Open Surgery for Recurrent Intracranial Aneurysms: Techniques and Long-Term Outcomes

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BACKGROUND: After occlusion of an aneurysm, a patient may experience aneurysm regrowth at the same site or develop de novo aneurysms. We present our experience in microsurgery of recurrent aneurysms with analysis of long-term results.

METHODS: The senior authors (R. T. and H. K.) performed recurrent aneurysm clipping on 44 patients at Teishinkai Hospital and Asahikawa Red Cross Hospital in Sapporo, Japan. Operative techniques included clipping only, clipping and protective bypass, trapping of aneurysm with bypass, proximal occlusion, and bypass. Postoperative outcome was analyzed retrospectively using the modified Rankin Scale.

RESULTS: Our series included 10 men (23%) and 34 women (77%), with a mean patient age of 63 years (range, 7–82 years). Before primary treatment, 11 patients (25%) had a ruptured aneurysm, while 33 patients (75%) had an unruptured aneurysm. The mean follow-up time after primary surgery was 7.6 years (range, 0.8–25 years). At our department the treatment of recurrent aneurysm included the clipping in 19 patients (43%), clipping with bypass in 6 patients (14%), aneurysm trapping with bypass in 10 patients (23%), and proximal occlusion and bypass in 9 patients (20%). The mean follow-up time after surgical treatment of recurrent aneurysms stood at 3.5 years (range 0.1–9 years). Altogether, 37 patients (84%) experienced favorable outcomes at last follow-up examination (modified Rankin Scale scores 0 and 1).

CONCLUSIONS: Microsurgery of recurrent aneurysms may be performed safely and effectively, as shown by our study, in which 84% of patients experienced favorable results.

INTRODUCTION

The surgical treatment of a previously clipped or coiled cerebral aneurysm represents one of the most difficult tasks in vascular neurosurgery. Although rare after successful initial treatment, recurrent aneurysms continue to be diagnosed due to the increasing availability of noninvasive angiographic screening worldwide. According to the literature, the incidence of aneurysm regrowth after clipping ranges from 0.02%–0.52% annually. Residual or recurrent aneurysm still carries a risk of subarachnoid hemorrhage (SAH) varying from 1.4%–2.2% within 10 years and from 9%–12.4% within 20 years depending on the history of rupture before initial treatment. A considerable long-term risk of SAH indicates active treatment when a progressive regrowth of an aneurysm occurs. Decision making regarding retreatment modalities varies depending on the institutional protocols and personal experience of the neurosurgeon. A general trend toward endovascular treatment of aneurysms diminishes the likelihood that neurosurgeons will perform repeat clipping due to significant technical difficulty and fear of complications.

Our study aims to show that meticulous planning of an open surgical procedure and utilization of very high magnification and skilled microsurgical techniques provide safe and effective...
treatment, confirming the importance of open microneurosurgery to treat this demanding condition.

METHODS

Between January 2005 and February 2014, the senior authors (R. T. and H. K.) performed recurrent aneurysm clipping on 44 patients at Teishinkai Hospital and Asahikawa Red Cross Hospital in Sapporo, Japan. Most patients initially received treatment elsewhere and were referred to the senior authors for further treatment when a residual/recurrent aneurysm was found. Patients with a recurrent aneurysm were included in the study regardless of the primary treatment modality (open microsurgery or endovascular treatment). Preoperative and postoperative assessment included comprehensive neuroradiologic examination of the cerebral vasculature including computed tomography (CT) angiography with 3D reconstruction and magnetic resonance angiography. Aneurysms <5 mm in size were considered small; from 5–14 mm, medium; from 15–24 mm, big; and ≥25 mm, giant. The strategy for the surgical procedure was based on the location, size, and initial treatment modality of the aneurysm because coiled aneurysms usually required bypass assistance. We analyzed patients’ clinical data retrospectively. We assessed the postoperative outcomes using the modified Rankin Scale (mRS). Univariate analyses of factors predicting outcomes was performed using Pearson’s χ² test and the Mann-Whitney U-test. We used SPSS for Windows version 16.0 (SPSS, Inc., Chicago, Illinois, USA) for all statistical analyses and set the significance level at P < 0.05.

