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ENDOVASCULAR TREATMENT OF DISTAL CEREBRAL ANEURYSMS

I.V. Senko[1], V.S. Kisilev[2, 3], A.O. Sosnov[2, 3], A.M. Perfiliev[2, 4], P.D. Matveev[1], P.Yu. Ivanova[4], D.A. Rzaev[2, 4, 5]

[1]*Federal Center for Brain and Neurotechnologies, Federal Medical and Biological Agency of Russia; Bld. 10, 1 Ostrovityanova St., Moscow 117513, Russia;*
[2]*Federal Neurosurgical Center (Novosibirsk), Ministry of Health of Russia; 132/1 Nemirovicha-Danchenko St., Novosibirsk 630087, Russia;*
[3]*Leningrad Regional Clinical Hospital; 45–49 Lunacharskogo St., Saint Petersburg, Russia;*
[4]*Novosibirsk State University; 2 Pirogova St., Novosibirsk 630090, Russia;*
[5]*Novosibirsk State Medical University; 52 Krasniy Ave., Novosibirsk 630091, Russia*

Contacts: Ilya Vladimirovich Senko *Senko.ilya@mail.ru*

Background. Due to rare occurrence of distal cerebral aneurysms, there are very few publications devoted to endovascular treatment. Due to current progress in the endovascular surgery, the number of successfully cured patients with distal aneurysms has been increasing recently.
Aim. To determine technical capabilities and evaluate results of endovascular treatment of patients with distal intracranial aneurysms.
Materials and methods. The work is based on analysis of data of endovascular treatment among 45 patients with distal cerebral aneurysms in two neurosurgical departments of federal medical centers. Of the 45 analyzed cases 30 were without aneurysm rupture and 15 were with rupture.
Results. Endovascular treatment of the distal aneurysms made it possible to achieve good treatment results (4–5 points on the Glasgow Outcome Scale (GOS)) in 97.8 % of cases: 5 points on GOS – in 68.9 %, 4 points on GOS – in 28.4 %. One (2.2 %) fatal outcome was obtained. The most frequent methods of embolization were embolization of aneurysm by coils with stent assistance (37.8 %) and installation of a flow-diverter stent (28.9 %). Embolization with only coils (20 %) or occlusion of parent artery (13.3 %) were used less frequently. In 3 out of 6 patients, the occlusion of parent artery was not planned.
Conclusion. Development of endovascular surgery and technical capabilities of performing operations in the distal cerebral arteries has made it possible to form a multidisciplinary approach to choosing the optimal method of shutting off the distal aneurysm from the bloodstream, taking into account the modern possibilities of open surgery. This is especially important for patients in serious condition due to ruptured aneurysm.

Keywords: distal cerebral aneurysm, endovascular treatment, flow-directing stent, coils, stent assistance

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INTRODUCTION

Current approach to treatment of distal cerebral aneurysms is multimodal. The literature includes a sufficient number of studies comparing different methods of treating cerebral aneurysms [1–10], but due to the rare occurrence and large anatomical and topographic heterogeneity of distal cerebral aneurysms, there are no separate randomized studies comparing the use of open and endovascular methods in the treatment of such patients. The main methods of endovascular treatment of distal aneurysms are selective embolization of the aneurysm with stent – or balloon-assisted coils, installation of a flow-diverter stent, and occlusion of parent artery with coils [3, 8, 24]. The first 2 methods are reconstructive, the third is deconstructive.

The distal location and anatomy of aneurysms did not allow full use of endovascular methods until recently. The main difficulties in endovascular embolization of distal aneurysms were and still are complicated navigation and stabilization of the microcatheter in the aneurysm cavity, as well as the use of assistive techniques [3, 5, 6, 8, 11, 22]. However, these problems are almost eliminated with the advent of the flow-diverter stents [16, 19, 23].

In addition, the previously cautious approach to use endovascular techniques in the acute period of hemorrhage is becoming a thing of the past with development of endovascular techniques and pharmacological support for the procedure. Endovascular treatment of distal aneurysms in subarachnoid hemorrhage conditions, especially in patients in severe condition, showed better results in comparison with the use of open surgery [1, 8–10, 15, 20].

The aim of the study was to determine the technical capabilities and evaluate the results of endovascular treatment of patients with distal cerebral aneurysms.

