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A. Kaliyev, Ye. Makhambetov, Ye. Medetov, M. Kulmirzayev,
S. Dusembayev, B. Kunakbayev, Ch. Nurimanov, S. Akshulakov

JSC "National Centre for Neurosurgery", Department of vascular and functional neurosurgery,
Astana, Kazakhstan.
E-mail: assylbek789@yahoo.com; yermakh@gmail.com; yerkin.medetov@gmail.com;
marat.kulmirzayev@gmail.com; dr.serik@gmail.com; kunakbaevb@gmail.com;
chingiz_nurimanov@mail.ru; raim@rambler.ru

TREATMENT OF COMPLEX INTERNAL CAROTID ANEURYSMS

Abstract.

Introduction: Nowadays different treatment modalities used in the treatment of complex internal carotid artery aneurysms.

Aims: Retrospectively evaluate the results of different treatment modalities other than direct clipping at single.

Design of the study: Retrospective cohort study.

Methods and Material: Clinical presentations, radiological data and outcomes of 64 patients with complex ICA aneurysms evaluated. 15 patients were male, 49 were female with mean age 53 years old.

Results: Follow up period ranged from 3 to 96 months. Parent artery ligation was performed in 12 cases and direct proximal clip placement in 1 case. Endovascular embolization of the aneurysm by coils was performed in 6 cases. Deployment of flow diverter device done in 13 cases. Combined strategy including preliminary bypass with further parent artery occlusion applied in 23 cases. Endovascular occlusion of the parent vessel by coils was done in 9 cases. Surgical morbidity was 20,3%, mortality 3,1%. Outcomes were evaluated by Modified Rankin Scale.

Conclusion: Precise assessment of collateral cerebral blood flow is an important stage in the preoperative planning. Despite new endovascular techniques, EC-IC bypass technique has very important role in the treatment of complex aneurysm. Trapping the aneurysm is still effective and minimally invasive option in selected cases. Combined team approach, with treatment modalities other than direct clipping for complex aneurysms can minimize postoperative morbidity with good outcomes.

Key-words: complex aneurysms, internal carotid artery, EC-IC bypass, flow diverter devices.

Introduction. Despite new endovascular and surgical treatment options, complex intracranial aneurysms are still a big challenge [1-5]. Complex aneurysms recognized as big or giant size, with broad calcified neck, fusiform shape, intraluminal thrombus, branches arising from the aneurysm, atherosclerotic wall of the aneurysms, absence of collateral blood flow[1, 2, 4, 6-9]. These features make such aneurysms difficult for direct surgical treatment with high level of morbidity and mortality [10-22].

For complex aneurysms, multidisciplinary, neurosurgical and interventional neuroradiology team approach is necessary. The aim of the study was to retrospectively evaluate the efficacy, safety and outcomes by methods other than direct clipping.

Subjects and Methods. We conducted retrospective study following experience at our department, between July 2008 and December 2018 to estimate the results of treatment modalities. The review of medical records found 64 patients who underwent endovascular, surgical and multimodality treatment. We reviewed characteristics of aneurysms, treatment modalities, follow up data and results.

Patient's characteristics. Using the criteria of complex aneurysms (table 1) 64 consecutive patients with 64 aneurysms were included into the study. Among 64 patients 15(23,4%) were male, 49(76,6%) were female. Patients age ranged between 19 and 72, with mean age of 53±11,4(Me±SD) years old. Patient's demographic data, clinical presentation, size and configuration of the aneurysm evaluated respectively (table 2). Aneurysm sac size ranged between 11 to 51 mm, with mean size 30±7,9 mm (Me±SD). Size of the neck ranged between 4 to 30 mm, mean size was 10±5,3mm(Me±SD). In 7 cases

fusiform configuration of the aneurysm was revealed. The most frequent location of the aneurysms was paraclinoid (43,8%) and cavernous (35,9%) and aneurysms in the supraclinoid part were found in 20,3%. We did not found significant difference between sex and aneurysm location. In 10(15,6%) cases patients had a history of aneurysmal intracranial bleeding, in 54(84,4%) cases aneurysms were unruptured. Cranial nerves palsy was the leading symptom in clinical presentation in 24(37,5%) cases, 23(35,9%) patients suffered from headache and visual disturbance was found in 17(26,6%) cases.

