Successful obliteration and shrinkage of giant partially thrombosed basilar artery aneurysms through a tailored flow reduction strategy with bypass surgery

Clinical article

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Object. The authors evaluated the efficacy of a new flow reduction strategy for giant partially thrombosed upper basilar artery (BA) aneurysms, for which proximal parent artery occlusion is not always effective.

Methods. Eight consecutive patients with severely symptomatic, partially thrombosed, giant upper BA aneurysms were treated with a tailored flow reduction strategy, or received conservative therapies. The flow reduction strategy comprised isolation of several branches from the upper BA at their origins with bypasses in addition to parent artery occlusion.

Results. The median follow-up period of all 8 patients was 15.0 months (range 4–31 months). In 6 patients treated with flow reduction, the mean decrease in residual blood lumen was $-10.7 \text{ mm} \ (95\% \text{ CI } -19.7 \text{ to } -1.7 \text{ mm}; p = 0.029)$ and the mean decrease in diameter of the aneurysms was $-11.5 \text{ mm} \ (95\% \text{ CI } -25.1 \text{ to } 2.1 \text{ mm}; p = 0.082)$. Complete or virtually complete thrombosis was achieved in all but 1 aneurysm (83%) and shrinkage was observed in 4 (67%). In those in whom complete or virtually complete thrombosis was achieved, significant shrinkage of the aneurysm was observed (mean decrease in diameter $-14.8 \text{ mm}; 95\% \text{ CI } -28.8 \text{ to } -8.8 \text{ mm}; p = 0.043$). Improvement or stabilization of symptoms occurred in 67% of the patients who received flow reduction treatment. Both patients who received conservative treatment had unfavorable outcomes.

Conclusions. The flow reduction strategy is effective at promoting complete thrombosis of the aneurysm. This strategy can also induce shrinkage of the aneurysm if successful thrombosis is achieved. Although the neurological outcome of the treatment appears favorable considering its intractable nature, further study of the treatment is necessary to confirm its clinical efficacy and safety. (DOI: 10.3171/2010.9.JNS10448)

Key Words • giant intracranial aneurysm • basilar artery • cerebral revascularization • extracranial-intracranial arterial bypass

The natural history of partially thrombosed giant aneurysms is extremely poor.4,5,7,26 Most such lesions progressively enlarge, much like malignant tumors,7 and result in irreversible progression of neurological deficits and fatal sequelae through resultant compression of the brainstem.2,3,23 Fatal SAH can occur even in a thrombosed aneurysm.5,22,27,30 Among such lesions, those in the upper BA are the most challenging to treat. The aneurysm usually incorporates 4 normal branches of the upper BA (bilateral PCAs and SCAs) or vital perforating arteries (Fig. 1A), which makes the lesions difficult to clip or trap.14 Although coil embolization of the aneurysm sac recently showed good outcome for BA aneurysms,21 the usefulness of coil embolization for partially thrombosed giant aneurysms is controversial because of the mass effect of the coil, the compaction of the coil, or the migration of the coil into the thrombus.9,18,29,30

The obliteration of the BA proximal to the SCA or the occlusion of bilateral VAs, which is known as hunte- rian occlusion, has been performed for such unclippable BA giant aneurysms (Fig. 1B).4,5,10,11,13,14,24–26 Obliterating the direct inflow from the basilar trunk by hunterian occlusion is believed to reduce the hemodynamic burden of the aneurysm and to promote complete thrombosis in the aneurysm sac, and therefore to reduce the size of the aneurysm.10 This strategy, however, has 2 problems. First, hunterian occlusion is not feasible for the patients with poor collateral networks including the PCoA if any EC-IC bypasses are not added.26 Second, even if hunterian

