Endovascular Coil Embolization of Cerebral Aneurysm Remnants After Incomplete Surgical Obliteration

Alejandro A. Rabinstein, MD; Douglas A. Nichols, MD

Introduction—The presence of an aneurysm remnant after incomplete or unsuccessful surgical clipping is associated with persistent risk of regrowth and rupture, and additional treatment is generally recommended. Attempts at surgical re-exploration are technically difficult and carry significant risk. Endovascular therapy can represent a valuable therapeutic alternative in these cases.

Methods—We reviewed the information on 21 patients with postsurgical aneurysm remnants treated at our institution with endovascular coil occlusion between 1991 and 2000. Clinical outcome was measured using the modified Rankin scale. Statistical analysis of outcome predictors was performed using the two-tailed Fisher exact test.

Results—Sixty-seven percent of the aneurysms were located in the anterior circulation. The median aneurysm size at the time of surgery was 9.9 mm (range 3 to 35 mm). The mean size of the aneurysm remnants before coiling was 6.4 mm (range 3 to 14 mm). Endovascular coiling resulted in total occlusion of the remnants in 81% of the cases. No major complications were associated with the endovascular treatment. Seventy-two percent of patients left the hospital without any functional impairment (modified Rankin scale 0 to 1). No cases of subarachnoid hemorrhage or symptomatic aneurysmal regrowth were noted after endovascular treatment over a mean follow-up of 22 months. Presence of disability or death was associated with an initial (presurgical) presentation with subarachnoid hemorrhage (P=0.04) and an interval between incomplete clipping and endovascular coil embolization ≤1 month (P=0.0005).

Conclusion—Endovascular coil occlusion of postsurgical aneurysm remnants is a safe and efficacious therapeutic alternative in selected cases. Postoperative angiography to identify aneurysm remnants that may be amenable to endovascular treatment should be considered in all patients. (Stroke. 2002;33:1809-1815.)

Key Words: aneurysm ■ endovascular therapy ■ surgery

Treatment of cerebral aneurysms aims at completely obliterating their lumen, thus permanently excluding the entire aneurysm from the arterial circulation. Although microsurgical clipping is usually successful in achieving this goal, postoperative aneurysm remnants can occur in 4% to 8% of patients who undergo angiography after surgery.1–11 These remnants are associated with persistent risk of hemorrhage from rupture and may also grow over time and produce symptoms by compressing neighboring structures. Although small, the danger of bleeding after incomplete aneurysm clipping persists for years and may result in serious and even fatal consequences.2–4,7,12–14

Over the last 10 years, remarkable progress has been made in the field of endovascular treatment. Technological advances continue to make it possible for a growing number of patients with cerebral aneurysms to be treated with a variety of endovascular strategies, most notably using electrolytically detachable platinum coils (Guglielmi detachable coils [GDCs]). Moreover, endovascular and surgical approaches are not mutually exclusive, and complex intracranial aneurysms are sometimes best treated by combining both techniques.15–17

Reoperation has been traditionally advocated in patients with incompletely obliterated aneurysms after clipping.3,7 However, these surgeries are often technically difficult and associated with an increased rate of complications.3,13 In addition, patients may not be medically stable for a second craniotomy or may refuse the procedure. Endovascular embolization has been successfully performed in patients with postoperative aneurysm remnants, and it may represent an excellent alternative to further surgery in such cases.16,18–23

We report the cumulative experience in our center using GDCs for the treatment of residual aneurysm after incomplete or unsuccessful clipping.

Materials and Methods

We collected information on all consecutive patients with aneurysm remnants after surgical clipping treated endovascularly at Saint Marys Hospital (Mayo Clinic, Rochester, NY) between the years 1991 and 2000. All patients were referred for endovascular treatment by experienced cerebrovascular neurosurgeons at our institution. Reasons for referral included presence of aneurysm remnant on postoperative angiogram, progressive enlargement of the remnant with associated mass effect, or new subarachnoid hemorrhage. In most cases surgical

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TABLE 1. Summary of Clinical and Radiological Information of Patients With Endovascular Treatment of Aneurysm Remnants After Surgical Clipping

