Endovascular Treatment With Bare Platinum Coils for Middle Cerebral Artery Aneurysms

Hidenori OISHI, Kensaku YOSHIDA, Takashi SHIMIZU, Munetaka YAMAMOTO, Naoaki HORINAKA, and Hajime ARAI

Department of Neurosurgery, Juntendo University School of Medicine, Tokyo

Abstract

Middle cerebral artery (MCA) aneurysms often have unfavorable anatomical characteristics preventing successful endovascular occlusion. We reviewed the outcomes of our series of endosaccular embolization of MCA aneurysms using bare platinum coils, angiographic images, and medical records. Immediate and follow-up angiographic results were categorized as complete occlusion, residual neck, and residual flow. Follow-up angiographic changes were categorized as unchanged, minor or major recurrence, and progressive thrombosis. Between December 2001 and August 2007, 112 patients with 113 MCA aneurysms underwent endovascular treatment, of whom 60 presented with subarachnoid hemorrhage (SAH) due to MCA aneurysm rupture. Immediate angiographic outcomes for 103 aneurysms revealed complete occlusion in 64, residual neck in 21, residual flow in 18, and failed embolization in 10. Follow-up angiography of 70 aneurysms demonstrated 41 unchanged, 10 minor recurrences, 12 major recurrences, 7 progressive thromboses, and no bleeding of coil embolized aneurysms. Outcomes of 58 SAH patients treated endovascularly revealed 45 good recovery and moderate disability, 10 severe disability or persistent vegetative state, and 3 deaths. Forty-four of the 45 patients with unruptured aneurysms treated endovascularly had no changes in their neurological status. One of 5 patients with complications had permanent morbidity. For patients with MCA aneurysms suitable for endovascular surgery, bare platinum coil embolization can be performed with acceptable low morbidity and mortality rates, with a lower risk of postprocedural aneurysmal bleeding.

Key words: bare platinum coil, endovascular embolization, middle cerebral artery aneurysm

Introduction

The International Subarachnoid Aneurysm Trial (ISAT)\cite{14,15} has proven the superiority of endovascular treatment for ruptured cerebral aneurysms compared with surgical clipping. However, surgical clipping remains the first treatment of choice for middle cerebral artery (MCA) aneurysms because of the unfavorable angioarchitecture for endovascular surgery, such as unfavorable dome/neck ratio (<2) or incorporation of adjacent branches, as well as the proximity to the cerebral surface permitting easy accessibility. Aneurysms located on the MCA account for 18% to 22% of all intracranial aneurysms.\cite{11,12,27} Nevertheless, MCA aneurysms comprised only 14.1% of all 2,143 aneurysms in the ISAT study.\cite{14}

The present study reviewed our technical results and clinical outcomes to evaluate the safety and efficacy of endovascular surgery for MCA aneurysms.

Materials and Methods

Six hundred ninety-four patients with 717 aneurysms were treated by endovascular surgery with bare platinum detachable coils between December 2001 and August 2007 at the Juntendo University Hospital and its affiliated facilities. Among them, 112 patients (mean age ± standard deviation [SD], 60.3 ± 12.4 years; 39 males and 73 females) harbored 113 MCA aneurysms including 60 ruptured and 53 unruptured aneurysms, and 1 patient had bilateral MCA aneurysms. The 60 patients with subarachnoid hemorrhage (SAH) due to rupture of MCA aneurysms were classified according to the Hunt and Hess scale,\cite{8} grade I in 12 patients, II in 25, III in 13, IV in 8, and V in 2. Two patients in grade IV at the time of written consent for coil embolization became grade V due to rebleeding immediately before the procedure. Although our criteria did not indicate patients in grade V for coil embolization, we treated them to comply with the family’s wishes.
Table 1 Characteristics of 112 patients with 113 middle cerebral artery aneurysms

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male:female ratio</td>
<td>39:73</td>
</tr>
<tr>
<td>Mean age (yrs)</td>
<td>60.3 ± 12.4</td>
</tr>
<tr>
<td>Ruptured/unruptured aneurysms</td>
<td>60/53</td>
</tr>
<tr>
<td>Hunt and Hess grade</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>12 (20)</td>
</tr>
<tr>
<td>II</td>
<td>25 (41.7)</td>
</tr>
<tr>
<td>III</td>
<td>13 (21.7)</td>
</tr>
<tr>
<td>IV</td>
<td>8 (13.3)</td>
</tr>
<tr>
<td>V</td>
<td>2 (3.3)</td>
</tr>
<tr>
<td>Mode of presentation of unruptured aneurysms</td>
<td></td>
</tr>
<tr>
<td>incidentally detected</td>
<td>38 (71.7)</td>
</tr>
<tr>
<td>associated lesion of another ruptured aneurysm</td>
<td>14 (26.4)</td>
</tr>
<tr>
<td>recurrence after clipping</td>
<td>1 (1.9)</td>
</tr>
<tr>
<td>Aneurysm size</td>
<td></td>
</tr>
<tr>
<td>mean (mm)</td>
<td>5.4 ± 2.3</td>
</tr>
<tr>
<td>&lt;5 mm</td>
<td>54 (47.8)</td>
</tr>
<tr>
<td>5–10 mm</td>
<td>55 (48.7)</td>
</tr>
<tr>
<td>&gt;10 mm</td>
<td>4 (3.5)</td>
</tr>
</tbody>
</table>

*Values in parentheses are percentages.

