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SURGERY OF COMPLEX ANEURYSM OF THE INTERNAL CAROTID ARTERY REGARDING COLLATERAL BLOOD FLOW. REVIEW OF THE LITERATURE

Abstract. This article provides an overview of contemporary literature on the results of microsurgery, endovascular and combined treatment of complex arterial aneurysms of the internal carotid artery, taking into account the collateral cerebral circulation. Analysis of the literature shows high rates of postoperative morbidity and mortality during endovascular and open surgical techniques separately. Each case of complex aneurysm requires an individual approach, a combination of endovascular and open surgical techniques, combined with the creation of additional sources of revascularization.
Keywords: complex aneurysm, internal carotid artery, extra-intracranial bypass, balloon occlusion test, endovascular embolization.

Arterial cerebral aneurysm is a local expansion of the blood vessel wall. The frequency of cerebral aneurysms is approximately 5% of the population [1]. Among them complex cerebral aneurysms are large and giant aneurysms with wide-neck aneurysm, with atherosclerotic changes of vessel and neck of the aneurysm, with the discharge of functionally significant blood vessel from the aneurysm, the presence of thrombotic masses in the aneurysm cavity, as well as deep localization on the base of the skull, with the impossibility of single-step, direct surgical or endovascular occlusion of aneurysms [2-8]. Occurrence of complex aneurysms of the total number of arterial cerebral aneurysms is from 3 to 11% [9]. Complex aneurysm of internal carotid artery (ICA) is from 60% to 80% of all complex celebral aneurysms [10]. The peak of occurrence of complex aneurysms is between 40 and 60 years with female predominance.

The clinical course of complex aneurysms is presented by intracranial hemorrhage, cerebral compression, ischemic complications related to thrombosis and occlusion of the carrying vessel and perforating vein.

The frequency of aneurysmal subarachnoid hemorrhage aneurysm at aneurism rupture is from 5.3% to 13.3% per year [11]. The frequency of re-rupture during the next 14 days is 18% [12]. The mortality rate during the second rupture is 60% within two years, 80% of patients die or become disabled over the next five years. In 65-85% cases, there might be a cerebral compression, ischemic complications associated with episodes of thromboembolism, thrombosis and occlusion of the carrying vessel and perforating vein are found in 5% [13].

Surgical treatment of complex aneurysms aims to prevent aneurysm rupture, reducing the mass effect caused by the aneurysm, the prevention of thromboembolic and ischemic complications [14].

Nowadays the surgical treatment of complex aneurysms is presented by microsurgical techniques, endovascular operations and combined methods.

Microsurgical treatments are:

– ligation of the ICA;

– ligation of the ICA with the imposition of extra-intracranial anastomosis;
– direct clipping of the aneurysm;
– trapping of the aneurysm.

Roentgen-endovascular surgical treatment of complex aneurysms includes [2, 3, 5, 14]:
– roentgen-endovascular embolization of aneurysm using micro spiral;
– roentgen-endovascular embolization of aneurysm using micro spiral with stent deployment, balloon-assisted coiling, etc.

Combined methods of surgical treatment are:
– roentgen-endovascular embolization of aneurysm with an extra-intracranial anastomosis.
– occlusion of the ICA with the extra-intracranial anastomosis.

Surgical treatments. With the introduction of the principles of microsurgery in neurosurgery, open surgery of cerebral aneurysms has evolved significantly [15-17]. Direct clipping of aneurysm with aneurysmal sac resection true in cases of giant aneurysmm, causing mass effect and neurological symptoms [18].

Taking into account the development and improvement of endovascular neurosurgery, microsurgical treatments of complex aneurysms are becoming less topical. The main advantage of endovascular surgery is a minimally invasive treatment, the earlier periods of postoperative rehabilitation. However, according to some data, the results of endovascular surgery indicate higher rates of recanalization of the aneurysm, repeated subarachnoid hemorrhage (SAH) and mortality [19].

Table 1 shows the results of microsurgical treatment of ICA complex aneurysms.

Table 1 – Results of microsurgical treatment of complex aneurysms

Author	Method	Number of cases	Compli-cations, %	Mortality, %
Bhawani Shankar Sharma et al [9]	Direct clipping of aneurysm	107	32	9
Dolencet al [20]	Direct clipping of aneurysm, trapping	107	6	3
Giampaoloetal [21]	Direct clipping of aneurysm	99	22,2	6,9
Shekhtman et al [10]	Direct clipping of aneurysm, trapping	93	14,8	7,5
Bai-nan Xu et al [22]	Direct clipping of aneurysm, trapping ICA ligation	51	9	4
Hiroyuki et al [23]	Direct clipping of aneurysm, trapping	27	18	1
Louiset al [24]	Trapping	20	35	0
JinLi et al [25]	Direct clipping of aneurysm, trapping	15	27	7
Cantoreetal [26]	Direct clipping of aneurysm, trapping	52	22,2	8

As the Table 1 shows, high rates of complications and mortality are presented at direct clipping of aneurysm, whereas Louisetal reports 0% mortality at trapping. Thus, in spite of modern microsurgical techniques, high rates of complications and mortality were observed in microsurgical methods of surgical treatment without regard to collateral circulation.