<table>
<thead>
<tr>
<th>Case</th>
<th>Age/Sex</th>
<th>Initial Presentation</th>
<th>Initial Size, mm</th>
<th>Location</th>
<th>Interval</th>
<th>Reason for Referral</th>
<th>Remnant Size, mm</th>
<th>Degree of Occlusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25/F</td>
<td>Mass effect (VFC, HA)</td>
<td>35</td>
<td>ICA</td>
<td>7 months</td>
<td>Worse mass effect</td>
<td>12</td>
<td>Complete</td>
</tr>
<tr>
<td>2</td>
<td>53/M</td>
<td>Mass effect (VFC)</td>
<td>6</td>
<td>ICA, AChA</td>
<td>9 months</td>
<td>Postop angiogram</td>
<td>5</td>
<td>Complete</td>
</tr>
<tr>
<td>3</td>
<td>38/F</td>
<td>SAH (WFNS 1)</td>
<td>7</td>
<td>VBJ</td>
<td>8 years</td>
<td>Regrowth on angiogram</td>
<td>8</td>
<td>Near-complete</td>
</tr>
<tr>
<td>4</td>
<td>46/M</td>
<td>SAH (WFNS 3)</td>
<td>7</td>
<td>PCoA</td>
<td>1 week</td>
<td>Postop angiogram</td>
<td>5</td>
<td>Complete</td>
</tr>
<tr>
<td>5</td>
<td>46/F</td>
<td>SAH (WFNS 1)</td>
<td>10</td>
<td>BA apex</td>
<td>11 years</td>
<td>Incidental</td>
<td>7</td>
<td>Complete</td>
</tr>
<tr>
<td>6</td>
<td>65/M</td>
<td>SAH (WFNS 2)</td>
<td>10</td>
<td>ACoA</td>
<td>10 years</td>
<td>Incidental</td>
<td>8</td>
<td>Complete</td>
</tr>
<tr>
<td>7</td>
<td>43/F</td>
<td>SAH (WFNS 3)</td>
<td>?</td>
<td>ACoA</td>
<td>15 years</td>
<td>Incidental</td>
<td>7</td>
<td>Complete</td>
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<tr>
<td>8</td>
<td>30/M</td>
<td>Mass effect (HA)</td>
<td>14</td>
<td>ICA bifurcation</td>
<td>7 months</td>
<td>Regrowth on angiogram</td>
<td>14</td>
<td>Complete*</td>
</tr>
<tr>
<td>9</td>
<td>42/F</td>
<td>SAH (WFNS 1)</td>
<td>3</td>
<td>ACoA</td>
<td>1 month</td>
<td>Recurrent SAH (WFNS 5)</td>
<td>3</td>
<td>Complete</td>
</tr>
<tr>
<td>10</td>
<td>44/M</td>
<td>SAH (WFNS 4)</td>
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<td>Recurrent SAH (WFNS 2)</td>
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<td>Complete</td>
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<tr>
<td>11</td>
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<td>BA trunk</td>
<td>26 years</td>
<td>SAH (WFNS 1)</td>
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<tr>
<td>12</td>
<td>55/F</td>
<td>Mass effect (visual loss)</td>
<td>15</td>
<td>ICA, ophthalmic</td>
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<td>8</td>
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<td>13</td>
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<td>VBJ</td>
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<td>Regrowth on angiogram</td>
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<tr>
<td>14</td>
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<td>7 days</td>
<td>Postop angiogram</td>
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<tr>
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<td>ACoA</td>
<td>4 days</td>
<td>Postop angiogram</td>
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<td>Complete</td>
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<tr>
<td>16</td>
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<td>Mass effect (visual loss)</td>
<td>6</td>
<td>ICA, ophthalmic</td>
<td>3 months</td>
<td>Postop angiogram</td>
<td>3</td>
<td>Complete</td>
</tr>
<tr>
<td>17</td>
<td>61/F</td>
<td>SAH (WFNS 3)</td>
<td>4</td>
<td>PICA</td>
<td>10 days</td>
<td>Postop angiogram</td>
<td>4</td>
<td>Complete</td>
</tr>
<tr>
<td>18</td>
<td>59/F</td>
<td>Incidental</td>
<td>10</td>
<td>BA apex</td>
<td>5 years</td>
<td>Possible SAH</td>
<td>12</td>
<td>Near-complete</td>
</tr>
<tr>
<td>19</td>
<td>63/M</td>
<td>Incidental</td>
<td>8</td>
<td>ACoA</td>
<td>4 years</td>
<td>Incidental</td>
<td>7</td>
<td>Complete</td>
</tr>
<tr>
<td>20</td>
<td>42/M</td>
<td>SAH (WFNS 2)</td>
<td>20</td>
<td>ACoA</td>
<td>1 day</td>
<td>Postop angiogram</td>
<td>6</td>
<td>Complete</td>
</tr>
<tr>
<td>21</td>
<td>52/F</td>
<td>SAH (WFNS 4)</td>
<td>5</td>
<td>BA apex</td>
<td>7 days</td>
<td>Postop angiogram</td>
<td>3</td>
<td>Complete</td>
</tr>
</tbody>
</table>