RESULTS

Our series included 10 men (23%) and 34 women (77%), with a mean patient age of 63 years (range, 7–82 years). Before primary treatment, 11 patients (25%) had a ruptured aneurysm, while 33 patients (75%) had an unruptured aneurysm. Securing the initial aneurysm was provided with clipping in 22 patients (50%), coiling in 20 patients (46%), wrapping in 1 patient (2%), and proximal ligation of the parent artery in 1 patient (2%). Size distribution was as follows: small—5 patients (11%), medium—21 patients (48%), big—13 patients (30%), and giant—5 patients (11%). The mean follow-up time after primary surgery was 7.6 years (range, 0.8–25 years). In the endovascular group, aneurysm regrowth required operative treatment on average 3.3 years (range, 1–25 years) after coiling, whereas in the microsurgical group, regrowth occurred on average 10.6 years (range, 0.8–24 years) after surgery.

Before surgery at our department, 3 patients (7%) experienced SAH. The mean size of aneurysms in this group was 5 mm (range, 5–10 mm). In the group experiencing unruptured recurrent aneurysms, 34 patients (77%) were asymptomatic, while the remaining 10 (23%) experienced progressive visual loss (3 patients or 7%), oculomotor palsy (1 patient or 2%), hemiparesis (2 patients or 5%), dysarthria (1 patient or 2%), dementia due to infarction after previous treatment (2 patients or 5%), and trigeminal neuralgia (1 patient or 2%). Among the asymptomatic group, the mean size of the aneurysms was 14 mm (range, 6–35 mm), whereas in the symptomatic unruptured group, the mean size was 28 mm (range, 12–60 mm).

Surgery was performed using the neurovascular microinstrument set (Kamiyama–Tanikawa set), the Kamiyama high-pressure irrigation-suction system, and an operating microscope (Mitaka Koki, MM80) allowing magnification of up to 25× (Figure 1, A–C). Opening of the skin was performed under an operating microscope in order to achieve perfect hemostasis and spare the superficial temporal artery (STA) or occipital artery if present after a previous surgery. A bone flap was removed, and the tightly attached underlying dura or dural patch installed during the first surgery was exposed. In the repeat craniotomy at the same site as the primary surgery, the bony opening was extended enough to allow for the safe intracranial dissection of the target area. Further steps depended on the strategy applied to treat the aneurysm using clipping and/or bypass assistance if necessary. The distribution of patients according to the surgical option used appears in Table 1.

Clipping Only

The clipping-only technique sufficiently secured aneurysms in 19 patients (43%). The main factors predetermining this strategy included the small-sized (6 of 19 cases or 32%) and medium-sized (10 of 19 cases or 53%) aneurysm sacs (P = 0.005), a lack of larger branches extending from the aneurysmal dome, and a suitable location for the safe dissection of the aneurysm using the related arteries. Only 2 patients (10%) with a large and 1 patient (5%) with a giant aneurysm were considered for clipping only. In every case, the prerequisite for direct clipping included the possibility of reconstructing the neck of the aneurysm, allowing for the application of perfect clip(s) (Figures 2 and 3).

Neck Clipping with Protective Bypass

We used neck clipping with protective bypass in 6 patients (14%). The decision to perform a protective bypass was based on a preoperative assessment of the risks of inadvertent damage or occlusion of such important branches like the ophthalmic or anterior choroidal arteries when dissecting the anterior circulation vasculature or the posterior cerebral or the posterior inferior cerebellar artery in the posterior circulation.

Aneurysm Trapping with Bypass Reconstruction

Trapping without bypass reconstruction may be unpredictable regarding postoperative ischemic complications even when patients tolerate preoperative occlusion tests well. This is particularly the case in the M2 and M3 branches of the middle cerebral artery (MCA). Ten patients (23%) underwent aneurysm trapping requiring bypass reconstruction. Indications for this technique included a large or giant-size dome occurring in 4 patients (40%) and 3 patients (30%), respectively. Typically, these aneurysms restricted access to the proximal artery or the related branches (Figure 4). One patient with a large fusiform recurrent aneurysm and segment wall sickness required trapping and bypass. In 3 patients (30%) with a medium-sized aneurysm, the same strategy was necessary due to an increased risk of parent branch occlusion after clipping.