MATERIALS AND METHODS

Distal intracranial aneurysms include aneurysms located in the distal parts of the large arteries of the carotid and vertebrobasilar systems: aneurysms of the A2–A5-segments of the anterior cerebral artery, the M2–M4-segments of the middle cerebral artery (MCA), the P2–P4-segments of the posterior cerebral artery (PCA), aneurysms of the cerebellar arteries located more distal to the place where they arise from the vertebral and basilar arteries.

The work is based on the analysis of results of endovascular treatment of 45 patients with distal cerebral aneurysms at the Federal Center for Brain and Neurotechnology of the Federal Medical and Biological Agency of Russia during the period from January 1, 2020 to December 31, 2021 ($n = 6$) and at the Federal Center for Neurosurgery of the Ministry of Health of Russia from January 1, 2014 to December 31, 2021 ($n = 39$).

The study included 10 men and 35 women aged from 29 to 78 years (median – 53 years). Among the admitted patients, 15 (33.3 %) had a history of distal cerebral aneurysm rupture, 5 (11.1 %) had pseudotumor and 5 (11.1 %) had embolic type of clinical course. In 20 (44.4 %) patients, the aneurysm was detected accidentally.

Seven patients with distal aneurysm rupture were admitted in the acute period (first 14 days) of hemorrhage, the remaining 8 – in the delayed period. After subarachnoid hemorrhage patients had lowered level of wakefulness from moderate stunning to sopor in 60 % of cases ($n = 9$). Hemorrhage from distal aneurysms was more often of types II and IV according the C.M. Fisher scale – both were in 46.7 % of cases, respectively. In the acute period of hemorrhage all patients underwent surgery on the 1st day of admission to the neurosurgical department of the Federal Center.

Surgical treatment of a patient with distal aneurysm was discussed jointly by neurosurgeons and specialists in X-ray surgical methods of treatment, while the method of closing off the aneurysm depended on the presence of an aneurysm rupture and its anatomy and topography.

Functional outcomes after endovascular treatment were assessed using the Glasgow Outcome Scale (GOS) at the time of hospital discharge.

Statistical data analysis was performed by the use of personal computer with the MacOS Sierra operating system (Apple Inc., USA) and the IBM SPSS Statistics v. 24 software (IBM Corp., USA). Descriptive nonparametric statistical methods were used.

RESULTS

Anatomical and topographical characteristics. The distal aneurysms that underwent endovascular treatment were more often located on PCA (19 cases) and the pericallosal artery (PA) (15 cases). In 8 cases, the aneurysms were located in the distal segments of cerebellar arteries, while in 3 cases – in MCA territory.

Thirty two (71.1 %) distal aneurysms had a saccular structure, 13 (28.9 %) – were fusiform aneurysms. At the same time, more than half (62.5 %) of saccular aneurysms had a relatively wide neck (more than 3 mm). The size of aneurysms varied from 2.2 to 29.3 mm: 0–7 mm – in 55.6 % of cases, 7.1–5 mm – in 33.3 %, 15.1–25 mm – in 6.7 % and more than 25 mm – in 4.4 %. In 10 (22.2 %) cases, the distal aneurysms were combined with aneurysms of other localization and 2 patients had 2 distal aneurysms on the same artery.

Methods of endovascular removal of distal aneurysms from the bloodstream. Methods of endovascular removal of distal aneurysms from the bloodstream are divided into reconstructive and deconstructive ones. The most frequent methods of embolization used in our work were aneurysm embolization with stent-assisted coils and installation of a flow-diverter stent (see Table).

Methods of endovascular shutdown of distal aneurysms from the bloodstream

Methodology	Number of patients, *n* (%)
Embolization with coils	9 (20)
Embolization with coils and with stent-assisted	17 (37.8)
Installation of a flow-diverter stent	13 (28.9)
Occlusion of the parent artery by coils	6 (13.3)

As a rule, installation of a flow-diverter stent and embolization with stent-assisted coils was used for non-ruptured distal aneurysms. For ruptured aneurysms, everything depended on the location and technical availability of the aneurysm for intravascular devices. We always tried to preserve the parent artery and perform the most effective embolization (class I and II according to the Raymond–Roy classification), more often it was possible to do with the help of coils using a removable assistive device. In 5 of 6 patients with Raymond–Roy class II embolization performed in the acute period, during re-hospitalization after 3–7 months the embolization was supplemented with either coils with a stent or the installation of a flow-diverter stent. If it was impossible to perform reconstructive embolization of the distal aneurysm in the acute period or if there were technical difficulties, the parent artery was closed with coils.

In cases of non-ruptured distal aneurysms of PCA and PA, the most effective treatment methods were the use of coils with a stent or a flow-diverter stent (Fig. 1–4).