Abbreviations used in this paper: BA = basilar artery; BOT = balloon occlusion test; EC-IC = extracranial-intracranial; mRS = modified Rankin scale; PCA = posterior cerebral artery; PCoA = posterior communicating artery; SAH = subarachnoid hemorrhage; SCA = superior cerebellar artery; STA = superficial temporal artery; VA = vertebral artery.
occlusion is performed successfully with bypass surgeries, some lesions are refractory to the treatment because of persistent blood flows into the aneurysm sac (Fig. 1B).20,28,30

We previously reported a new strategy that effectively reduced the flow into the aneurysm and could be a successful salvage treatment for a giant partially thrombosed upper BA aneurysm refractory to hunterian occlusion.28 This strategy, called flow reduction, is supposed to reduce blood flow into an aneurysm through isolating several branches from the upper BA in addition to obliteration of the BA with staged procedures (Fig. 1C and D). However, the results of flow reduction strategy for the aneurysm have never been fully documented, and the safety and efficacy for the aneurysm has not been well clarified. In this study, we assess the radiological and neurological outcome of a series of giant partially thrombosed upper BA aneurysms to confirm whether the new strategy is effective for intractable aneurysms.

**Methods**

**Clinical Data**

The study population consisted of 8 consecutive symptomatic patients with giant partially thrombosed aneurysms at the upper BA who were admitted to the National Cardiovascular Center, Osaka, Japan, beginning in July 2003 (Table 1). Five aneurysms were identified at the BA bifurcation and 3 lesions at the bifurcation between the BA and the SCA. The diameter of all aneurysms was ≥ 25 mm. Preoperative CT scans or MR images of all the aneurysms revealed a thrombus in the aneurysmal sac. All of the patients suffered from progressive neurological
deficits due to enlargement of the lesions. Five patients had already received some previous surgical treatment including hunterian occlusion (Cases 2, 3, and 5) or coil embolization of the aneurysm sac (Cases 1 and 6) before the treatment, all of which failed to prevent progressive enlargement of the lesions and exacerbation of symptoms.

**Treatment Protocol**

Flow reduction treatment for the aneurysms is a tailored strategy consisting of occlusion of some terminal branches of the BA, the SCAs, and the PCAs at their origins in addition to hunterian occlusion. An EC-IC bypass such as an STA-SCA bypass or an STA-PCA bypass is needed for each branch targeted for occlusion without any collateral arteries. The purpose of this strategy is to reduce the blood flow around the aneurysm by isolating several of the upper basilar branches from the BA in addition to proximal BA obliteration (Fig. 1C and D), rather than simply altering the direction of blood flow around the aneurysm by hunterian occlusion (Fig. 1B). In principle, each branch from the upper BA is independently perfused by 1 bypass or 1 collateral artery after this treatment. Flow reduction strategies are classified into 2 types: 1) maximum flow reduction, in which the configuration of the aneurysm is transformed into a “blind-alley” formation by obliteration of all but 1 artery around the aneurysm (Fig. 1C); and 2) moderate flow reduction, in which the configuration of the aneurysm is transformed into a “slow-flow, sidewall-type” formation by obliteration of 1 or 2 arterial branches of the upper BA in addition to hunterian occlusion (Fig. 1D).

In all but 1 case (Case 2) treated with left-side surgery alone, multistage procedures were performed on both sides to complete flow reduction treatment. None of the patients underwent a BOT before flow reduction treatment. Neither an antplatelet nor an anticoagulation agent was administrated during the preoperative and postoperative periods. Flow reduction treatment was performed on those patients who consented to the treatment. The treatment and the study were performed according to our institution’s ethical guidelines.