Proximal Occlusion and Bypass

When branches extend outward from the aneurysm dome, we prefer using proximal occlusion of the parent artery supported by bypass reconstruction to provide undisturbed blood flow in the related vasculature. In such cases, trapping carries significant risks of
ischemic complications. We utilized proximal occlusion and bypass in 9 patients (20%). Among these cases, 3 aneurysms (33%) were giant, two (22%) were large, and four (45%) were medium sized. Six of the nine aneurysms (67%) were located in the basilar artery.

Coiled Aneurysms
When operating on coiled aneurysms, a marked adherence of the dome to the surrounding structures was typical, with frequent aneurysm sac penetration and coil extrapolation into the subarachnoid space. After temporary clipping, we opened the aneurysm and extruded coils using special coil scissors developed by the senior author (H. K.) and the SONOPET device (Figure 5, A–D). After total disengagement of the coils and thrombus, an aneurysm neck was reconstructed and clipped in 7 of 20 patients (35%). In 2 patients (10%), the bypass procedure was necessary to provide the safe coil removal and neck clipping, whereas trapping or proximal occlusion and bypass was necessary in 5 patients (25%) and 6 patients (30%), respectively.

Bypass Procedure
In total, 25 patients (57%) underwent the bypass procedure for clipping recurrent aneurysms. A low-flow bypass (LFB) was performed in 15 of 25 cases (60%). High-flow bypass (HFB) with or without a combination of LFB was performed in 8 cases (32%). In 2 cases (8%), an in situ bypass technique was carried out. Large and giant aneurysms indicated the bypass procedure in eight (32%) and six (24%) cases, respectively. Eleven medium-sized aneurysms (44%) were operated on using bypass, whereas none of the small aneurysm required bypass assistance. As a donor vessel, we used a branch of the ipsilateral STA in LFB and the radial artery or saphenous vein in HFB. The indications for LFB included the trapping of the aneurysm of small caliber arteries and for the protection of the distal blood flow in parent artery during HFB. In later cases, LFB was sutured to the distal frontal branch supplying the motor cortex in order to diminish the risk of hemodynamic impairment should problems occur during HFB suturing to the more proximal arteries. HFB was used only when STA was absent due to previous surgery.

Surgical Outcome
After surgery, all patients were imaged with CT, CT angiography, and magnetic resonance imaging in order to prove the complete securing of the aneurysm and bypass patency, as well as to rule out ischemic complications. In all cases, bypass was patent postoperatively. Immediately after surgery, 27 patients (67%) experienced no new neurologic deficits; 23% experienced new neurologic deficits including hemiparesis, cranial nerve palsy, or visual acuity impairment (Table 2). The mean follow-up time after surgical treatment of recurrent aneurysms stood at 3.5 years (range, 0.1–9 years). At last follow-up, 32 patients (73%) were neurologically intact without disability and 5 patients (11%) had only minor deficits causing a slight disability (Tables 1 and 2).
Altogether, 37 patients (84%) experienced favorable outcomes (mRS, 0 and 1). Notably, all patients (100%) with small aneurysms and 19 of 21 patients (91%) with medium-sized aneurysm were neurologically intact at last follow-up ($P = 0.049$). A similar outcome was found in 4 of 10 patients (40%) and in 3 of 7 patients (43%) with a large and giant aneurysm, respectively. Furthermore, 30 of 34 patients (88%) with anterior circulation aneurysms and 7 of 10 patients (70%) with posterior circulation aneurysms experienced favorable postoperative outcomes (mRS, 0 and 1). Among 25 patients who underwent the bypass procedure, 14 (56%) had a larger or giant aneurysm. After surgery, 18 patients (72%) in the bypass group had a favorable outcome. Finally, 18 of 19 patients (95%) with the aneurysm treated through clipping only (due to its smaller size and suitable location) were neurologically intact at last follow-up ($P = 0.025$).