Table 1 – Criteria for ICA complex aneurysm

Criteria for complex aneurysm	Features
Size	≥11 mm
Neck	≥4 mm
Shape	Regular/Fusiform
Atherosclerotic changes of parent artery, aneurysm dome and neck	Yes/No
Intraluminal thrombus	Yes/No
Absence of collateral blood flow	Yes/No
Presence of ≥3 of listed factors make aneurysm complex.	

Table 2 – Patient's characteristics

Number of patients	64
Number of aneurysms	64
Mean age	53
Headache	23
Cranial nerves palsy	24
Visual disturbances	17
Ruptured/ Unruptured	10/54
Aneurysm size giant/large	56/8
Cavernous	25
Paraclinoid	21
Supraclinoid	18

Collateral cerebral blood flow assessed by routine balloon test occlusion. Patients treated by endovascular intervention, parent artery occlusion, trapping the aneurysm by bypass surgery or combination of listed methods. Clinical, radiological and angiographic follow up was available. Follow up period ranged between 3-96 months. Outcomes of the treatment assessed by Modified Rankin Scale.

Treatment strategy. Treatment strategy was based on preoperative clinical, radiological and angiographic examination by our multidisciplinary team. Flow chart of treatment strategy presented in table 3. In our department, neurosurgeons are able to perform both microsurgical and endovascular cases. Preoperative assessment of collateral cerebral blood flow performed by double catheter balloon test occlusion. Patients who did not tolerate 30 minutes temporary parent vessel occlusion with 15 minutes drug induced hypotension selected for EC-IC bypass with further endovascular intervention or parent artery occlusion. Selection for either low or high flow bypass done according to anatomy of collateral vessels. Low flow bypass selected in cases when we had to protect of only one territory, such as middle cerebral artery. If there were no any collateral arteries and necessity to cover two main ACA and MCA territories we performed high flow bypass surgery. In some cases, during the angiography and BTO we observed elevation and compression of A1 or M1 segment by aneurysm dome. These patients also underwent preliminary low flow bypass procedures even if they tolerated BTO. This strategy used because of awareness of aneurysm thrombosis, growth and further compression of collateral arteries that could lead to insufficiency of blood circulation and ischemic complications.

Table 3 – Modified Rankin Scale at the time of discharge.

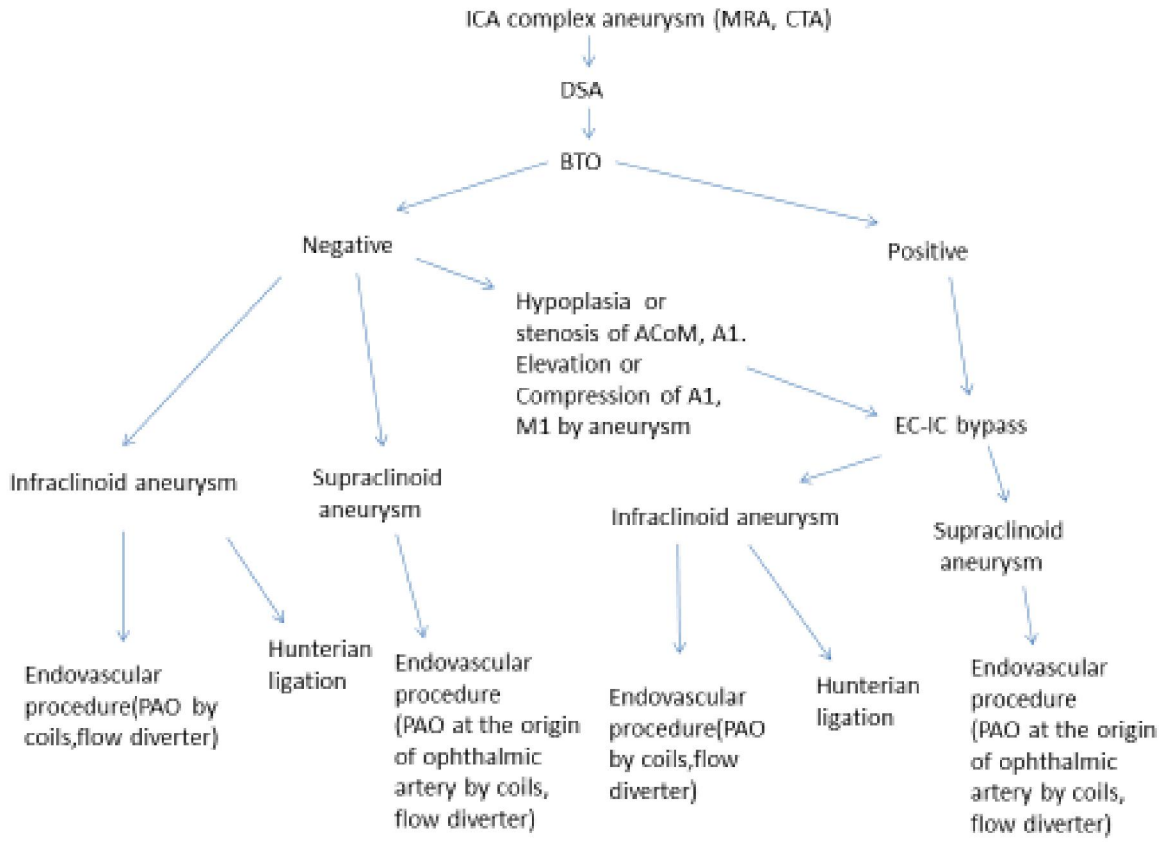
Modified Rankin Scale	Patients number
0	17
1	32
2	8
3	5
4	0
5	0
6	2
Total	64