ACA indicates anterior choroidal artery; ACoA, anterior communicating artery; BA, basilar artery; F, female; HA, headache; hydro, hydrocephalus; ICA, internal carotid artery; M, male; PCoA, posterior communicating artery; PE, pulmonary edema; PICA, posterior inferior cerebellar artery; Postop, postoperative; SAH, subarachnoid hemorrhage; TIA, transient ischemic attack; VBJ, vertebrobasilar junction; VC, vocal cord; VFC, visual field cut; and VSP, vasospasm.

*Delayed occlusion by thrombosis of residual lumen.

Clipping had been performed in our center (16 patients), but 5 patients had undergone clipping at another hospital.

We gathered data regarding age at the time of coiling, sex, initial clinical presentation at the time of surgery, initial aneurysm size, aneurysm location, reason for referral for endovascular treatment, interval between surgery and coiling, size at the time of coiling, degree of aneurysm occlusion after endovascular embolization, complications from the endovascular procedure, clinical outcome assessed at the time of hospital discharge using the modified Rankin scale,24 time of clinical follow-up, and time to last angiographic follow-up. Severity of subarachnoid hemorrhages was defined using the World Federation of Neurological Surgeons (WFNS) grading system.25

Technique

All procedures were performed under general anesthesia in a dedicated interventional neuroangiography suite with biplane fluoroscopy, digital subtraction angiography (DSA), and road-mapping capabilities. Using a modified Seldinger technique, 6F arterial sheaths were placed in one or both femoral arteries. A baseline angiogram was obtained that optimally demonstrated the neck of the aneurysm remnant and its relationship to the parent vessel, it was generally maintained for road-mapping purposes throughout the duration of the procedure. A microcatheter was then advanced over a microguidewire under road-mapping guidance into the aneurysm remnant. If the aneurysm remnant had a wide neck, the balloon-assisted neck remodeling technique was used.26 GDCs were then advanced and detached in the aneurysm remnant until it was not technically possible to advance an additional GDC without it protruding into the parent vessel. Serial DSA were obtained throughout the procedure to monitor the progress of aneurysm remnant occlusion. Once the aneurysm remnant was deemed to be satisfactorily occluded, all catheters were removed through the femoral sheaths after obtaining a final DSA. The femoral sheaths were then removed from the femoral arteries and hemostasis was obtained with a vascular closure device. Anticoagulation was allowed to reverse spontaneously. In general, heparinization was not routinely continued after the procedure. The patients were awakened from general anesthesia and then admitted to the neuro-intensive care unit for 24-hour observation and monitoring. Patients were discharged 24 to 48 hours after the procedure unless they were still recovering from the sequelae of a recent subarachnoid hemorrhage. Angiographic follow-up was routinely recommended, and these studies were available in all but 5 patients in this series.

Statistical analysis of outcome predictors was performed using the 2-tailed Fisher exact test and the level of significance was established by $P<0.05$.

Results

Twenty-one patients with aneurysm remnants after surgical clipping were treated with endovascular embolization using
GDCs. A summary of the clinical and radiological information is provided on Table 1. Sixty-two percent of the patients were women, and the mean age at the time of coiling was 51 years (range 25 to 84 years). Thirteen patients (62%) had initially presented with subarachnoid hemorrhage; of those, 5 were WFNS grade 1, 2 were WFNS grade 2, 3 were WFNS grade 3, 2 were WFNS grade 4, and in 1 individual not enough information was available for grading. In the remaining cases, the aneurysms had been originally identified secondary to symptoms of local mass effect (29%) or incidentally (9%).