**DISCUSSION**

The development of aneurysms should not be considered a once-in-a-lifetime event, but rather a continuous process.6,7 Even after the successful total occlusion of an aneurysm, a patient may experience aneurysm regrowth at the same site or develop de novo aneurysms, which carry the risk of SAH. The literature on this topic shows that the recurrence rate after complete clipping varies from 0.02%—0.53% annually.1,5,7,8 Furthermore, a 9%—12.4% risk of SAH within 20 years after surgery has been found depending on the history of rupture before initial treatment.75 In unruptured, incompletely clipped aneurysms, the risk of growth and rupture remains unknown. The incidence of aneurysm recurrence after coiling due to compaction is even higher and comprises 14%—28% depending on various factors.9,14 Of note, inflow aneurysms located in the basilar artery bifurcation or paracoidl nidus segment of internal carotid artery (ICA) are at a much higher risk of recurrence after coiling.9,15 The mechanisms of coil compaction may include the insufficient endothelization of the luminal surface of the aneurysm neck.16,17 In addition, a larger aneurysm size before the initial procedure and its location in the posterior circulation or in ICA seems to correlate with higher rates of compaction.18

Although the indications for recoiling are not yet clearly established, reports have shown that endovascular retreatment may carry low morbidity and mortality rates.19 On the contrary, we consider additional repetitive coiling ineffective in providing long-term securing of the aneurysm, which may instead increase the risk of procedure-related complications including rupture and distal thromboembolism as previously reported.20

The mechanisms of aneurysm regrowth after clipping are manifold. Clip slippage may occur when the aneurysm neck is wide and strongly calcified or when the neck is grasped with the distal third of the clip blades, where the compression force is weakest.7,9,21 Some historical cases of silver-clip fracture due to corrosion have been reported.22 According to Ebina et al.,23 fragility of the vascular wall at the clip edge may lead to regrowth in the setting of hemodynamic stress. Several reports considered the role of vasa vasorum in the growth of thrombosed giant aneurysms in cases of recurrence.24,25 Arterial medial wall defects and hypertension may play a role in aneurysm recurrence or the development of de novo aneurysms.21,26

**Indications for Surgery**

The microsurgical treatment of recurrent aneurysms is safer when performed in tertiary centers of excellence because it requires exclusive expertise in vascular neurosurgery. When analyzing a case, many factors should be taken into account, including the patient’s condition, age, the size and site of a recurrent aneurysm, the rupture state, and the patient’s and patient’s relatives’ wishes. In our opinion, when a patient is independent in his or her daily life and otherwise somatically in good condition, surgical treatment may be considered reasonable despite an advanced age (older than 75 years). Undoubtedly, the size of the aneurysm remnant represents a key factor determining the treatment strategy. We believe surgical treatment is indicated when the size of the filling of the recurrent aneurysm is $\geq 3$ mm. Furthermore, in accordance with previous reports, we think that a residual neck of 1—2 mm is worth close screening due to the risk of aneurysm recurrence after a long period of time.27

When postcoiling regrowth occurs, especially in the case of large and broad-neck aneurysms with a high risk of coil compaction, we recommend open microsurgery as the first option to prevent further SAH. We have faced several cases of progressive coil-mass penetration throughout the aneurysm sac, resulting in