Surgical treatment included Hunterian parent artery ligation in 12 cases and direct trapping of the aneurysm by proximal and distal clip placement in 1 fusiform aneurysm case. Endovascular embolization of the aneurysm by coils with balloon or stent assistance was performed in 6 cases. In 13 cases we deployed flow diverter devices. Combined strategy including preliminary bypass surgery with further surgical or endovascular intervention was applied in 23 cases. Endovascular occlusion of the parent vessel by coils was done in 9 cases.

Hunterian ligation performed in aneurysms located in the cavernous and paraclinoidpart of the ICA. At our later experience, we started to occlude aneurysms located at the paraclinoid and supraclinoid segments by coils at the origin of the ophthalmic artery. This technique implemented because of risk of remnant filling of the aneurysm through external carotid artery system anastomosis.

Results. At the time of data collection, 54 patients (84%) were available for follow up. Follow up period ranged between 3 to 96 months with mean period of 15 months. We observed significant prevalence of female patients among males, and mean age of male was lower than female. Immediate postoperative exclusion of the aneurysm from the circulation was achieved in 61 cases (95,3%). In two cases there was a remnant filling of the aneurysm through meningeal anastomosis from the external carotid artery. These aneurysms were located in the cavernous part of the ICA and did not require additional treatment. Third patient underwent EC-IC bypass and parent artery ligation for ICA supraclinoid aneurysm. On postoperative DSA there was a tiny retrograde filling of the aneurysm through ophthalmic artery. He suffered subarachnoid hemorrhage after two weeks of discharge. He was readmitted to the hospital and underwent additional endovascular embolization of parent artery and remnant aneurysm through the anterior communicating artery. In the group of endovascular embolization with coils, one case of giant aneurysm required second attempt due to significant recanalization of the sac. Combined strategy using bypass procedures with further surgical or endovascular options were performed in 23 cases. 16 patients underwent single STA-MCA bypass, in 6 cases we have done high flow bypass using radial artery graft, in 1 case we created double STA-MCA bypass. After creating an EC-IC bypass patients undergone parent artery occlusion in 18 cases or deployment of flow diverter in 5 cases. Because of small number of in stent thrombosis during our initial experience with flow diverter stent, we did protective bypasses before stent deployment in cases of unfavorable anatomy, insufficient collateral cerebral blood circulation and potential risk of parent artery occlusion due to stent thrombosis. Bypass patency was evaluated using digital subtraction angiography. Early bypass occlusion, during 7 days after the procedure occurred in 2 cases. The longest follow up of bypass patency is 60 months. Surgical associated permanent morbidity occurred in 13 cases (20,3%), two patients (3,1%) died after endovascular stent assistant embolization with coils due to the in stent thrombosis and severe ischemic stroke. At the time of discharge from the hospital outcomes evaluated by Modified Rankin Scale (table 4). Modified Rankin Scale 0 and 1 observed in 49 cases, score 2 was in 8, in 5 cases patients were discharged with score 3. Two patients had score 6. No new aneurysm formation detected. Among patients who were available for MRI follow up, significant aneurysm size decrease observed in cases with parent artery occlusion.