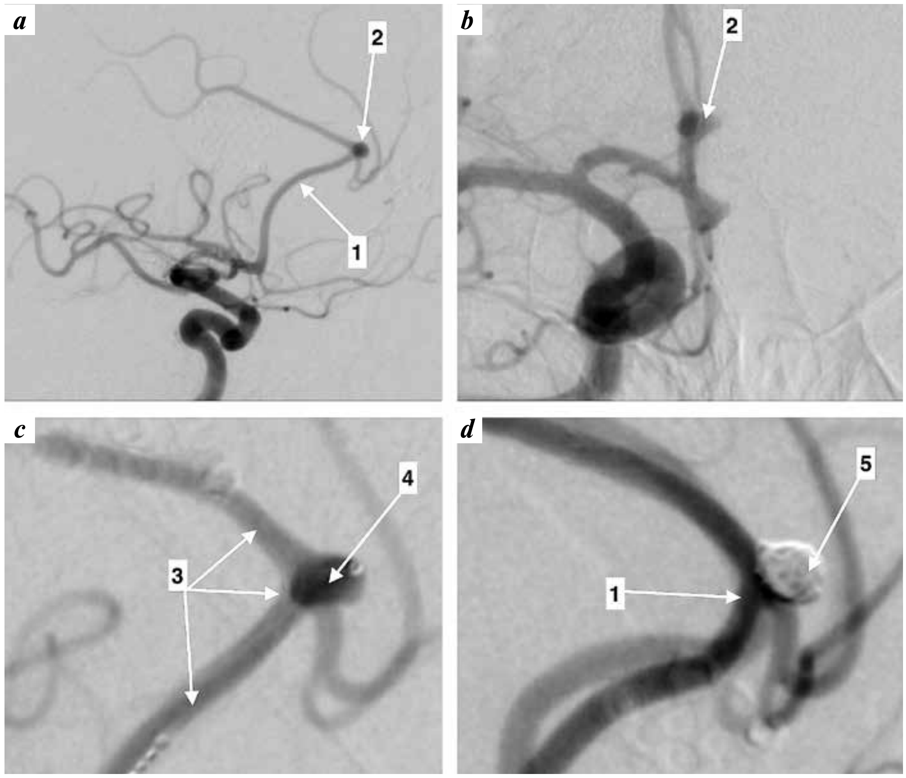

Fig. 1. *Embolization of the pericallosal artery (PA) aneurysm with stent assistance: a – cerebral angiogram (CAG), lateral projection; b – CAG, direct projection; c – stent installation; d – embolization of PA aneurysm. 1 – PA; 2 – PA aneurysm; 3 – stent in the PA; 4 – microcatheter in the aneurysm cavity; 5 – coils*

