Feasibility and Efficacy of Endovascular Therapy for Ruptured Distal Anterior Cerebral Artery Aneurysms

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Abstract

Surgical clipping has been the primary treatment option for ruptured distal anterior cerebral artery (DACA) aneurysms. Therefore, the literature on endovascular therapy is sparse. The present study investigated the feasibility and efficacy of endovascular therapy for ruptured DACA aneurysms in 31 patients, 26 females and 5 males (mean age 63.2 ± 12.6 years). Mean aneurysm size and neck width were 4.8 ± 2.3 mm and 2.2 ± 0.7 mm, respectively. The Hunt and Hess (H/H) grades just prior to the treatment were scored as H/H grades 1–3 in 20 patients and H/H grades 4–5 in 11 patients. Fifteen patients had an intraparenchymal hematoma (IPH) surrounding the ruptured aneurysm on the initial computed tomography. Overall, 22 patients had a modified Rankin scale (mRS) score of 0–2 and 9 had a mRS score of 3–6 at discharge. H/H grade was closely related to the clinical outcomes, whereas the presence of IPH was not. Overall immediate angiographic outcomes were complete occlusion in 15, residual neck in 11, and residual aneurysm in 5. The overall recurrence rate was 35.3%. Complications including posttreatment rebleeding occurred in 5 patients. Symptomatic vasospasm occurred in 1 of the 18 patients with H/H grades 1–3. Endovascular therapy of ruptured DACA aneurysms is feasible and effective. However, the risks of recurrence and posttreatment bleeding remain to be resolved.

Key words: intracranial aneurysm, subarachnoid hemorrhage, distal anterior cerebral artery, endovascular therapy, feasibility and efficacy

Introduction

Aneurysms arising from the anterior cerebral arteries (ACA) distal to the anterior communicating artery have been called distal ACA (DACA) aneurysms. DACA aneurysms are usually located on the branching points of the pericallosal or callosomarginal arteries, are relatively rare, and make up approximately 5–6% of all intracranial aneurysms.2,5) Although endovascular therapy of ruptured intracranial aneurysms has become an important and well-known alternative to surgical clipping,14,16,17,28) the reports regarding the DACA aneurysms are sparse. The purpose of this article is to report the feasibility and efficacy of endovascular therapy for ruptured DACA aneurysms.

Materials and Methods

From April 2002 through March 2011, 674 patients with aneurysmal subarachnoid hemorrhage (SAH) underwent endosaccular coil embolization at the Juntendo University Hospital and affiliated hospitals. Among those, 31 patients (4.6%) with a ruptured DACA aneurysm were the subjects of this study. The patient selection criteria for endovascular therapy included a clearly recognized neck separate from the surrounding vessels and aneurysm size between 2 and 20 mm on digital subtraction angiography (DSA). However, to a large extent, patient selection depended on the principal author’s (H.O.) experience. The exclusion criteria included patients with no chance of recovery due to the severe initial brain damage and/or systemic complications, intraparenchymal hematoma (IPH) requiring surgical relief of mass effect, contraindication for using contrast medium for cerebral angiography, presence of voluminous intra-aneurysmal thrombus, and patient’s or family member’s refusal. Patients with dissecting or fusiform aneurysms, aneurysms treated with parent artery sacrifice, aneurysms associated with brain arteriovenous malformations, and mycotic aneurysms were excluded.
All of the endovascular procedures were performed under general anesthesia to decrease the size of the motion artifacts and to stabilize the patients’ vital signs. Systemic heparinization was initiated in patients without IPH to maintain activated clotting time between 250 and 300 seconds throughout the procedure after the placement of the arterial introducer sheath and was stopped without the reversal of protamine sulfate at the end of the procedure in most patients. However, it was prolonged for 24–48 hours after the procedure in patients with a wide-necked aneurysm or periprocedural thromboembolic complications. Systemic heparinization was not initiated in patients with IPH to prevent the enlargement of IPH. We determined to use one or two working projections that provided the best views of the aneurysm neck, body, and microcatheter approach route, with three-dimensional reconstructed rotational DSA. If that was not available, multiple projections of two-dimensional DSA were performed to obtain optimal working projections. After the procedure, angiograms in the frontal, lateral, and working projections were acquired to assess the degree of aneurysm occlusion and to rule out angiographically detectable thromboembolic events.