**Radiological Evaluation**

Before the operation and in the follow-up examination, the diameters of the contrast filling in residual blood lumen in the aneurysms were measured on angiograms, and the maximum external diameters of the aneurysms (aneurysm size) were measured on axial T1-weighted MR images. The decrease in value was calculated by subtracting the postoperative residual blood lumen or the diameter of the aneurysm size from the preoperative value in each case. The efficacy of the treatment for thrombosis of the aneurysm was classified into the following 4 categories, according to the diameter of the contrast filling in residual blood lumen in the last follow-up angiogram:26 1) 0 mm = complete thrombosis; 2) < 5 mm of the lumen and contrast filling of only an ectatic aneurysmal base where major arteries emerged = virtually complete thrombosis; 3) > 5 mm = incomplete thrombosis; and 4) increase in size = enlarged residual lumen. The patency of the bypasses was also examined by angiography in all cases. The response to treatment in terms of aneurysm size at the last follow-up examination was classified into the following 4 categories: 1) > 50% decrease in size = marked shrinkage; 2) 10%–50% decrease in size = moderate shrinkage; 3) 0%–10% decrease in size = stabilization; and 4) increase in size = enlargement. All radiological outcomes were assessed by an investigator blinded to the information on treatment.

**Neurological Evaluation**

Neurological outcomes were scored with the mRS before the last treatment and at last follow-up. Permanent complication was defined as an increase in mRS score at the last follow-up examination compared with the score before surgery. All neurological outcomes were assessed by an investigator blinded to the information on treatment.

**Statistical Analysis**

Differences between the preoperative and postoperative size of an aneurysm or residual blood lumens were tested with the paired t-test. Two-sided probability values < 0.05 were considered significant. Statistical analysis was performed with a commercially available computer software package (JMP version 7.1.2, SAS Institute).

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**TABLE 1: Characteristics of 8 consecutive patients with partially thrombosed giant aneurysms of the upper BA**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Location</th>
<th>Aneurysm Size (mm)</th>
<th>Initial Symptoms</th>
<th>Previous Interventions</th>
<th>Flow Reduction Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>74, F</td>
<td>BA-SCA</td>
<td>30</td>
<td>hemiparesis, consciousness disturbance</td>
<td>endosaccular coil embolization</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>29, M</td>
<td>BA bifurcation</td>
<td>35</td>
<td>oculomotor nerve palsy, mild hemiparesis</td>
<td>hunterian occlusion w/ clip placement (between PCA and SCA)</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>37, F</td>
<td>BA bifurcation</td>
<td>45</td>
<td>character change</td>
<td>hunterian occlusion w/ coil embolization</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>65, F</td>
<td>BA-SCA</td>
<td>25</td>
<td>hemiparesis, oculomotor nerve palsy</td>
<td>none</td>
<td>yes</td>
</tr>
<tr>
<td>5</td>
<td>69, M</td>
<td>BA-SCA</td>
<td>38</td>
<td>oculomotor nerve palsy</td>
<td>hunterian occlusion w/ clip placement</td>
<td>yes</td>
</tr>
<tr>
<td>6</td>
<td>26, F</td>
<td>BA bifurcation</td>
<td>30</td>
<td>SAH, diplopia</td>
<td>endosaccular coil embolization</td>
<td>yes</td>
</tr>
<tr>
<td>7</td>
<td>54, M</td>
<td>BA bifurcation</td>
<td>28</td>
<td>diplopia</td>
<td>none</td>
<td>yes</td>
</tr>
<tr>
<td>8</td>
<td>47, M</td>
<td>BA bifurcation</td>
<td>26</td>
<td>mild hemiparesis</td>
<td>none</td>
<td>no</td>
</tr>
</tbody>
</table>
Flow reduction strategy for thrombosed giant basilar aneurysms

Results

Six of the 8 patients (Cases 2–7) underwent surgeries using a flow reduction strategy. Two patients (Cases 1 and 8) underwent no additional surgery because of their advanced age and according to their wishes, and these patients received periodical follow-up examinations with imaging. The mean ages of the 6 patients undergoing flow reduction treatment and the 2 who received conservative treatments were 46.7 and 60.5 years, respectively. The median follow-up period for all patients was 15.0 months (range 4–31 months). The preoperative mRS scores for the 6 patients undergoing flow reduction treatments were 3 in 3 cases, 2 in 2 cases, and 1 in 1 case; mRS scores for the 2 patients who underwent conservative treatments were 2 and 3.