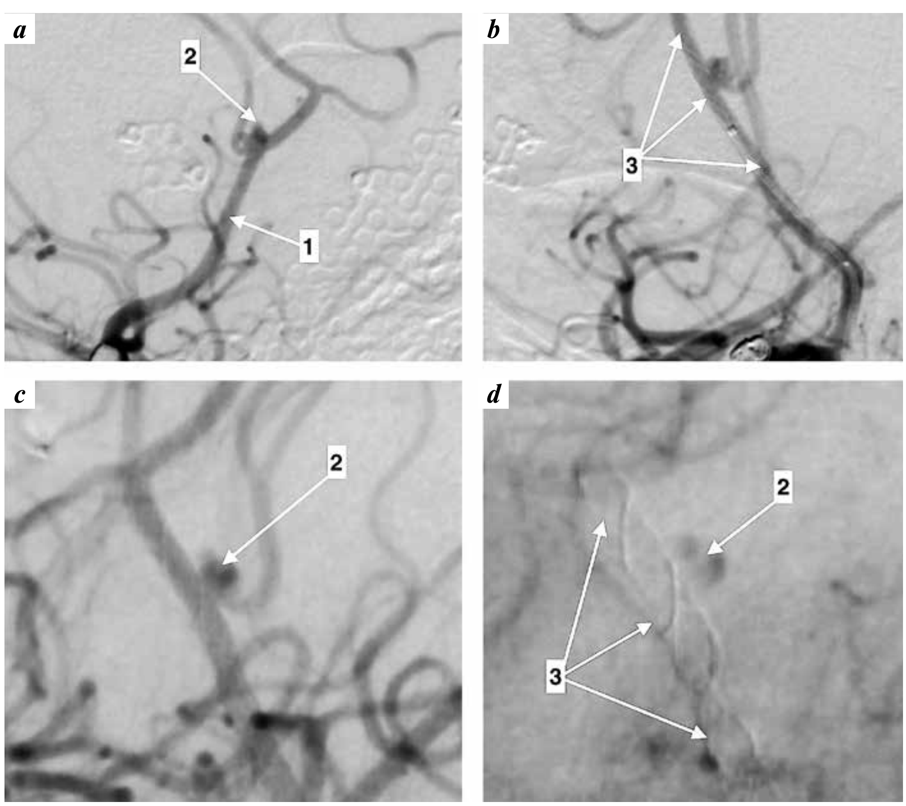

Fig. 2. *Installation of a flow-diverter stent for pericallosal artery (PA) aneurysm: a – cerebral angiogram (CAG), lateral projection; b – installation of flow-diverter stent; c – CAG, early arterial phase; d – CAG, late arterial phase. 1 – PA; 2 – aneurysm and stagnation of contrast agent in the aneurysm; 3 – flow-diverter stent*

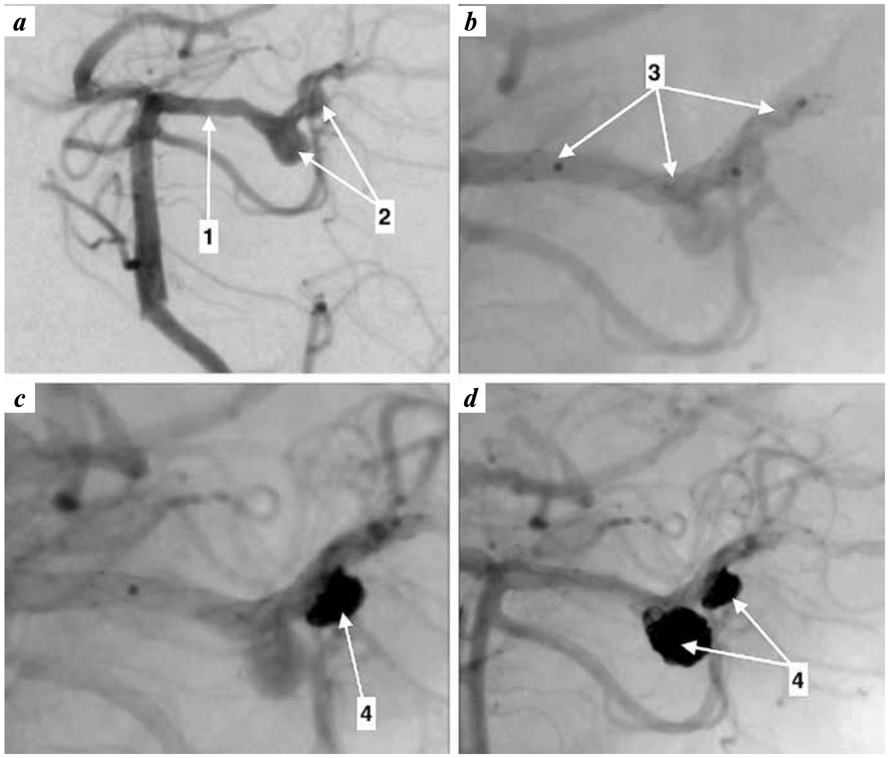

Fig. 3. *Embolization of the posterior cerebral artery (PCA) aneurysm with stent assistance: a – cerebral angiogram, oblique projection; b – stent placement; c – embolization with coils of the 1st aneurysm; d – embolization with coils of the 2nd aneurysm. 1 – PCA; 2 – PCA aneurysms; 3 – stent in PCA; 4 – aneurysms embolized by coils*