Table 4 – Flow chart of treatment strategy



Discussion. The aim of the treatment of any aneurysm is a total exclusion from the blood circulation. Treatment modalities for complex intracranial aneurysms located at the ICA are still an object for discussion. Both microsurgical and endovascular techniques faces big challenges during the management of these lesions. There are several causes, which are associated with poor outcomes, such as giant size of the dome and neck of the aneurysm, fusiform or dolichoectatic shape, calcified atherosclerotic neck, branches arising from the aneurysm. Such features make these lesions extremely difficult for direct microsurgical clipping or endovascular embolization. However, we think that more aggressive approach for complex aneurysms must be used due to the poor natural history.

According to our retrospective study, we have concluded the importance of multidisciplinary team approach, including neurosurgical and interventional points. Preoperative precise radiological and angiographic assessment of the aneurysm's dome and neck configuration, presence of intraluminal thrombus and branches arising from the aneurysm should be performed. Special attention to the cerebral collateral blood flow, especially in cases with potential risk of the parent artery occlusion. BOT is a safe and effective method to make a prognosis about tolerance in case of parent artery occlusion [23]. However, there are some reports of ischemic complications even when patients tolerate the BOT [24-28].

In recent report, we performed BOT in all cases, which were scheduled for potential parent artery occlusion. In case of absence of any collateral blood circulation BOT cancelled immediately and we created high flow bypass. Another reason for declining the BOT was hypoplasia of A1 segment of ACA, compression of the A1 or M1 segment by the sac of the aneurysm. In such cases, we decided to create protective low flow bypass. Our decision based on after the acute abruption of the flow in the parent artery and aneurysm there is an increasing volume of the aneurysm due to the thrombosis, that may cause further compression of the surrounding brain tissue and vessels, which may be the reason of ischemic complications and worsening of neurological signs [29, 30]. We have our own experience when a patient tolerated temporary balloon occlusion of the parent artery with further ICA sacrifice. Postoperatively we observed severe neurologic deficit due to the insufficient collateral circulation, emergency EC-IC bypass was performed and a patient did well after the surgery.

Volume decrease of the aneurysm is an important factor, especially in cases with mass effect causing neurological deficit. Parent artery occlusion is related with higher rate of aneurysm sac shrinkage and improvement of symptoms caused by aneurysm size [31-33]. In our experience, among patients treated with therapeutic parent artery endovascular or Hunterian ligation, we could detect significant aneurysm size reduction.

In the past decades, endovascular occlusion of the aneurysms became the first line option in many centers. Outcomes of endovascular treatment of aneurysms became better due to new instruments and devices. However, in some series endovascular management of complex aneurysms is associated with still high rates of recanalization, morbidity and mortality [34]. Introduction of new flow diverter devices promises improvement of the results of endovascular methods. Deployment of flow diverter stents is associated with low level of complications, higher occlusion rates in cases of regular shape aneurysms [35]. Higher morbidity rates of flow diverter deployment occur in cases of complex, giant aneurysms with wide neck [36-38]. In ourinitialseries we encountered technical issues, such as flow diverter migration, stent thrombosis with further occlusion of the parent artery. These complications led to severe ischemic stroke and death in 2 cases. According to this, in our later cases when we anticipated to deploy flow diverter, we created protective bypass if there are no anterior and posterior communicating arteries.

Since the introduction of EC-IC bypass by Yasargil, treatment options for complex aneurysms obtained new opportunities [39]. Trapping the aneurysm by microvascular anastomosis is commonly used worldwide. Complex anatomy of the aneurysm makes complex aneurysms impossible for clipping or endovascular methods. In such cases, EC-IC bypass with further parent artery occlusion sometimes is the only treatment option. Recent reports demonstrated safety, high occlusion rates and long term bypass patency [40]. Furthermore, described bypasses are used as rescue tool in situations of parent artery occlusion and cerebral blood flow insufficiency [41]. At our center, preliminary EC-IC bypass with parent artery occlusion was performed in 22 cases. Current report shows high rates of the aneurysm occlusion, long term bypass patency, and acceptable level of morbidity. In this group, we did not experience any mortality.