| Table 1. Characteristics of Aneurysm Procedures in 44 Patients |
|-----------------|-----------------|-----------------|-----------------|
|                  | Clipping        | Protective       | Trapping        | Occlusion       | |
| Patients, number (%) | 19 (43) | 6 (14) | 10 (23) | 9 (20) |
| Mean size, mm     | 8.7           | 16.3           | 19.5           | 22.3           |
| Size distribution, number (%) | $P = 0.037$ |
| Small             | 6 (32) | 0       | 0       | 0       |
| Medium            | 10 (53) | 3 (50) | 3 (30) | 4 (44) |
| Big               | 2 (11) | 2 (33) | 4 (40) | 2 (22) |
| Giant             | 1 (5) | 1 (17) | 3 (30) | 3 (34) |
| Location, number (%) | $P = 0.001$ |
| Anterior circulation | 17 (89) | 6 (100) | 8 (80) | 3 (33) |
| Posterior circulation | 2 (11) | 0       | 2 (20) | 6 (67) |
| Bleeding history, number (%) |
| Ruptured          | 3 (16) | 0       | 0       | 0       |
| Unruptured        | 16 (84) | 6 (100) | 10 (100) | 9 (100) |
| Last follow-up modified Rankin Scale, number (%) |
| 0                 | 18 (95) | 4 (67) | 5 (50) | 5 (56) |
| 1                 | 1 (5) | 0       | 3 (30) | 1 (11) |
| 2                 | 0     | 2 (23) | 2 (20) | 1 (11) |
| 3                 | 0     | 0       | 0       | 1 (11) |
| 4                 | 0     | 0       | 0       | 1 (11) |
an unreasonable number of attempts at endovascular treatment that failed to provide a final solution. Instead, coil compaction and the lack of neck endothelization suggest that the endovascular approach in such situations is ineffective, requiring open surgery. When operating on previously coiled recurrent aneurysms, we commonly find a strongly degraded and paper-thin aneurysm wall, which is consistent with other reports. Furthermore, as a striking finding, we also frequently noticed signs of perifocal inflammation and arachnoiditis around the dome of the coiled aneurysm. Importantly, the lack of endothelization and arachnoiditis around the aneurysm cannot be directly visualized by angiography because it shows only “shadows” from the coils and contrasted blood.

The benefits of prophylactic aneurysm occlusion should be meticulously weighed against the risks associated with treatment regardless of its modality. The need for a detailed discussion is strongly emphasized in such cases, requiring wisdom and patience from the neurosurgeon or neurointerventionalist.

Microsurgical Treatment

On the basis of our experience, recurrent aneurysms may be successfully treated by microsurgical means regardless of the
technical difficulty associated with the procedure. Indeed, 73% of our patients were neurologically intact after surgery on a recurrent aneurysm. The meticulous planning of surgery combined with flawless clipping allows us to safely secure an aneurysm. In cases requiring a repeated procedure, dissection of the target area is commonly onerous because the neurosurgeon deals with the conglomeration of old clips, vessels, and surrounding brain or cranial nerves incorporated into tight scar tissue. This requires an extremely high level of dexterity and surgical experience. Using a high magnification on the surgical microscope, a bloodless operative field ensures a more reliable identification of the involved structures. Tiny but important perforating arteries are often obscured within scar adhesions, and their painstaking detachment from the surrounding areas while dissecting the aneurysm is essential to avoiding ischemic complications after surgery.

Five important steps during the procedure should be meticulously planned for repeat cases. These include 1) dissection toward the aneurysm, 2) bypass assistance if necessary, 3) mobilization of the old clip(s), 4) removal of coils and thrombus, and 5) placement of the new clip(s).

**Step 1: Dissection Toward the Aneurysm.** We performed dissection via the pterional approach using different modifications according to the aneurysm site for most of the cases included in our study. In the transsylvian approach, the use of high magnification is important in order to avoid damage to the superficial Sylvian veins. Their occlusion may lead to postoperative venous。

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**Table 2. Postoperative Course in 44 Patients**

<table>
<thead>
<tr>
<th>Neurologic Symptoms</th>
<th>Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No new symptoms</td>
<td>29 (66)</td>
</tr>
<tr>
<td>Temporary hemiparesis</td>
<td>4 (9)</td>
</tr>
<tr>
<td>Permanent hemiparesis</td>
<td>2 (5)</td>
</tr>
<tr>
<td>Temporary oculomotor palsy</td>
<td>3 (7)</td>
</tr>
<tr>
<td>Permanent oculomotor palsy</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Permanent trochlear nerve palsy</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Visual acuity impairment</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Worsening*</td>
<td>2 (5)</td>
</tr>
<tr>
<td>Improvement†</td>
<td>1 (2)</td>
</tr>
</tbody>
</table>