Strategies for Flow Reduction Treatment

Among the 6 patients who underwent flow reduction treatment, 2 (Cases 2 and 4) were treated with maximum flow reduction strategy and the other 4 patients (Cases 3, 5, 6, and 7) were treated with moderate flow reduction strategy. The bypass surgeries performed on the 6 patients were classified as 10 STA-SCA bypasses in 5 patients, and 3 STA-PCA bypasses in 3 patients. The obliteration of the BA was performed proximal to the SCA in all but 1 case (Case 2) because the aneurysms usually incorporated the SCAs. All bypasses were confirmed to be patent on postoperative angiograms. Table 2 shows the treatment procedures for each patient.

Thrombosis and Size Reduction of Aneurysms

The mean diameter of the residual blood lumens after flow reduction treatment was significantly smaller than that before treatment (5.3 mm vs 16.0 mm, respectively; p = 0.029), and the size of the residual blood lumen decreased significantly (mean decrease −10.7 mm, 95% CI −19.7 to −1.7 mm; Fig. 2 left). The mean diameter of the aneurysms after flow reduction treatment tended to be smaller than that prior to treatment (22.8 mm vs 34.3 mm, respectively; p = 0.082), although the difference was not significant. The mean decrease in aneurysm size after the flow reduction treatment was −11.5 mm (95% CI −25.1 to 2.1 mm; Fig. 2 right).

Regarding the success of attempted thrombosis of an aneurysm, complete thrombosis was achieved in 4 patients, virtually complete thrombosis in 1, and enlargement of residual blood lumen in 1 (Table 2). Regarding the response to flow reduction treatment for aneurysm size, marked shrinkage of the aneurysm was achieved in 2 patients, moderate shrinkage in 2, stabilization in 1, and enlargement in 1 (Table 2). Thus, complete or virtually complete thrombosis was obtained in 83% and shrinkage of the aneurysm was observed in 67% of the aneurysms in the patients treated with flow reduction treatment. In 1 patient (Case 5), the P1 segment of the PCA underwent coil embolization because clipping the P1 segment was difficult. This was the only case in which effective flow reduction could not be induced because of recanalization of the coil, which resulted in enlargement of both the aneurysm size and residual blood lumen. When the analysis is limited to those in whom complete or virtu-

### Table 2: Summary of procedures and outcomes in both treatment groups

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Location</th>
<th>Procedure</th>
<th>Follow-Up Angiogram &amp; MRI</th>
<th>Initial/Follow-Up mRS Scores</th>
<th>Follow-Up (mos)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Residual Lumen of Aneurysm</td>
<td>Aneurysm Size</td>
<td></td>
</tr>
<tr>
<td>flow reduction Tx</td>
<td></td>
<td></td>
<td>complete thrombosis</td>
<td>marked shrinkage</td>
<td>2/0</td>
</tr>
<tr>
<td>2</td>
<td>BA bifurcation</td>
<td>lt STA-PCA bypass, lt PcoA and P2 clipping</td>
<td>complete thrombosis</td>
<td>moderate shrinkage</td>
<td>3/0</td>
</tr>
<tr>
<td>3</td>
<td>BA bifurcation</td>
<td>lt STA-SCA bypass, lt SCA proximal clipping, rt STA-SCA bypass, rt PCA (P1) clipping</td>
<td>complete thrombosis</td>
<td>stabilization</td>
<td>3/4</td>
</tr>
<tr>
<td>4</td>
<td>BA-SCA</td>
<td>lt STA-SCA bypass, lt SCA proximal clipping, rt PCA (P1) clipping, rt STA-SCA bypass, rt SCA proximal clipping, rt STA-PCA bypass, BA clipping</td>
<td>enlargement</td>
<td>enlargement</td>
<td>3/3</td>
</tr>
<tr>
<td>5</td>
<td>BA-SCA</td>
<td>rt STA-SCA bypass, rt SCA proximal clipping, lt STA-SCA bypass, lt PCA (P1) coil embolization*</td>
<td>virtually complete thrombosis</td>
<td>marked shrinkage</td>
<td>1/0</td>
</tr>
<tr>
<td>6</td>
<td>BA bifurcation</td>
<td>lt STA-SCA bypass, lt SCA proximal clipping, rt STA-SCA bypass, rt SCA proximal clipping</td>
<td>complete thrombosis</td>
<td>moderate shrinkage</td>
<td>2/3</td>
</tr>
<tr>
<td>7</td>
<td>BA bifurcation</td>
<td>rt STA-SCA bypass, rt SCA proximal clipping, lt STA-SCA bypass, lt STA-PCA bypass, lt PCA (P1) clipping, BA clipping</td>
<td>complete thrombosis</td>
<td>marked shrinkage</td>
<td>2/unknown</td>
</tr>
<tr>
<td>conservative Tx</td>
<td></td>
<td></td>
<td>incomplete thrombosis</td>
<td>enlarged</td>
<td>3/5</td>
</tr>
<tr>
<td>1</td>
<td>BA-SCA</td>
<td>none</td>
<td>incomplete thrombosis</td>
<td>not available</td>
<td>2/unknown</td>
</tr>
<tr>
<td>8</td>
<td>BA bifurcation</td>
<td>none</td>
<td>not available</td>
<td>not available</td>
<td>2/unknown</td>
</tr>
</tbody>
</table>