The strategy for parent artery occlusion is still controversial. In cases of ICA sacrifice, when the aneurysm is located in the paraclinoid or supraclinoid part there is a risk of remnant flow through the

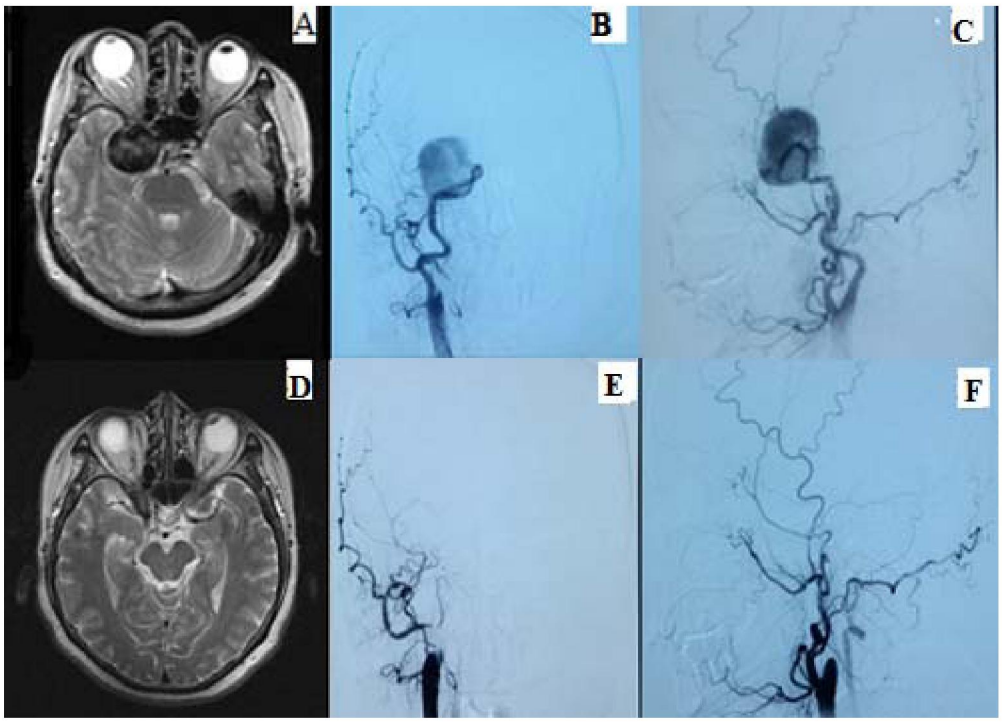


Figure 1 – Female, 58 y.o. Giant aneurysm of the cavernous part of ICA. Ligation of the ICA was performed. A, B, C preoperatively. Follow up after 6 months (D, E, F): aneurysm is occluded completely. The size of the aneurysmdecreased significantly