The simple technique of using a single microcatheter was primarily chosen. If, however, the simple technique could not be used, then the balloon-assisted technique was used to achieve a satisfactory anatomical outcome. Coils of the appropriate size and shape were selected according to the target aneurysm. As our standard procedure, we inserted the coils within the aneurysm as densely as possible, or until another coil could no longer be inserted, without compromising the parent artery lumen even after an angiographic complete obliteration was achieved. The main type of coils used was the Guglielmi detachable coils (Stryker, Fremont, California, USA). We also used other brands of coils (Trufill DCS/Micrus coil; Cordis, Miami Lakes, Florida, USA, and Electro Detach Coil; Kaneka Medical, Kanagawa). The biologically modified coils (Matrix 2; Stryker, and Cerecyte; Cordis) were used in 9 aneurysms selected after June 2009. The coils within the aneurysm as densely as possible, or until another coil could no longer be inserted, without compromising the parent artery lumen even after an angiographic complete obliteration was achieved. The main type of coils used was the Guglielmi detachable coils (Stryker, Fremont, California, USA). We also used other brands of coils (Trufill DCS/Micrus coil; Cordis, Miami Lakes, Florida, USA, and Electro Detach Coil; Kaneka Medical, Kanagawa). The biologically modified coils (Matrix 2; Stryker, and Cerecyte; Cordis) were used in 9 aneurysms selected after June 2009. The microcatheter used was a braided one (Excelsior SL 10; Stryker) with the tip manually steam shaped. The navigation of the microcatheter into the aneurysm was performed basically under the assistance of a 0.012-inch microguidewire (GT wire; Terumo, Tokyo).

Pretreatment clinical status of each patient was evaluated by Hunt and Hess (H/H) grade just prior to the endovascular surgery. The size and neck width of the aneurysms were measured by catheter angiography. Clinical outcomes and complications were assessed according to the patients’ medical records and operative records. Clinical outcomes at discharge of each patient were assessed according to the modified Rankin scale (mRS). The principal investigator (H.O.), while considering the coauthors’ opinions, conducted the evaluations of all the angiographic outcomes. The degree of aneurysm occlusion was defined using the criteria previously described by Raymond et al. If there was no contrast filling of the dome, body, or neck of the aneurysm, it was defined as complete occlusion. If the contrast medium entered a part of the neck, but did not fill the body and/or dome of the aneurysm, it was defined as residual neck. If the contrast medium entered the body and/or dome of the aneurysm, it was defined as residual aneurysm.

Our standard radiological follow-up protocol is to perform a plain skull radiograph at 1 month, magnetic resonance (MR) angiography at 6 months, and catheter angiography at 1 and 2 years after the endovascular therapy. MR angiography could be substituted for catheter angiography if the patient’s condition was determined to be unsuitable or if the patient refused repeated catheter angiography. If the aneurysm occlusion was stable at the 2-year follow-up, the patient would undergo MR angiography every subsequent year. We defined the change of aneurysm occlusion as: unchanged, stable area of aneurysm filling; improved, decreased area of aneurysm filling; and recurrence, increased area of aneurysm filling.

Complications were defined as neurologic deterioration, abnormal neuroimaging findings, and treatment-related undesirable events. Symptomatic vasospasm was defined as the onset of neurological deterioration with arterial narrowing on the catheter angiography or MR angiography without other potential causes of neurological deterioration, such as hydrocephalus, rebleeding, or seizures. Shunt-dependent hydrocephalus was not strictly defined. The treatment strategy of symptomatic vasospasm and shunt-dependent hydrocephalus was determined by the principal investigator (H.O.) in Juntendo University Hospital and by the head of each individual affiliated hospitals.