* Recanalization 1 month after intervention.
The diameter of the aneurysms significantly smaller than that before treatment (p = 0.029, paired t-test). The diameter of the residual blood lumen (right) after flow reduction treatment tended to be smaller than that before the treatment, although the difference was not significant (p = 0.082).

Illustrative Cases

Case 1. This 74-year-old woman presented with progressive left oculomotor palsy and right hemiparesis. A left BA-SCA partially thrombosed aneurysm showed progressive enlargement in diameter from 20 mm to 30 mm in 1 year (Fig. 3A). The left SCA originated from the aneurysmal dome (Fig. 3B). After STA-SCA anastomosis and the clipping of the SCA origin were performed on the left side, the aneurysmal residual lumen underwent coil embolization. Transient improvement followed and the perifocal edema was reduced (Fig. 3C). During the observation period, however, the patient again showed neurological progression due to enlargement of the lesion refractory to the treatments (Fig. 3D). The patient was treated conservatively without further surgical intervention according to her wishes.

Case 3. This 37-year-old female with a partially thrombosed BA bifurcation giant aneurysm suffered progressive character change with confusion of speech and disorientation. Both the BA and persistent primitive trigeminal artery had undergone coil embolization at another hospital for the purpose of hunterian occlusion, which failed to prevent progressive enlargement of the aneurysm, and the patient was referred to our institution. The Mini-Mental State Examination score at admission was 17 of 30. Preoperative images revealed the persistent flow to the aneurysm sac via the large right PCoA (Fig. 4A and B). The left PCA was supplied by the collateral flow via the collateral arteries. Preoperative MR images also demonstrated that the giant aneurysm (45-mm in diameter) with a huge thrombus inside the aneurysm severely compressed the midbrain (Fig. 4C). The patient underwent flow reduction treatment. In the first stage, the STA-SCA bypass and clipping of the SCA at its origin were performed on the left side through the left subtemporal approach (Fig. 4D). One week later, the P1 segment on the right PCA was clipped after an STA-SCA bypass on the same side through the right subtemporal approach (Fig. 4D). Postoperative angiography and CT angiography revealed the disappearance of the residual lumen of the aneurysm (Fig. 4E and F). The patency of both STA-SCA bypasses was also confirmed (Fig. 4G and H). The postoperative course was uneventful and no therapeutic morbidity was observed. A clinical improvement occurred after the treatment, in which the Mini-Mental State Examination score
Discussion