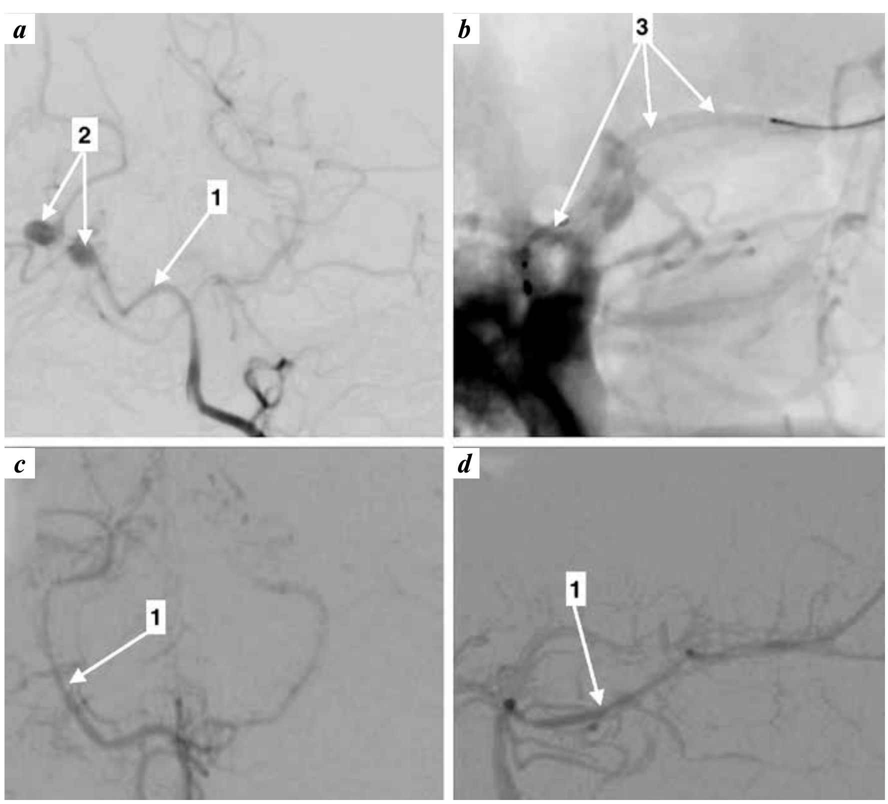

Fig. 4. *Installation of flow-diverter stent in case of aneurysm of the posterior cerebral artery (PCA): a – cerebral angiogram (CAG), direct projection; b – installation of flow-diverter stent; c – CAG, direct projection, control 3 months later; d – CAG, lateral projection, control 3 months later. 1 – PCA; 2 – PCA aneurysms; 3 – flow-diverter stent*

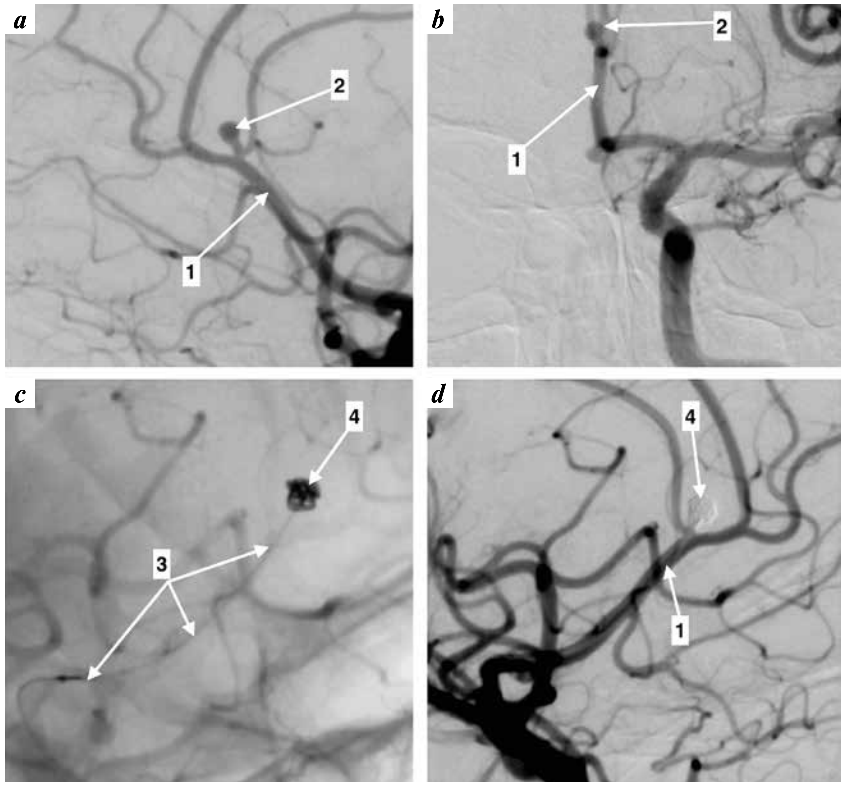

Fig. 5. *Embolization by coils of the pericallosal artery (PA) aneurysm with rupture: a – cerebral angiogram (CAG), lateral projection; b – CAG, direct projection; c – installation of microcatheter into the aneurysm cavity and introduction of coils; d – total embolization of PA aneurysm. 1 – PA; 2 – aneurysm of A3 PA segment with narrow (1.8 mm) neck; 3 – microcatheter in the PA and aneurysm cavity; 4 – coils in the aneurysm cavity*