The coauthors reviewed all the data. Qualitative data are expressed as numbers and/or percentages. Mean values are presented as the means ± standard deviations. Statistical analysis was performed using the standard chi-square test with or without Yates’ correction. Differences were considered significant at p < 0.05. Unfortunately, we could not analyze the patients with ruptured DACA aneurysms left untreated or surgically treated for various reasons left...
unexplained in the present report.

**Results**

Table 1 shows the patients’ and aneurysms’ characteristics. There were no significant differences in age, sex, aneurysm size, neck width, or H/H grade between patients with or without IPH. All procedures were completed. We performed a simple technique in all the aneurysms except one, in which we used a balloon-assisted technique using an over-the-wire balloon microcatheter (HyperForm; ev3, Irvine, California, USA).

Overall clinical outcomes at discharge showed mRS 0 (15), 1 (1), 2 (6), 3 (1), 5 (6), and 6 (2). Figure 1 shows the clinical outcomes at discharge according to the H/H grade. There was a significant difference in clinical outcomes between the patients with H/H grades 1–3 and those with grades 4–5. Figure 2 shows the clinical outcomes at discharge according to the presence of IPH. There were no significant differences in the clinical outcomes between the patients with or without IPH. Long-term clinical follow-up (mean 36.5 ± 3.0 months) was available for 20 patients. During the clinical follow-up period, no patients suffered aneurysmal SAH.

Table 2 shows the anatomical outcomes. Ten aneurysms were evaluated with catheter angiography, and 7 aneurysms were evaluated with MR angiography. Although there were no significant differences, there was a trend of a high rate of residual aneurysm in the aneurysms with IPH and of complete occlusion in the aneurysms without IPH.

Seventeen aneurysms had a radiological follow-up (catheter or MR angiography) 3 months or more after the treatment (mean 9.0 months, range 3.0–63.7 months).

**Table 1 Patients’ and aneurysms’ characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Patients with IPH</th>
<th>Patients without IPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>31</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Mean age (yrs)</td>
<td>63.2 ± 12.6</td>
<td>59.6 ± 13.8</td>
<td>66.6 ± 10.6</td>
</tr>
<tr>
<td>Female</td>
<td>26 (83.9%)</td>
<td>12 (80.0%)</td>
<td>14 (87.5%)</td>
</tr>
<tr>
<td>Aneurysm size (mm)</td>
<td>4.8 ± 2.3</td>
<td>4.7 ± 2.5</td>
<td>4.8 ± 2.3</td>
</tr>
<tr>
<td>Neck width (mm)</td>
<td>2.2 ± 0.7</td>
<td>2.4 ± 1.1</td>
<td>2.2 ± 0.7</td>
</tr>
<tr>
<td>Hunt and Hess grades</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2</td>
<td>0</td>
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<tr>
<td></td>
<td>4</td>
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<td></td>
<td>5</td>
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IPH: intraparenchymal hematoma.

**Table 2 Anatomical outcomes**

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Aneurysms with IPH</th>
<th>Aneurysms without IPH</th>
</tr>
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<tbody>
<tr>
<td>Immediate anatomical outcome</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete occlusion</td>
<td>15/31 (48.4%)</td>
<td>5/15 (33.3%)</td>
<td>9/16 (56.3%)</td>
</tr>
<tr>
<td>Residual neck</td>
<td>11/31 (35.5%)</td>
<td>7/15 (46.7%)</td>
<td>4/16 (25.0%)</td>
</tr>
<tr>
<td>Residual aneurysm</td>
<td>5/31 (16.1%)</td>
<td>3/15 (20.0%)</td>
<td>2/16 (12.5%)</td>
</tr>
<tr>
<td>Follow-up anatomical outcome</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unchanged</td>
<td>9/17 (52.9%)</td>
<td>6/9 (66.7%)</td>
<td>3/8 (37.5%)</td>
</tr>
<tr>
<td>Improved</td>
<td>2/17 (11.8%)</td>
<td>2/9 (22.2%)</td>
<td>0/8 (0%)</td>
</tr>
<tr>
<td>Recurrence</td>
<td>6/17 (35.3%)</td>
<td>1/9 (11.1%)</td>
<td>5/8 (62.5%)</td>
</tr>
</tbody>
</table>

IPH: intraparenchymal hematoma.