In the present study, we assessed the radiological and neurological results of flow reduction treatment for a series of partially thrombosed giant upper BA aneurysms. Our results suggest that this treatment can significantly decrease the blood lumen of the aneurysm and can induce successful thrombosis of the aneurysms. Although our results did not show a significant difference between the preoperative and postoperative diameters of aneurysms, significant shrinkage of the aneurysm was obtained in those in whom complete or virtually complete thrombosis was achieved, which may indicate that the treatment promotes the shrinkage of the aneurysms if successful thrombosis is achieved. The improvement or stabilization of the symptoms occurred in 67% despite the intractable nature of the aneurysms.

Thrombosis and Size Reduction of the Aneurysms

Proximal parent artery (hunterian) occlusion is considered for unclippable partially thrombosed giant aneurysms.5,6,26 This treatment is supposed to promote thrombosis of the aneurysmal sac, and then to prevent a fatal rupture. However, some cases are refractory to hunterian occlusion due to the persistence of blood flows into the aneurysmal sac.20,28,30 A previous study on hunterian occlusion for the upper BA aneurysms showed the lowest successful thrombosis rate (66% rate for complete or virtually complete thrombosis) of all the posterior fossa aneurysms.26 Recently some studies on hunterian occlusion accompanied by EC-IC bypass surgeries (flow alteration treatment) have documented a high obliteration rate for giant aneurysms.10,13,14,25 These studies, however, did not confine the subject to giant partially thrombosed upper BA aneurysms. One very large PCoA26 or an excessive flow produced by an EC-IC bypass appears to be responsible for the persistent filling of the aneurysm sac after hunterian occlusion. The 4 branches arising from the upper BA (bilateral SCAs and PCAs) can also disturb complete thrombosis of the aneurysm sac because they act as outlets of collateral blood flow after obliterating the BA proximal to the SCA (Fig. 1B). This speculation is supported by the contrasting high successful thrombosis rate (70%–98%) after hunterian occlusion for aneurysms at sites with less branching arteries than the upper BA, such as carotid cavernous, VA, or carotid paracavernous aneurysms.6,26 The flow reduction strategy can reduce the outflow as well as inflow to the aneurysm, which results in stagnating the blood flow into the aneurysm (Fig. 1C and D).

Preventing enlargement or shrinkage of the lesion is another goal for the treatment of the giant partially thrombosed aneurysm. Several possible mechanisms underlying the enlargement of the aneurysms have been reported, such as formation of intrathrombotic vascular channels19 and repeated bleeding within the outer layer of the thrombosed sac and aneurysmal wall.2,23 The organization of the thrombus in the aneurysm resulting from flow reduction strategy can block the blood flow to intrathrombotic vascular channels, which can prevent enlargement or even promote shrinkage of the aneurysm through absorption of the organized thrombus.

Neurological Outcome and Ischemic Complications

The neurological outcome of flow reduction treatment appears favorable considering the formidable nature of posterior circulation giant aneurysms. Michael17 reported 6 cases of conservatively managed giant posterior fossa symptomatic aneurysms, in which 5 (83%) of these patients died of neurological causes within 4 years after initial presentation. In another series of giant aneurysms, 2 (29%) of 7 patients with giant upper BA aneurysms who underwent only exploration died within 2 years, and poor outcome was observed in 4 patients (57%).3 Even if treated with hunterian occlusion, the giant upper BA aneurysm shows the lowest successful outcome (64%) and the highest fatal outcome (31%) of all the posterior fossa aneurysms.26

One of the factors associated with neurological results for flow reduction treatment appears to be age: all 3 patients younger than 40 years of age experienced good outcome, whereas the other 3 patients did not. Ischemic
complications can also be a possible factor that affects the outcome, although our results showed no ischemic complication associated with insufficient perfusion caused by obliteration of the BA. Several studies on hunterian occlusion showed that 13% to 17% of the patients could not tolerate occlusion of the proximal BA or bilateral VA.\textsuperscript{25,26} We did not perform any preoperative BOTs because flow reduction treatment ensures sufficient blood supply for each branch arising from the upper BA and because BOT has a notable complication rate (3.2%).\textsuperscript{10}