The 52 patients had 53 unruptured MCA aneurysms detected as incidental lesions in 38 aneurysms, associated with another ruptured aneurysm in 14, and recurrent lesion after clipping in 1. Aneurysm sizes ranged from 2 to 11 mm (mean ± SD, 5.4 ± 2.3 mm); 54 were less than 5 mm, 55 between 5 to 10 mm, and 4 were larger than 10 mm. These characteristics are summarized in Table 1.

A retrospective review of angiographic images, medical records, outpatient charts, and operative records was performed to determine the technical results, periprocedural complications, and clinical outcomes. The decision regarding surgical treatment (clipping versus coiling) was made by the first author (H.O.) based on either digital subtraction angiography with multiple projections or three-dimensional (3D) computed tomography angiography. The patient selection criteria for coil embolization included a clearly recognized aneurysm neck separate from the surrounding vessels, and size between 2 and 20 mm. However, to a large extent, the patient selection depended on the physician’s experience. The exclusion criteria included Hunt and Hess grade V, intracerebral hematoma requiring surgical relief of mass effect, contraindication for using contrast medium for cerebral angiography, presence of voluminous intra-aneurysmal thrombus, and consent refusal by the patient or family member. Fusiform aneurysms, distal MCA aneurysms, and mycotic aneurysms treated with parent artery obliteration were excluded from this study.

Patients with SAH underwent endovascular surgery as soon as possible after admission. All procedures were performed under general anesthesia and systemic heparinization was initiated in all patients, except those with intraparenchymal hematoma, to maintain activated clotting time between 250 and 300 seconds throughout the procedure after the placement of the femoral sheath. Systemic heparinization was stopped at the end of the procedure in most patients. However, heparinization was prolonged for 24–48 hours after the procedure in patients with a wide-necked aneurysm or periprocedural thromboembolic complications. Patients with unruptured aneurysm were given oral aspirin 100 mg a few hours prior to the procedure and this was continued for 1–3 months. Basically, the standard endovascular technique was performed if a satisfactory embolization result could be expected. Adjunctive techniques such as balloon-remodeling or double-catheter techniques were used for aneurysms with unfavorable angioarchitecture for which the standard technique was expected to be unsuccessful.

Neuroimaging follow-up studies were performed at 3 months with magnetic resonance (MR) angiography, and at 6 months, 1 year, and 2 years with conventional angiography. MR angiography was substituted for conventional angiography if the patient’s condition was thought to be unsuitable or if the patient refused repeated conventional angiography. Evaluations of anatomical outcomes were previously described. In brief, if the neck and sac of the aneurysm were completely occluded, this was defined as complete occlusion. If the contrast medium slightly entered the neck, but did not fill the body of the aneurysm, it was defined as residual neck. If contrast medium appeared in the body and dome of the aneurysm, it was defined as residual flow. Attempted embolization occurred if the coils were not placed into the aneurysm because of technical difficulties such as vessel tortuosity or instability of coil placement.

Results

Endovascular surgery for aneurysms was feasible in 102 patients with 103 MCA aneurysms (91.2%). The standard technique was used in 70 (68.0%), the balloon-remodeling technique in 21 (20.4%), and the double-catheter technique in 12 (11.7%). The balloon-remodeling technique used a very high-compliance balloon catheter (HyperForm; Micro Therapeutics, Irvine, Calif., U.S.A.). The Guglielmi detachable coil (GDC; Boston Scientific, Fremont, Calif., U.S.A.) was mainly used. Endovascular surgery was attempted but failed in 10 patients with 10 aneurysms because of unfavorable aneurysm an-
Coil Embolization for MCA Aneurysms

Illustrative Cases

Case 1: A 68-year-old female initially presented with headache, and was referred to our department for treatment of an unruptured left MCA bifurcation aneurysm (Fig. 1A). The patient was given oral aspirin 100 mg a few hours before the procedure. Near complete occlusion of the aneurysm was achieved using the standard technique with 14 10-type GDCs (total length 104 cm) (Fig. 1B). Systemic heparinization was not reversed, and she was transferred to the intensive care unit without neurological deficits. Two hours after the end of the procedure, she developed progressive right hemiparesis and global aphasia. Urgent angiography revealed occlusion of the adjacent M2 branches (Fig. 1C), so selective thrombolysis was performed as soon as possible using urokinase 120,000 IU. Complete recanalization was achieved (Fig. 1D) and she made an immediate full neurological recovery. She was discharged 2 weeks after the procedure without clinical complications.

