Gunka I, Krajickova D, Lesko M, Renc O, Raupach J, Jiska S, et al. Safety of early carotid endarterectomy after intravenous thrombolysis in acute ischemic stroke. *Ann Vasc Surg*. 2017; pii: S0890-5096(16)31148-7. http://doi.org/10.1016/j.avsg.2017.03.195

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