The aneurysms were located in the anterior circulation in 14 patients (67%), and they were multiple in 4 cases (19%). The median aneurysm size at the time of surgery was 9.9 mm (range 3 to 35 mm). The intervals between surgery and subsequent endovascular treatment were very variable, ranging between 1 day and 26 years. Eight patients were treated endovascularly ≤1 month after incomplete clipping. The reason for referral for endovascular embolization was the presence of residual aneurysm on postoperative angiograms in 8 cases, increasing size of remnants on serial follow-up angiograms in 4, new or recurrent subarachnoid hemorrhage in 4, incidental recognition of an unsuspected remnant on images obtained for a different indication (headaches, intracranial atherosclerosis, or syncope) in 4, and worsening mass effect in 1. The mean size of the aneurysm remnants before coiling was 6.4 mm, with a range between 3 and 14 mm.

Fifteen of the 21 aneurysm remnants treated were fully obliterated after embolization. In 2 additional patients, small remnants that had persisted after coiling subsequently developed thrombosis leading to complete obliteration of the aneurysms. Overall, endovascular coiling resulted in total

<table>
<thead>
<tr>
<th>TABLE 2. Clinical Predictors of Disability or Death After Endovascular Treatment in Patients With Incompletely Clipped Aneurysms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clinical Outcome</strong></td>
</tr>
<tr>
<td>After Clipping</td>
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<tr>
<td>mRs &lt;2</td>
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<tr>
<td>mRs ≥2</td>
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</table>
| mRs indicates modified Rankin scale; SAH, subarachnoid hemorrhage; n, number of patients.
occlusion of the aneurysm in 81% of the cases. In the remaining 4 patients, total occlusion of the aneurysm remnant could not be achieved; however, endovascular embolization led to a marked reduction in residual aneurysm size in every case. Follow-up angiography was obtained immediately after the procedure in all patients and at later times in 76% of them. In those patients who underwent late angiographic studies, the mean interval to the last angiography was 21 months (range 8 days to 5.5 years).

No major complications occurred during or immediately after endovascular coil embolization. Two patients received treatment with papaverine during the procedures because of the presence of vasospasm. One patient had recurrent transient ischemic episodes starting within days of a successful basilar apex aneurysm remnant embolization. The symptoms resulted from a left posterior cerebral artery occlusion and resolved spontaneously 2 months later. This was the only case of vessel occlusion after endovascular treatment documented in the current series.

Fifteen patients (72%) left the hospital without any functional impairment (modified Rankin scale 0 to 1). Three patients (14%) had slight or moderate disability (modified Rankin scale 2 to 3) at the time of discharge, and 3 patients (14%) died in the hospital (modified Rankin scale 6). In all cases, persistent disability or demise was secondary to the effects of subarachnoid hemorrhage, delayed ischemic injury from vasospasm (prior to coil placement), mass effect from the aneurysm or complications from surgery, and not directly related to the endovascular intervention. Causes of death were delayed ischemic brain damage in 2 cases (one complicated with secondary reperfusion hemorrhage) and pulmonary embolism in 1. Clinical follow-up after hospital discharge was available in all but 1 patient, with a mean follow-up time of 22 months (range 40 days to 5.5 years). No cases of subarachnoid hemorrhage or symptomatic aneurysmal regrowth were noted after endovascular treatment.

Presence of disability or death was associated with an initial (presurgical) presentation with subarachnoid hemorrhage ($P=0.04$) and an interval between incomplete clipping and endovascular coil embolization $\leq 1$ month ($P=0.0005$) (Table 2). No statistical correlation was found between clinical outcome and original aneurysm size, size of postsurgical remnant, aneurysm location, reason for referral for endovascular treatment, or degree of aneurysm occlusion after coil placement.