Case 2: A 71-year-old male was referred to our hospital for endovascular treatment of incidentally detected bilateral asymptomatic MCA bifurcation aneurysms (Fig. 2A, B). The right and left aneurysms were treated by embolization with 5 10-type GDCs (16 cm) and 5 10-type GDCs (31 cm) using the standard procedure, resulting in complete occlusion and residual neck, respectively (Fig. 2C, D). The patient was discharged without neurological deficits and...
Fig. 1  Case 1. A: Left internal carotid angiogram showing a middle cerebral artery aneurysm measuring 7 mm in diameter. B: Left internal carotid angiogram immediately postembolization showing complete occlusion with patency of the M2 branches. C: Left internal carotid angiogram, performed urgently after the patient developed right hemiparesis and global aphasia, showing occlusion of the M2 branches. D: Left internal carotid angiogram after selective intra-arterial thrombolysis showing complete recanalization of the occluded M2 branches.

Fig. 2  Case 2. A, B: Right (A) and left (B) internal carotid angiograms showing small middle cerebral artery aneurysms. C: Right internal carotid angiogram immediately postembolization showing complete occlusion of the aneurysm. D: Left internal carotid angiogram after embolization showing residual neck. E–H: Follow-up magnetic resonance angiograms and axial source images taken 2 years after the treatment showing stable appearance of the coil embolized aneurysms without evidence of recanalization.

was clinically still doing well at the 2-year follow-up examination. The follow-up MR angiograms and axial source images showed stable appearance of the coil embolized aneurysms (Fig. 2E–H).

Case 3: A 68-year-old male was referred to us with Hunt and Hess grade II SAH due to rupture of a left MCA aneurysm. Left internal carotid angiography revealed a small irregularly shaped aneurysm (Fig. 3A). First, a 3D GDC (3 × 4) was delivered to make a stable cage, then 5 additional helical GDCs were placed with satisfactory occlusion (Fig. 3B–D). His postoperative course was uneventful, and he was discharged 3 weeks posttreatment without neurological deficits. Angiography at the 1-year follow-up examination revealed exclusion of the aneurysm from the parent circulation (Fig. 3E).

Discussion

Various studies have evaluated the endovascular
Coil Embolization for MCA Aneurysms

291

Fig. 3 Case 3. A: Left internal carotid angiogram showing a ruptured bi-lobed middle cerebral artery aneurysm. B: Left internal carotid angiogram showing a three-dimensional coil delivered to make an appropriate cage. C, D: Subtracted (C) and unsubtracted (D) left internal carotid angiograms immediately postembolization showing complete occlusion. E: Left internal carotid angiogram at the 1-year follow-up examination showing no recurrence of the aneurysm.

treatment of MCA aneurysms. Only 15% of MCA aneurysms treated endovascularly were successfully embolized, so that 85% were not.23) Only 16.1% of all MCA aneurysms were suitable for endovascular treatment on the basis of 3D imaging, but a complete occlusion rate of 86.8% was obtained in the selected cases.4) Furthermore, among 30 treated MCA aneurysms thought to be amenable to endovascular surgery, complete obliteration was achieved in 80% with no recurrence at the 6-month follow up. Treatment of MCA aneurysms by the endovascular technique was recommended for patients with favorable angioarchitecture.7) A total of 68 MCA aneurysms were treated in the Juntendo University Hospital during the study period. Among them, 30 aneurysms (44.1%) were treated with endovascular surgery and the remaining 38 aneurysms (55.9%) were treated with surgical clipping. The use of adjunctive techniques such as balloon-remodeling or stent-assisted techniques, and the introduction of novel coils with complex shapes and 3D structures are more likely to increase the proportion of MCA aneurysms treatable by the endovascular method.1) Experience of coil embolization for 149 MCA aneurysms found 96.8% feasibility including use of the balloon-remodeling technique in 44.3%.9) In the present series, we successfully treated 91.2% of the MCA aneurysms judged by the first author (H.O.) as

suitable for endovascular surgery by preprocedural anatomical evaluation. In Case 1, the working angle could not clearly show the aneurysm neck or the surrounding vessels due to their superimposition over the petrous portion of the left internal carotid artery. Therefore, branch occlusion occurred due to coil protrusion into the branch. Careful evaluation of the angioarchitecture using digital subtraction angiography performed in multiple projections and 3D angiography, which are available in most new-generation neurointerventional angiosuites, may be helpful for precise visualization of the aneurysm neck, shape, and size.