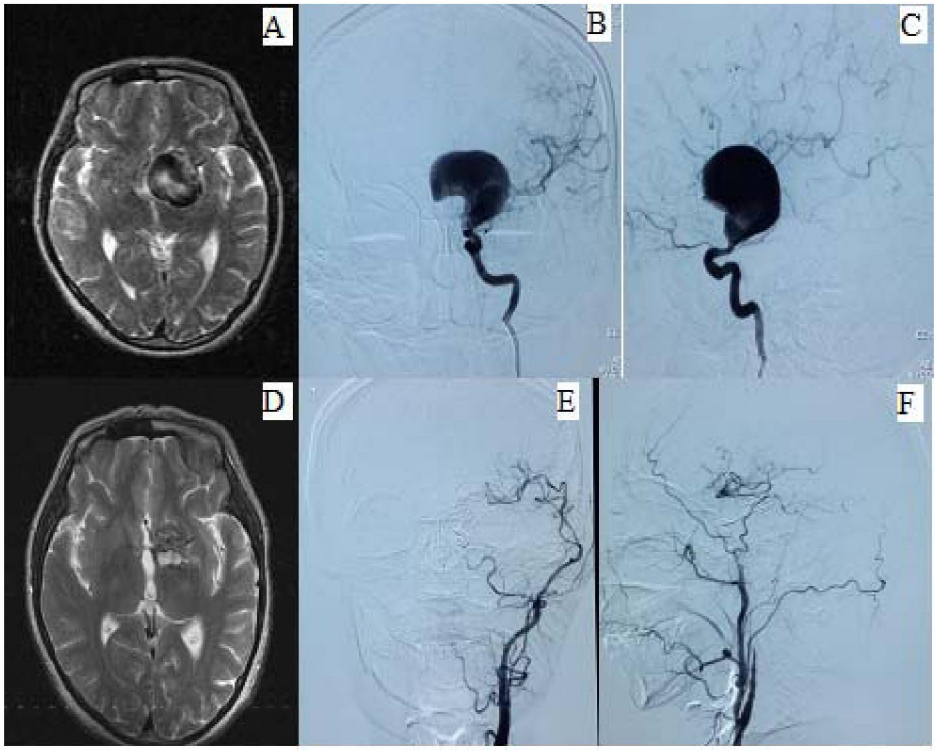


Figure 2 – Female, 36 y.o. Giant aneurysm of left paraclinoidICA (A, B ,C). STA-MCA bypass with endovascular occlusion of ICA at the level of ophthalmic artery origin. MRI and DSA after 6 months demonstrates exclusion of the aneurysm, volume decrease and bypass patency (D, E, F)

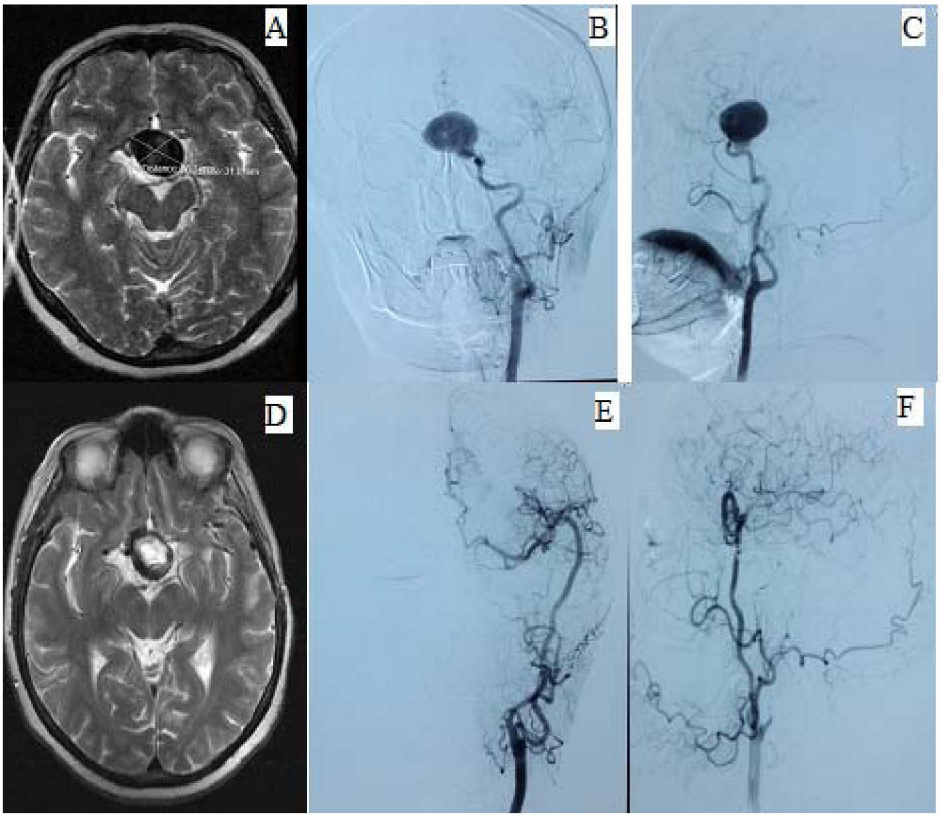


Figure 3 – Female, 51 y.o. with giant aneurysm of paraclinoid left ICA (A, B, C). High flow bypass with endovascular occlusion of ICA. Follow up after 12 months (Pictures D, E, F): exclusion of the aneurysm, bypass patency and aneurysm volume decrease

branches of external carotid artery. Vessels such as ophthalmic or meningohypophyseal trunk sometimes can lead to significant aneurysm filling, with reported cases of rupture and aneurysm growth [42]. Our experience with 15 patients when we performed parent artery occlusion in the cervical part of ICA with or without creation of EC-IC bypass showed remnant filling of the aneurysm through ophthalmic artery only in 3 cases. As described previously one of these patients suffered subarachnoid hemorrhage and underwent another surgery. However, now the mechanism of this hemorrhage is not clear. Of course, some of the paraclinoid aneurysms in our series we could perform clipping as well, but our early and midterm follow up of surgical ligation or endovascular ICA occlusion showed good results and low rates of complications.