Case Illustrations

Case 19
A 63-year-old man was referred for evaluation of asymptomatic atherosclerotic disease involving both carotid bifurcations, with progressive severity demonstrated on serial carotid duplex examinations. Four years before this referral, he had undergone a left carotid endarterectomy for left cerebral hemisphere transient ischemic attacks. Preoperative angiography at that time revealed a 6×7-mm anterior communicating artery aneurysm (Figure 1A). The aneurysm was surgically clipped several weeks after the left carotid endarterectomy. A postoperative angiogram was not obtained. The patient made a good recovery after both surgical procedures.

On referral, an angiogram was obtained as a prelude to left carotid angioplasty and stenting. It demonstrated a deeply ulcerated recurrent atherosclerotic lesion involving the distal left common carotid artery and left carotid bulb over a 4-cm segment producing a focal area of 70% stenosis (not shown), an ulcerated atherosclerotic plaque involving the proximal 2 cm of the cervical right internal carotid artery, also producing a similar degree of focal stenosis (Figure 1B), and a 4×7 mm...
recurrent or residual anterior communicating artery aneurysm remnant posterior to the aneurysm clip (Figure 1C) that opacified on the right carotid injection only. The recurrent left carotid atherosclerotic lesion was deemed not to be amenable to treatment with balloon angioplasty and stenting; therefore, it was surgically treated with an interposition graft.

Six weeks after the left carotid surgery, balloon angioplasty and stenting of the right carotid atherosclerotic disease was performed with a good angiographic result (Figure 1D). Six weeks after the right carotid angioplasty and stenting procedure, the anterior communicating artery aneurysm remnant was coiled. Five GDCs measuring a total length of 28 cm were detached in the residual lumen, resulting in total occlusion of the remnant (Figure 1E and 1F). Follow-up angiography (not shown) obtained 14 months after the coiling procedure demonstrated persistent total occlusion of the aneurysm remnant.

Case 16
A 53-year-old woman presented with a 1-year history of decreased visual acuity in the left eye. A brain magnetic resonance image (not shown) demonstrated a paraclinoidal left internal carotid artery aneurysm. An ophthalmologic evaluation demonstrated fundoscopic changes consistent with left optic atrophy, associated with mildly reduced visual acuity, and prolonged latency on visual evoked responses. A cerebral angiogram demonstrated a 4×6-mm left carotid–ophthalmic aneurysm that projected medially (Figure 2A and 2B). It was thought that the aneurysm could have been responsible for the patient’s left optic nerve damage. The aneurysm was surgically clipped and, at the same time, the left optic nerve was decompressed. Unfortunately, the patient had an acute deterioration of her left visual acuity and before discharge she had no light perception on her left eye, a condition that has persisted until the present. A postoperative angiogram demonstrated a 3-mm aneurysm remnant (Figure 2C and 2D).

The patient returned 3 months after hospital discharge for endovascular treatment of the aneurysm remnant. Two GDCs measuring a total length of 12 cm were detached in the aneurysm remnant utilizing the balloon-assisted neck remodeling technique. Immediate (not shown) and 6-month follow-up angiography (Figure 2E through 2H) demonstrated total occlusion of the aneurysm remnant.

Discussion
We report our experience using endovascular embolization with GDCs for the treatment of cerebral aneurysm remnants after incomplete surgical clipping. In this series, endovascular coil embolization resulted in complete aneurysmal occlusion in 17 of 21 treated patients (81%) and near-complete occlusion in the remaining 4. There were no serious complications related to endovascular treatment. Clinical outcomes were generally favorable and all treated aneurysms remained asymptomatic after coiling for the duration of the follow-up (mean 22 months, range 40 days to 5.5 years). Poor outcomes were significantly associated with a history of subarachnoid hemorrhage before the original surgery and a short interval (≤1 month) between clipping and endovascular coiling. We
speculate that the latter association can be explained by a greater clinical severity of those patients who required early additional treatment (8 patients composed this group; of these, 4 had severe vasospasm and 2 had recurrent subarachnoid hemorrhage after clipping).