The complication rate of endovascular surgery for all intracranial aneurysms is between 12% and 15.4%.2) Furthermore, the rates of aneurysm perforation and thromboembolic events are 2.3% to 4.5% and 8.5% to 12.7%, respectively.2,3,6,17) Complications related to the endovascular technique occurred in 13 (25.5%) of 51 patients with MCA aneurysms, comprising 3 ruptures and 10 thromboembolisms.21) Only one intraprocedural rupture and one thromboembolic stroke occurred during the procedure in 30 patients with endovascularly treated MCA aneurysms.7) In the present study, the rates of intraprocedural aneurysm perforation and thromboembolic events were 1.8% and 2.7%, respectively, rather better than previously reported rates. Our series of endovascular surgery for MCA aneurysms showed that procedure-related permanent morbidity occurred in only 1 case (0.9%), and there were no mortalities. Thus, our results compared favorably to other large series of endovascular surgery for all intracranial aneurysms with morbidity and mortality rates of 4–8.9% and 1.3–4.8%, respectively.3,5,6,17,20)

Angiographic occlusion of MCA aneurysms widely varies. Complete occlusion was achieved in 41.8%, residual neck in 43.6%, and residual aneurysm in 14.6%.21) Embolization of 30 MCA aneurysms resulted in 80% complete occlusion and 20% partial occlusion.7) Complete occlusion was achieved in 33 (86.8%) of 38 MCA aneurysms that were primarily selected for coil embolization.4) Complete occlusion was achieved in 77.2%, near complete occlusion in 19.5%, and incomplete occlusion in 3.4% in a large study of 149 MCA aneurysms.9) Immediate angiographic outcomes for our present series demonstrated complete occlusion in 62.1%, residual neck in 20.4%, and residual flow in 17.5%. Comparison of our present series with others is difficult because all reports are retrospective, so have inherent limitations and biases. The evaluations of angiographic occlusion often differs between independent physicians. Furthermore, increasing experience and development of devices

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such as a very high-compliance balloon catheter and intracranial stents might lead to the improvement of immediate angiographic results without complications.

Recanalization or regrowth may develop even after the aneurysm has been completely occluded. Therefore, not only clinical follow-up but also radiological follow-up examinations are mandatory for patients who undergo coil embolization of cerebral aneurysms. Although major recurrence, which ideally requires re-treatment, occurred in 17.1% in the present study, we have never experienced patients who suffered aneurysmal bleeding during the clinical follow-up period. We believe that aneurysms embolized with coils are protected from rupture in the medium period.

A study of 413 patients with MCA aneurysms found that 94% of patients achieved good or excellent outcomes 6 months after the surgical treatment. However, half of the patients had good clinical grades and unruptured aneurysms. The International Cooperative Study reported that the mortality rate after surgical treatment for MCA aneurysms was lower than that for aneurysms located at other sites. In contrast, poor management outcomes after 1 year were found in 32% of 561 patients with MCA aneurysms compared with 25% for other anterior circulation aneurysms. One limitation of the present study is that we could not collect the data of MCA aneurysms treated surgically in our department. Moreover, the patients in this study had aneurysms that were predetermined to be suitable for coil embolization. For these reasons, we could not compare our results with our own surgical clipping of MCA aneurysms and those in affiliated hospitals. Global treatment results of endovascular surgery and surgical clipping for MCA aneurysms are also difficult to compare.

The results of this study indicate that endovascular surgery for MCA aneurysms is feasible with acceptable mortality and morbidity rates and can prevent future aneurysmal bleeding. We advocate that patient selection for endovascular surgery is of paramount importance. A prospective study with more rigorous indications and follow-up strategy is needed to definitively assess the feasibility and efficacy of endovascular surgery for MCA aneurysms.

Acknowledgment

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References

Coil Embolization for MCA Aneurysms

Commentary

The results achieved by the authors with endovascular occlusion of ruptured and unruptured MCA aneurysms rank among the best reported world-wide. In my opinion, at least two factors may have played a crucial role in obtaining such good outcome with low morbidity. One is the policy of establishing the indication for endovascular treatment by only one person (the first author of this article). This guarantees continuity in decision-making and certain reproducibility. The other is the fact that a significant number of MCA aneurysms have been treated over the past years, which is somewhat in contrast to previous traditions. Obviously, this is likely to yield the intended results by gradually accumulating experience with this heterogeneous group of rather difficult aneurysms. On the other hand, even with improved endovascular techniques and better clinical results with these procedures, I believe that microsurgical clipping should remain an important treatment modality also in the future; not only for MCA aneurysms but for these vascular lesions in general. It is, therefore, our duty to continue providing an adequate training in both endovascular coiling and microsurgical clipping of ruptured and unruptured aneurysms.

Helmut BERTALANFFY, M.D.
Department of Neurosurgery
University Hospital of Zurich
Zurich, Switzerland