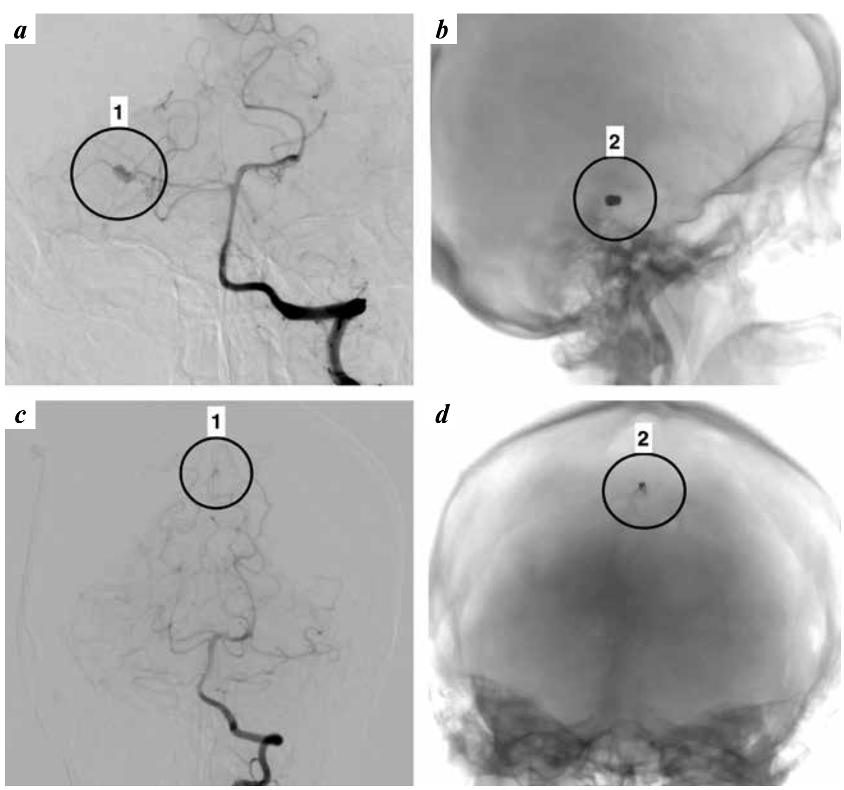

Fig. 6. *Embolization of distal aneurysm of the posterior cerebral artery (PCA) together with the parent artery: a – cerebral angiogram, oblique projection; b–d – embolization by coils. 1 – aneurysm of the P4 segment of the PCA; 2 – coils in the aneurysm cavity*