Conclusion. Current article summarized data of patients with complex internal carotid artery aneurysms treated at single center by methods other than direct clipping. According to our results, assessment of collateral cerebral blood flow is an important stage in the preoperative planning. Major complications in our study were associated with ischemia due to the insufficiency of cerebral circulation. We conclude that whatever treatment option planned, one should pay precise attention to the potential risk of major vessels occlusion. Even in the era of flow diverters, EC-IC bypass technique has very important role in the complex aneurysm management. Parent artery occlusion is still effective and minimally invasive option, but to estimate the results, we need longer follow up and comparison with other treatment modalities. In cases with flow diverter devices risk of complications is higher in the aneurysms with very wide neck, stenosis and severe tortuosity of parent artery. Combined team approach of surgical and endovascular modalities for complex aneurysms can minimize postoperative morbidity and helps to achieve good outcomes.

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All authors have equal contribution to this article, such as data collection, evaluation of results of treatment,attendance to patient care and surgery.

А. Калиев, Е. Махамбетов, Е. Медетов, М. Кулмирзаев, С. Дюсембаев, Б. Кунакбаев, Ч. Нуриманов, С. Акшулаков

"Ұлттық Нейрохирургия Орталығы" АҚ, Тамырлы және функционалды нейрохирургия бөлімшесі, Астана, Қазақстан

ІШКІ КҮРЕТАМЫРДЫҢ КҮРДЕЛІ АНЕВРИЗМАЛАРЫН ЕМДЕУ

Түйіндеме.

Кіріспе: қазіргі уақытта ішкі күретамырдың күрделі аневризмаларын емдеудің әртүрлі әдістері қолданылуда.

Мақсаты: бір орталықта орындалған тікелей клипстеуден басқа емдеудің әртүрлі әдістерінің қорытындыларын ретроспективтік бағалау.

Зерттеу дизайны: ретроспективті шоғырламалық зерттеу.

Әдістері мен материалдары. Ішкі күретамырдың күрделі аневризмалары бар 64 пациенттің рентгенологиялық деректері және емдеу нәтижелері, клиникалық суреті талданды. 15 пациент – ер адам, 49 пациент – әйел адам, орташа жасы 53 жасты құрады.

Нәтижелері. Операциядан кейінгі бақылау кезеңі 3 айдан бастап 96 айға дейінгі мерзімді құрады. 12 жағдайда тасымалдаушы артерияны жауып тастау және 1 жағдайда ішкі күретамырдың проксималды тікелей клипстеу орындалды. 6 жағдайда микроспиральдарымен аневризмалардың эндоваскулярлық эмболизациясы орындалды. 13 жағдайда ағынды қайта бағыттаушы стентті орнату орындалды. 23 жағдайда тасымалдаушы артерияны кейіннен окклюзиялаумен экстра-краниалды анастомазды алдын-ала салуды

құрайтын біріктірілген стратегия қолданылды. 9 жағдайда микроспиральдарымен ішкі күретамырлардың эндоваскулярлық окклюзиясыорындалды. Операциядан кейінгі асқынулар 20,3%, өлім-жітім 3,1% құрады. Нәтижелер Рэнкиннің түрлендірілген шкаласы бойынша бағаланды.

Қорытынды. Коллатералдық мидың қанағымын бағалау операция алдындағы жоспарлаудың маңызды кезеңі болып саналады.Жаңа эндоваскулярлық әдістерге қарамастан, күрделі аневризмаларды емдеуде экстра-краниалды анастомаз әдісі маңызды рөлді атқарады. Тасымалдаушы артерияны окклюзия жолымен аневризманы окклюзиялау әлі де тиімді және шағын инвазиялық емшара. Күрделі аневризмаларды клипстеуден басқа біріктірілген топтық тәсіл операциядан кейінгі асқынуларды оң нәтижелі жағдайларға дейін жеткізе алады.