*Giant and big basilar artery aneurysm patients.
†Improved trigeminal neuralgia in giant basilar artery aneurysm patient.
congestion and venous infarction in the affected region. If damage occurs, we prefer to not coagulate the vein but rather control the bleeding using either available hemostats (Surgicel or Gelfoam) or a microsuture to close the bleeding site. When opening the Sylvian fissure, sharp dissection with microscissors supplemented by dynamic retraction of a suction-irrigation tube is advised. The surgical view is kept clean with almost continuous irrigation of the dissected area. Such a technique allows for better visualization of the neural structures and small vessels under a surgical microscope. Superficial Sylvian veins, the deep Sylvian vein, branches of the MCA, the temporal lobe uncus, and the oculomotor nerve usually interfere with the view of the transsylvian approach, indicating the meticulous dissection and mobilization of these structures. Importantly, the vessels and cranial nerves should be dissected sufficiently long enough; otherwise, manipulation during clipping and retraction may cause stretching or even a rupture at the site where their segments are attached to the scar. If anterior clinoidectomy is necessary, we prefer the extradural removal of the clinoid process with exposure of the optic canal and intracavernous portion of the proximal ICA followed by cutting the distal and proximal dural ring. Exposure of the aforementioned structures allows for the safe mobilization of vessels while clipping the aneurysm. After approaching the proximal segment of the parent artery, the aneurysm dome and old clips are visualized and dissected from adherence.

**Step 2: Bypass Assistance.** Meticulous analysis of preoperative images allows for an assessment of the need for bypass in order to avoid major ischemic complications after clipping. The decision depends on various factors, including the size and site of the recurrent aneurysm, number of previous procedures, and severity of atherosclerotic changes in the cerebral vasculature. In general, complex cases with several failed attempts to secure the aneurysm usually indicate the need for bypass assistance because prolonged temporary clipping or the need for trapping is highly expected. In our experience, patients who underwent a bypass procedure recovered worse than those whose surgery included clipping only (e.g., some disability at follow-up in 44% and 5%, respectively, of patients). However, this difference is expected because, in the bypass group, 54% of patients had a large or giant recurrent aneurysm, an entity carrying extremely high surgical risks a priori.

To ensure distal blood circulation, LFB or HFB is used. The selection of bypass types depends on the diameter of the parent vessels distal to the aneurysm and the existence of collateral flow for the adequate supply of the affected region. Usually, occlusion of branches distal to the first and farther divisions (M2, P2, A2, etc.) do not necessitate HFB. By contrast, ICA, basilar, or vertebral arterial complex recurrent aneurysms may require the HFB procedure if preoperative balloon occlusion tests show insufficient collateral flow.

STA is the most common donor vessel when performing LFB via anterior approaches. In HFB, we prefer to use a radial artery graft because its diameter approximates the diameter of intracranial ICA and it lacks valves. By contrast, the saphenous vein graft diameter is usually significantly larger, which, in our opinion, increases the risk of hyperperfusion syndrome or intracranial hemorrhage after surgery.

A recurrent ICA aneurysm may be treated with a “double-insurance bypass” if indicated. This includes LFB and HFB sutured to the ipsilateral M2 branches subsequently. One of the greatest benefits of such a strategy is the possibility for direct monitoring of MCA blood pressure after the suturing of STA to MCA. Pressure is measured through a small catheter inserted into the side branch of the STA graft. Occlusion of STA proximal to this side branch after a graft is sutured to M2 allows direct measurement of the blood pressure in the MCA vasculature. Further temporary occlusion of ICA provides blood pressure monitoring in HFB. We call this strategy “double insurance” because the blood pressure in the HFB graft directly corresponds to the perfusion of the supplied region, whereas other tools such as intraoperative indocyanine green videoangiography or dopplerography may yield false-positive results. A contrasted vessel may show filling, but quantitative estimation of perfusion is not informative, which is also the case when the sound of the flow is measured using Doppler sonography. Alternatively, a Charbel microflow probe may also allow direct measurement of graft functioning, which may show the flow parameters in milliliters per minute. Comparing the measurements before and after applying HFB provides useful information for the control of periprocedural regional perfusion.