The main indication for the creation of microvascular anastomoses during the surgery of complex aneurysms is a potential risk of occlusion of carrying vessel. At determination of the indications for anastomosis it is important to select patients who have a lack of collateral blood flow and the risk of developing neurological symptoms. The main methods of valuation of collateral cerebral circulation are the balloon occlusion test, CT, MRI perfusion, positron emission tomography, electrophysiological monitoring.

Available methods of evaluation of collateral cerebral circulation is a balloon-occlusion test (BOT) [27, 28]. BOT is performed using two diagnostic catheters by temporary occlusion of the arterial lumen using a balloon and performing cerebral angiography. The procedure is performed under X-ray operating intravenously injected 5000 U of heparin, the directed catheter is inserted through the common femoral artery and then catheterised necessary vessel, the directed catheter with microcatheter balloon set into the lumen of the rocky segment of the ICA. Next step is inflating of the balloon to a complete occlusion of the lumen of the ICA. Within 30 minutes the patient's general state of health and neurological status is evaluated. At the same time an assessment of venous phases in both hemispheres is carried out, which is an indirect sign of assessing the adequacy of collateral cerebral blood flow. BOT is considered positive if the patient is tolerance to the occlusion of the ICA and there are no changes in state of health and neurological status for 30 minutes after occlusion. Negative BOT considered if within 30 minutes there will be focal neurological symptoms. When venous phase delay on the side of the occlusion balloon over 2 seconds, BOT is also considered as negative [29]. In some cases, even at positive BOT, delayed ischemic disorders occur in 2-22% of cases [30].

At negative BOT and insufficient collateral cerebral blood flow, the first stage of the operation is carried out imposing extra-intracranial anastomosis. The choice of the method of revascularization based on the assessment of cerebral perfusion through BOT, radiological and electrophysiological methods of investigation [27, 28, 30]. Low-flow extra-intracranial anastomosis is performed to cover one artery, while high-flow extra-intracranial anastomosis (high-flowbypass) is indicated for patients at change of neurological picture during implementation of BOT with possibility of covering two systems [30, 31].

The method of single photon emission computed tomography (SPECT) is aimed at assessing the amount of residual blood flow. SPECT result less than 70-75% of the residual blood is an indication for high-flow EICMA, between 70-75 and 90% is the indication for the imposition of low-flow EICMA between the superficial temporal artery and the branch of the middle cerebral artery. At residual blood flow of more than 90% anastomosis not recomended [20]. Assessment of collateral cerebral blood flow in combination BOT and SPECT, we significantly reduce the risk of postoperative ischemic complications and mortality [19, 32, 33].

Roentgen endovascular methods include aneurysm embolization using micro spiral, embolization by micro spirals with balloon-assisted coiling or intravascular stent, the stent of flow redistributor at the neck of the aneurysm, in some cases in conjunction with the use of micro spirals.

Roentgen endovascular embolization using micro spirals. In 1991, it was first performed roentgen endovascular embolization of cerebral aneurysms with the help of micro spirals [9.34]. The method comprises stages of carrying micro spiral into cavity of the aneurysm through a micro catheter lumen, after total aneurysm embolization micro spiral is removed. This method is particularly relevant for small aneurysms with narrow neck and saccular configuration of aneurysm. However, at large and giant aneurysms of the internal carotid artery, embolization by micro spirals is not always the method of choice. For embolization of large and giant aneurysms, especially in wide-neck only with the help of micro spirals often carries a high risk of spiral fall into the lumen of the carrier vessel. For total embolization of aneurysms, a large number of micro spirals, which could aggravate the already existing mass effect, is required. In addition, the risk of recanalization and the need for re-operation after embolization of complex aneurysms of the ICA by micro spirals remains at a high level. Thus, according to N. Chalouhietal, embolization by micro spirals at large and giant aneurysms of the ICA was accompanied by complications in 9.8% of cases. The period of postoperational observation averaged 25 months. In 39% of cases there were recanalization of aneurysms, 33% of cases required reoperation. Mortality was 5.3% [35].

Complex, large and giant aneurysms, located above the dural ring, can cause destruction of the cranial nerves and other severe complications as a result of the rise of mass effect of the aneurysm [36, 37]. According to some reports, mortality due to embolization by micro spirals with rise of mass effect reaches 11% [38]. The economic component of the micro embolization by micro spirals also should be noted. Thus, the total embolization of complex aneurysms requires significant costs due to the need of using a large number of micro spirals [38, 39].

Total embolization of complex aneurysms by micro spirals with good outcomes require careful analysis of the results of radiological methods of research, the choice of a suitable projection during the operation, selection of necessary materials [38]. Unsatisfactory results of treatment described in the literature require the search and selection of alternative roentgen endovascular treatment of complex aneurysms of the ICA.