Түйін сөздер: күрделі аневризмалар, ішкі күретамыр артериясы, экстра-интракраниалды анастомоз, ағынды қайта бағыттаушы стент.

А. Калиев, Е. Махамбетов, Е. Медетов, М. Кулмирзаев, С. Дюсембаев, Б. Кунакбаев, Ч. Нуриманов, С. Акшулаков

АО Национальный Центр Нейрохирургии, отделение сосудистой и функциональной нейрохирургии, Астана, Казахстан

ЛЕЧЕНИЕ СЛОЖНЫХ АНЕВРИЗМ ВНУТРЕННЕЙ СОННОЙ АРТЕРИИ

Аннотация.

Введение: в настоящее время применяются различные методы лечениясложные аневризмы внутренней сонной артерии.

Цель: ретроспективно оценить результаты различных методов лечения, кроме прямого клипирования выполненных в одном центре.

Дизайн исследования: ретроспективное когортное исследование.

Методы и материалы. Были проанализированы клиническаякартина, рентгенологические данные и результаты лечения 64 пациентов сосложными аневризмами ВСА. 15 пациентов – мужчины, 49 – женщины, средний возраст составил 53 года.

Результаты. Период послеоперационного наблюдения составил от 3 до 96 месяцев. Лигирование несущей артерии было выполнено в 12 случаях и прямое клипирование проксимального отдела ВСА в 1 случае. Эндоваскулярная эмболизация аневризмы микроспиралями была выполнена в 6 случаях. Установка поток перенаправляющего стента выполнено в 13 случаях. Комбинированная стратегия, включающая предварительное наложение экстра-интракраниального анастомоза с последующей окклюзией несущей артерии, применена в 23 случаях. Эндоваскулярная окклюзия ВСА микроспиралями выполнена в 9 случаях. Послеоперационные осложнения составили 20,3%, летальность 3,1%. Результаты оценивались по модифицированной шкале Рэнкина.

Заключение. Оценка коллатерального мозгового кровотока является важным этапом предоперационного планирования. Несмотря на новые эндоваскулярные методы, метод экстра-интракраниального анастомоза играет очень важную роль в лечении сложных аневризм. Окклюзия аневризм путем окклюзии несущей артерии все еще эффективна и минимально инвазивная процедура. Комбинированный командный подход, кроме прямого клипирования сложных аневризм, может минимизировать послеоперационныеосложнения с благоприятными результатами.

Ключевые слова: сложные аневризмы, внутренняя сонная артерия, экстра-интракраниальный анастомоз, поток перенаправляющий стент.

Information about authors:

Kaliyev Assylbek, JSC “National Centre for Neurosurgery”, Department of vascular and functional neurosurgery, Astana, Kazakhstan; assylbek789@yahoo.com

Makhambetov Yerbol, JSC “National Centre for Neurosurgery”, Department of vascular and functional neurosurgery, Astana, Kazakhstan; yermakh@gmail.com; https://orcid.org/0000-0002-7451-8756

Medetov Yerkin, JSC “National Centre for Neurosurgery”, Department of vascular and functional neurosurgery, Astana, Kazakhstan; yerkin.medetov@gmail.com; https://orcid.org/0000-0002-0043-0700

Kulmirzayev Marat, JSC “National Centre for Neurosurgery”, Department of vascular and functional neurosurgery, Astana, Kazakhstan; marat.kulmirzayev@gmail.com; https://orcid.org/0000-0003-2678-0511

Dusembayev Serik, JSC "National Centre for Neurosurgery", Department of vascular and functional neurosurgery, Astana, Kazakhstan; dr.serik@gmail.com; https://orcid.org/0000-0002-3044-3406

Kunakbayev Baurzhan, JSC "National Centre for Neurosurgery", Department of vascular and functional neurosurgery, Astana, Kazakhstan; kunakbaevb@gmail.com; https://orcid.org/0000-0002-0489-8319

Nurimanov Chingiz, JSC "National Centre for Neurosurgery", Department of vascular and functional neurosurgery, Astana, Kazakhstan; chingiz_nurimanov@mail.ru; https://orcid.org/0000-0002-8251-7980

Akshulakov Serik, JSC "National Centre for Neurosurgery", Department of vascular and functional neurosurgery, Astana, Kazakhstan; raim@rambler.ru

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