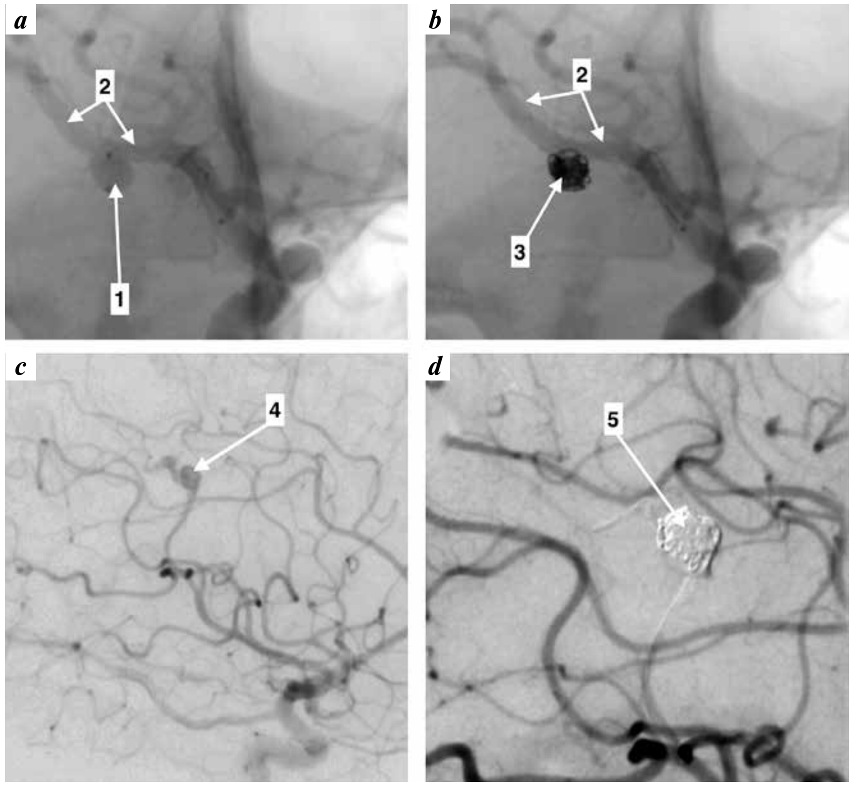

Fig. 7. *Embolization of distal aneurysms of the middle cerebral artery (MCA): a, b – embolization of the M2 segment MCA aneurysm using coils and stent; c, d – embolization of the M4 segment MCA aneurysm together with the parent artery. 1 – aneurysm of the MCA M2 segment; 2 – stent in the lumen of M2 segment; 3 – coils in the cavity of the M2 segment aneurysm; 4 – aneurysm of the MCA M4 segment; 5 – coils in the lumen of the MCA M4 segment aneurysm*

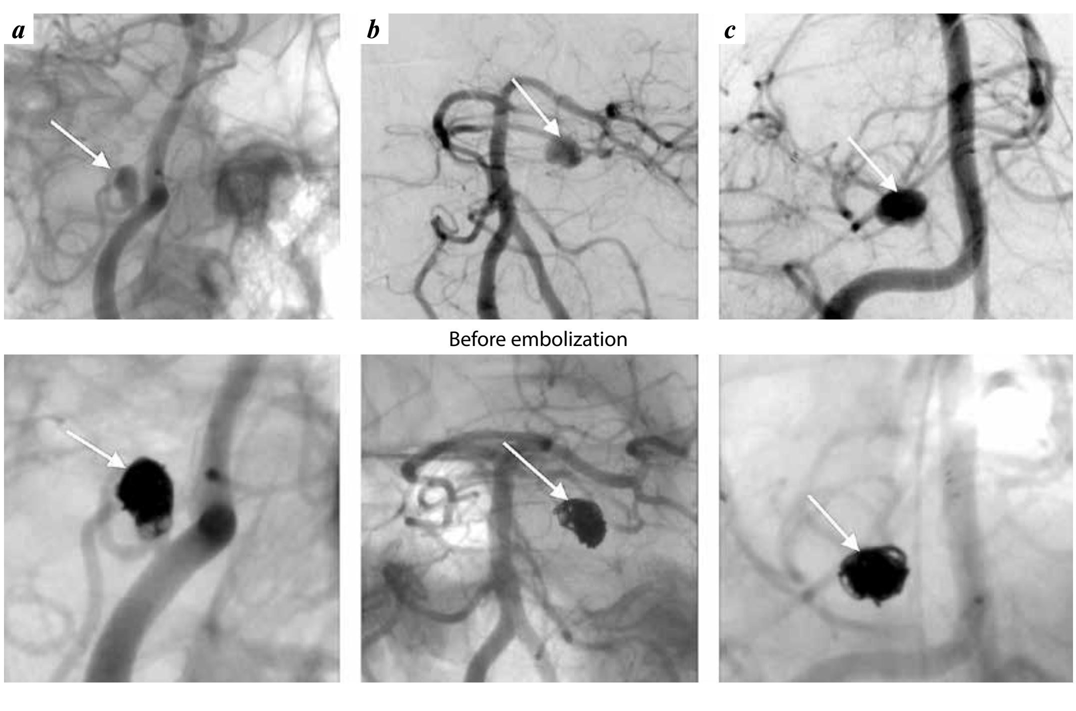

Fig. 8. *Embolization of distal cerebellar artery aneurysms: a – embolization of aneurysm of the P2 segment of the posterior inferior cerebellar artery with preservation of the artery lumen; b – embolization of aneurysm of the S2 segment of the upper cerebellar artery with preservation of the artery lumen; c – embolization of aneurysm A2 segment of the anterior inferior cerebellar artery with artery occlusion. Arrows indicate cerebellar artery aneurysms before and after embolization*