Perforating artery thrombosis is another problem that influences outcome. Vital perforating arteries adjacent to the aneurysm, such as the circumflex arteries of the brainstem or the thalamoperforating arteries, may be at risk for occlusion due to local thrombosis around the obliterated BA or the aneurysm neck induced by flow reduction treatment. The treatment is considered safe as long as critical perforators are spared with the persistent blood flow, which is usually maintained according to the demand of the perforators. The reduced flow can be slight enough to avoid hemodynamic injury to the aneurysm wall, thus allowing complete organization of the thrombus. Our only patient who experienced complications because of postoperative perforator occlusion (Case 7) had already presented with minor stroke in the midbrain before the surgery. Pessin et al.\textsuperscript{22} suggested that obstruction of perforating arteries at their origins by an intraluminal thrombus was a major cause of stroke in patients with partially thrombosed aneurysms. Thus, the patients presenting with stroke may be at higher risk for perforator occlusion after flow reduction treatment. In the present study, we classified flow reduction strategy into 2 subgroups according to its treatment design: maximum flow reduction (Fig. 1C) and moderate flow reduction (Fig. 1D). Selecting an adequate design may increase the safety of the treatment even for the patients presenting with stroke caused by the aneurysm.

The flow reduction treatment may have the potential risk of bilateral temporal lobe injury, although we were able to avoid this type of complication in all of our cases. Venous infarct or contusional hematoma after excessive temporal lobe retraction have been cited as drawbacks of the subtemporal approach.\textsuperscript{8} Injury of the bilateral temporal lobes results in a severe behavioral impairment known as Klüver-Bucy syndrome.\textsuperscript{15} The risks should be reduced by careful manipulations to the temporal lobe, including preservation of the temporal basal vain and gentle retraction of the temporal lobe.

**Limitation of the Study**

Our study has several limitations. First, the number of cases we studied was small and the follow-up period...
Flow reduction strategy for thrombosed giant basilar aneurysms

of the cases was relatively short. The rare situation has been reported in which the completely thrombosed aneurysm treated by endovascular trapping exhibits continued growth supplied by the vasa vasorum.12 Thus, further follow-up studies are needed for the present cases to confirm the long-term outcome of flow reduction treatment. Second, the subject of the present study was not randomized and includes only 2 conservatively treated patients, which makes the comparison of neurological results in the present study difficult. Considering the formidable natural history of the lesion in the literature, however, the results of flow reduction treatment can be more favorable than those of conservative treatment. Third, the subject of the present study included 3 patients who had already undergone hunterian occlusion, which may make it difficult to assess our results in comparison with those of simple hunterian occlusion mentioned in the literature. However, all 3 patients experienced dramatically improved or stabilized outcome after flow reduction treatment, which suggests a potential of flow reduction treatment as a salvage surgery for unsuccessful hunterian occlusion. Further studies to compare the efficacy of flow reduction treatment with that of hunterian occlusion are needed.

Conclusions

This study on giant partially thrombosed upper BA aneurysms supports the efficacy of flow reduction strategy in promoting complete thrombosis of the aneurysm. This strategy may also be effective at shrinking the aneurysm if successful thrombosis is achieved. Although the neurological outcome of the treatment is favorable considering the formidable nature of the lesion, further study is necessary to confirm its clinical efficacy and safety.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Miyamoto. Acquisition of data: Miyamoto, Funaki. Analysis and interpretation of data: Miyamoto. Drafting the article: Miyamoto. Critically revising the article: Miyamoto. Reviewed final version of the manuscript and approved it for submission: all authors. Statistical analysis: Miyamoto. Administrative/technical/material support: Funaki, Iihara, Takahashi.

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