Roentgen endovascular embolization by micro spirals with balloon balloon microcatheter. The balloon microcatheter first popularized by Moretetal in 1994 [40]. The operation consists of carrying the balloon at the level of the aneurysm neck. The balloon is inflated during introduction of micro spirals into the cavity of the aneurysm, thereby preventing migration and the distal emboli by spirals into the lumen of the carrier. In addition, balloon-assisted coiling allows modeling micro spirals according to the shape of the aneurysm. An important step in the operation is the need to periodically blowing the balloon for the resumption of blood flow in the artery, it is particularly important in the absence of adequate collateral cerebral circulation. After the total aneurysm embolization, balloon is deflated and removed [41]. Nowadays, roentgen endovascular embolization of complex aneurysms of the ICA with balloon microcatheter is rarely used in cases of emergency, in the period of aneurysm rupture, when the introduction of antiaggregant drugs and stent placement is associated with a high risk of repeated hemorrhage [42].

Roentgen endovascular embolization by micro spirals with stent-assisted. In 1997 V. V. Halbach etal for the first time carried out the placement of the intravascular stent into the lumen of cerebral artery at embolization of cerebral aneurysms [43]. Stent placement at complex aneurysm embolization allows remodeling carrying vessel and the neck of the aneurysm, reducing the risk of migration of micro spirals into the lumen of the carrying vessel. It is important to note that after the embolization of aneurysms using intravascular stent reduces the risk of aneurysm recanalization. Operation consists of aneurysm embolization by micro spirals with prior or subsequent disclosure of the stent at the level of the aneurysm neck. In addition, the stent can be used in emergency situations when migrating of spirals in the vessel lumen and the need to press a spiral towards the artery wall. Nowadays, self-expanding stents of various modifications, shapes and sizes are presented.

Embolization of the aneurysm with the installation intravascular stent requires conducting preoperative preparation using antiaggregant drugs. Acetylsalicylic acid at 325 mg once daily per os and clopidogrel at 75 mg once daily per os, at least three days before surgery is prescribed [44]. In emergency situations patients assigned the so-called loading dose of clopidogrel at 600 mg and acetylsalicylic acid at 650 mg for at least 8 hours before surgery [45]. After the operation, patients continue to take clopidogrel at 75 mg once daily and acetylsalicylic acid at 100 mg once daily for 6 months.

A group of researchers led by Vikram Huded conducted 9 surgeries for complex aneurysms of the internal carotid artery by using micro spirals with installation of intravascular stent. The result of the study indicates the absence of complications and mortality in this procedure, but a small number of cases should be noted [18]. According to the literature review, 45% of aneurysms were embolized totally on the first attempt, complications of embolization of aneurysms with endovascular stent installation reaches 19%, mortality rate is 2.1% [46]. Stenosis in the stent location area after surgery is observed in 2.5% of cases [47, 48].

Roentgen endovascular stenting with flow distributor stent. Roentgen endovascular embolization of complex aneurysms with the help of micro spirals, with the installation of endovascular stent or balloon-assisted is effective and safe methods, however, according to the literature, complications and recanalization of aneurysms are not uncommon. Also important economic aspect, as the total complex aneurysms embolization coils in combination with one or another technique requires a significant amount of consumables. The economic aspect also important, because the total embolization of complex aneurysms by micro spirals in combination with one or another technique requires a significant amount of materials. Flow redistributor stents are reconstructive method based on the change in hemodynamic indicators of carrying vessel, blood stagnation in the cavity of the aneurysm with subsequent thrombosis and neointimal process at the level of the stent [49]. Flow redistributor stents is a tube consisting of platinum, cobalt and nickel. The structure of the stent is in an extremely small amount of cells (0.02-0.05 mm^2). The operation consists of carrying a stent using a special catheter to the level of the aneurysm neck with further stent removal of the catheter and its final installation. In order to induce the aneurysm thrombosis, a combination of installing loose embolization by micro spirals with flow redistributor stents is used.

Currently a number of clinical studies on the efficacy and safety of flow redistributor stents is conducted.

Safety and efficacy of flow redistributor stents Pipeline (eV3, Irvine, CA, USA) were demonstrated in the PITA study that included 31 patients with unruptured aneurysms, follow-up was 6 months. In 52% of cases flow redistributor stents in combination with micro spirals were applied, in 48% of cases isolated flow redistributor stents were applied. In 93.3% of cases, it was observed a total occlusion of aneurysms. Within 6 months, the mortality was 0%, complications were 6.5% [50]. Studies in Budapest have shown similar results. 19 large and giant complex aneurysms in 18 patients were included in the study. Cerebral angiography is carried out after 6 months after surgery, showed a total occlusion of the aneurysm of 17 patients. Complications comprised 5.5%, one case ended with fatal case [51].