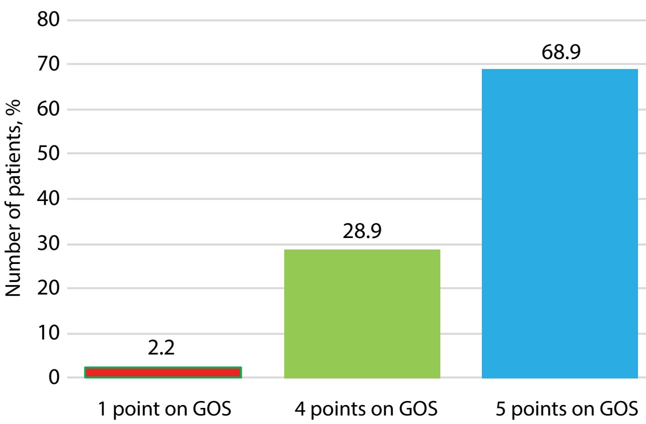

Fig. 9. *Results (outcomes) of endovascular treatment of distal aneurysms of the brain (n = 45). GOS – Glasgow Outcome Scale*

In case of ruptured aneurysms of PA and PCA, the use of the above mentioned techniques is not always safe due to risk of stent thrombosis and/or delayed occlusion of the aneurysm. At the same time, modern achievements in pharmacological disaggregant therapy and improvement of assistive devices might reduce these problems to a minimum. In our work, we used the coil embolization or occlusion of the parent artery more often in cases of ruptured distal aneurysms of PCA and PA (Fig. 5, 6).

In our study, the distal MCA aneurysms were embolized only in 3 cases, which is due to greater availability and traditional approaches to treatment of these aneurysms by open surgery. At the same time, the M2-segment of the MCA aneurysms were successfully reconstructively embolized by the use of coils with or without assisted techniques, and the M4-segment of the MCA aneurysm in a seriously ill patient was embolized by the use of closure of the parent artery (Fig. 7).

The cerebellar artery aneurysms have a small diameter and a tortuous course that also complicates endovascular manipulations in their lumen. In our study, we performed embolization of 8 distal cerebellar artery aneurysms: 2 of the posterior inferior cerebellar artery, 3 of the anterior inferior cerebellar artery and 3 of the superior cerebellar artery (Fig. 8). Embolization of these aneurysms more often resulted in occlusion of the parent artery (in 3 of 8 cases). At the same time, only 1 patient with occlusion of the posterior inferior cerebellar artery showed appearance of neurological symptoms that almost completely regressed by the time of discharge (GOS – 4 points).

Thus, the use of existing embolization techniques is possible not only for typical proximal aneurysms, but also for distal ones.

Results of endovascular treatment of distal aneurysms. The results of surgical treatment, of course, depend not only on the treatment method used, but also on the structure of the analyzed group of treated patients with distal aneurysms. Given that patients are admitted to federal neurosurgery centers either in the delayed period of hemorrhage or with unruptured aneurysms, the results of treatment might predict to be better than in regional vascular centers. In our study, only 7 of 15 patients with ruptured distal aneurysm were admitted and treated (with embolization) in the acute period of hemorrhage (during the first 14 days).

Good results of treatment in our work were obtained in 97.8 % of cases (Fig. 9).

There was 1 fatal outcome as a result of rupture of the PCA aneurysm during embolization and decrease in the level of wakefulness after surgery to atonic coma.

The main types of neurological deficits at the time of hospital discharge (4 points according to GOS) were moderate coordination disorders after embolization of cerebellar artery aneurysm, visual disturbances after embolization of PCA aneurysms, paresis (up to 4 points) as a result of cerebral angiospasm after embolization of ruptured MCA and PA aneurysms, and a slight decrease in the mnestic-intellectual abilities after subarachnoid hemorrhage.

CONCLUSION

In the present work, we demonstrated the technical capabilities of endovascular embolization of distal cerebral aneurysms with good treatment outcomes. Development of capabilities of endovascular surgery allows closing off from the bloodstream those aneurysms which may be difficult to access during open surgery that is especially important in patients with hemorrhage and those in serious condition.

It is important to conduct a study of endovascular treatment of distal cerebral aneurysms at the regional vascular centers in cases of aneurysm rupture and compare the results of treatment with those after open surgery.

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Authors' contribution

I.V. Senko: research design development, data obtaining, processing and analysis, article writing;
V.S. Kisilev: data obtaining and analysis, scientific editing of the article;
A.O. Sosnov, P.D. Matveev: editing of the article;
A.M. Perfiliev, P.Yu. Ivanova: data obtaining and processing;
D.A. Rzaev: research design development.

ORCID of authors

I.V. Senko: https://orcid.org/ 0000-0002-5743-8279
V.S. Kisilev: https://orcid.org/0000-0002-7406-9874
A.M. Perfilyev: https://orcid.org/0000-0002-4065-5736
P.D. Matveev: https://orcid.org/0000-0002-1114-6238
D.A. Rzayev: https://orcid.org/0000-0002-1209-8960

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