The persistence of aneurysm remnants after surgical clipping may result from technical or anatomic difficulties at the time of surgery, slippage of a placed clip, or regrowth of an aneurysmal sac from an incompletely excluded neck.\textsuperscript{3,7,13} These remnants are sometimes recognized or suspected in the operating room but cannot be treated because of limitations imposed by the configuration or location of the aneurysm. In other cases, however, residual aneurysmal filling is unexpectedly identified on immediate or delayed postoperative angiography after a presumably successful clip placement. Although valuable, intraoperative angiography carries a 4% false-negative rate for the detection of aneurysm remnants.\textsuperscript{27} Therefore, repeat postoperative angiography is always advisable after surgical clipping to confirm the complete obliteration of the aneurysm.\textsuperscript{5}

Although the natural history of incompletely clipped aneurysm over many years is not fully elucidated, several studies and reports have documented the danger created by aneurysm remnants.\textsuperscript{3,4,7,12,13} Drake et al\textsuperscript{3} reported 24 episodes of recurrent hemorrhage in a series of 115 reoperated patients after failed initial aneurysm surgery. On the basis of their study of 715 patients over a mean follow-up period of 8 years, Feuerberg et al\textsuperscript{4} derived an annual risk of rebleeding from study of 715 patients over a mean follow-up period of 8 years, after failed initial aneurysm surgery. On the basis of their of recurrent hemorrhage in a series of 115 reoperated patients year. Lin et al\textsuperscript{7} reported 14 patients with rebleeding from aneurysmal residua after surgical treatment of up to 0.8% per year. Lin et al\textsuperscript{7} reported 14 patients with rebleeding from aneurysms that had regrown after incomplete surgical treatment. In addition, enlarging remnants can produce compressive symptoms from local mass effect.\textsuperscript{3,7} Consequently, treatment of the aneurysm remnants is usually advocated, especially in young people.\textsuperscript{7} In our series, 5 patients (4 with subarachnoid hemorrhage and 1 with compressive symptoms) were referred for endovascular embolization as a result of new or recurrent neurological symptoms related to the incompletely clipped aneurysm.

Reoperative management of intracranial aneurysms often presents formidable challenges to the cerebrovascular surgeon. Not infrequently, anatomic or technical difficulties encountered during the original surgery account for the persistence of an aneurysmal remnant. Additionally, scars or dense adhesions surrounding the aneurysm may further complicate a second surgery, especially when there has been a prolonged interval between surgical interventions.\textsuperscript{3} Rates of 7% for major morbidity and 5.2% for mortality were reported in the largest series of reoperated patients currently available in the literature.\textsuperscript{3} Clinical outcomes were poor after reoperation in 3 of 19 and 7 of 19 patients in 2 other series.\textsuperscript{7,13} Intraoperative rupture also seems to be more common during second operations,\textsuperscript{13} whereas it was not observed in any of our endovascularly treated patients.

Our series represents the largest reported experience of endovascular coil embolization after incomplete surgical clipping. A number of case reports and small case series from other groups\textsuperscript{16,17,19–23} confirm the feasibility and safety of this treatment strategy, and a comparison of their combined experience with ours is presented in Table 3. Although these initial results are promising, reliable evaluation of efficacy will require a much longer follow-up, because it is well known that bleeding from remnants can occur many years after treatment.\textsuperscript{2,3,13}

As endovascular techniques continue to evolve, they now offer an alternative to surgical clipping in the management of cerebral aneurysms. They can also be a useful adjunct to surgery in the treatment of complex aneurysms that can be best handled through a combined approach. Surgical and endovascular strategies can be successfully integrated into a single therapeutic plan, the order of the interventions depending on the particular characteristics of each patient.\textsuperscript{15,16} This is particularly true in cases of aneurysm remnants, when not only endovascular embolization can complete the occlusion.
of partially clipped aneurysms but also surgery can be performed after incomplete endovascular coiling.28–30

In conclusion, our experience using GDCs for obliteration of aneurysm remnants has been very favorable. We observed no complications directly related to the endovascular procedure and were able to achieve total occlusion of the aneurysm remnant in most cases. Patients had excellent clinical outcomes except those with complications from surgery or prior subarachnoid hemorrhage. Although studies with more extensive follow-up are still necessary to confirm its long-term effectiveness, endovascular coil embolization should be regarded as a valuable adjunctive tool for the treatment of aneurysm remnants after incomplete surgical clipping.

References
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