When bypass grafts are sutured and the blood pressure in the affected vessels is controlled, the neurosurgeon may safely proceed to further operative steps, namely, to dissection and removal of the old clip(s).

**Step 3: Mobilization of the Old Clip(s).** In our opinion, the old clips should be removed. This is due to the fact that, frequently, old clips obscure the aneurysm rests, disturbing new clip application and interfering with the surgical view. Typically, old clips are surrounded by stiff connective tissue. However, even if a clip has been in place for many years, it always can be cleaned from the covering connective tissue. We use a small scalpel and microscissors, which are effective in cutting the scar against the smooth metallic surface of the clip (Figure 6). Usually, dissection is initiated from the spring of the clip, which appears in the surgical view first with the further release of the blades. It is worthwhile to free the blades completely before opening the old clip. Otherwise, any remaining attachments to the aneurysm may cause its rupture when attempting to remove the clip. Some authors suggest that the removal of a previously applied clip is always required to completely secure the aneurysm. If many clips are applied during primary surgery, their removal may require longer, temporary occlusion of the patent artery, necessitating bypass to replace the blood flow distally.

**Step 4: Removal of Coils and/or Thrombus.** Removal of coils and/or thrombus is necessary for the appropriate placement of the final clip and for eliminating the mass effect. Coil removal can be performed only through the opening of the aneurysm sac, which requires either temporal clipping of the affected segment or clipping of the neck. The latter option can be ineffective because coils might prevent the complete closing of the clip blades and the aneurysm may bleed after opening the sac. As a rule, coils are densely attached to each other and to the inner surface of the aneurysm wall, making their removal laborious. This may be
facilitated by cutting the coils into multiple pieces using specially designed coil-cutting microscissors. Next, the coils are removed in a piecemeal fashion. Recently, we successfully used an ultrasound device (SONOPET) to disrupt the coils. While using SONOPET in such situations, its power and suction settings are put to the maximum level, so the tip of the device should remain inside the aneurysm when switched on in order to prevent any inadvertent damage to surrounding structures. After the total removal of coils and thrombus, the neck of the aneurysm is visualized and dissected for placement of the final clip.

Step 5: Final Clipping. The final clipping of a recurrent aneurysm is usually performed using multiple clips aimed at complete neck occlusion. In some cases, total occlusion is not always possible due to the perforating arteries branching from the sac of the recurrent aneurysm. This requires proper adjustment to the clips’ position in order to reach maximal occlusion of the aneurysm, while leaving a small possible aneurysm rest supplying the important branch. A thick and atherosclerotic aneurysm wall may necessitate suturing of the edges of the incised sac in order to facilitate clip placement at the neck. Final clipping is performed through different combinations of regular or fenestrated clips using such techniques as tandem clipping or multiple fenestrated clipping. When bypass assistance is not established, these techniques may be difficult to perform safely due to the risk of the prolonged temporary clipping of the parent artery. Bypass ensures sufficient distal flow, and the neurosurgeon has more freedom to adjust the clips to the best possible position.

Surgical Outcome
In our study, 84% of patients experienced a favorable postoperative course (mRS, 0 and 1), which supports the safety and efficacy of the microsurgical approach in the management of recurrent aneurysms. Limitations of the study are its small number of patients and single-center–based analysis. Some prospective studies show similar or even better outcomes after endovascular treatment when compared with open surgery. However, we find that not all recurrent aneurysms are amenable to coiling.

CONCLUSIONS
The treatment of recurrent aneurysms should be centralized to tertiary centers of excellence in order to achieve the best results. Microsurgery of recurrent aneurysms may be performed safely and effectively, as shown by our study, where 84% of patients experienced favorable results despite the extreme difficulty characterizing such surgery. The appropriate selection of patients, meticulous preoperative planning, and flawless surgical procedures ensure an uneventful postoperative course. The surgical risks should be weighed against the estimated natural course of the disease. Further studies are needed to understand the mechanisms of aneurysm recurrence after primary treatment.


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