![Fig. 1](image1.png) Clinical outcomes at discharge according to Hunt and Hess (H/H) grade. mRS: modified Rankin scale.

![Fig. 2](image2.png) Clinical outcomes at discharge according to presence of intraparenchymal hematoma (IPH). mRS: modified Rankin scale.
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Discussion

DACA aneurysms have several anatomical characteristics such as small size, wide neck, branch originating in the aneurysm neck, and ACA anomalies (e.g., azygos ACA, fenestrated ACA). Furthermore, ruptured DACA aneurysms have a high incidence of accompanying IPH. These characteristics were thought to be unfavorable for endovascular therapy. Although surgical clipping is considered as the primary treatment, it is difficult when comparing with other anterior circulation aneurysms because of the narrow operative field, protection of bridge veins, and interhemispheric adhesions.

The outcome of surgically treated patients with ruptured DACA aneurysms was previously reported. Favorable outcome (good recovery and moderately disability) was obtained in 81% of the patients who had small and medium (<15 mm) aneurysms (n = 48). However, grade V patients were excluded due to their treatment indication. In the present series, 71% of the patients showed a favorable outcome (mRS 0–2) and 29% of the patients showed an unfavorable outcome (mRS 3–6). When excluding grade V patients, 22 of 27 patients (81.5%) showed a favorable outcome, and 5 of 27 patients (18.5%) showed an unfavorable outcome. The clinical outcome of patients with DACA aneurysm endovascularly treated was compared with patients surgically treated. The outcomes at 1 month showed 61.5% of good recovery in 13 patients endovascularly treated and 40% of good recovery in 55 patients surgically treated. They found that the rates of moderate and severe disability were higher after clipping surgery than endovascular surgery. Therefore, the clinical outcome of the endovascular treatment of ruptured DACA is comparable to that of surgical clipping.

An 89% success rate of endovascular therapy was reported for the 28 DACA aneurysm cases. A couple of key technical points were described: shaping the microcatheter into a “J” and using softer and fewer coils. We usually shape the microcatheter into an “S” to stabilize the microcatheter tip within the aneurysm. Although the appropriate shape of microcatheter may depend on the physicians’ choice, it is crucial to achieve microcatheter stabilization. Moreover, the support of the guiding catheter is mandatory to facilitate easy microcatheter navigation and coil insertion. We advanced the guiding catheter as distal as possible and used the triple coaxial system (7-French guiding catheter and 4-French coaxial catheter) if necessary. Patients with severely tortuous arterial anatomy precluding easy catheter access may be considered as candidates for surgical clipping.

The adjunctive techniques such as balloon-assisted or double-catheter have made it possible to obtain satisfactory occlusion for wide-necked aneurysms. However, the small caliber of ACA and the distal location of the aneurysm increase the risk of the parent artery injury and intraprocedural aneurysm rupture. Although the low profile self-expanding stents allowed stent-assisted coiling of the aneurysms located on the small and distal cerebral vessels, there are the risks of in-stent thrombosis and stent malpositioning.

Previous studies regarding the surgical clipping of ruptured DACA aneurysms show that the outcomes of patients are closely related to preoperative clinical status. The results in the present study were similar. Primary brain damage is the greatest determining factor of the clinical outcome of patients undergoing endovascular therapy.

The overall recurrence rate was 35.3% in the present series. The high rate of recurrence may be closely associated with poor initial angiographic outcome. We frequently could not achieve sufficiently dense packing of the aneurysms due to the characteristics of DACA aneurysms mentioned above. This suggests the importance of long-term radiographic follow-up after endovascular therapy.

It is noteworthy that the posttreatment rebleeding...
risk of the DACA aneurysms is higher than that of aneurysms in other locations regardless of surgical clipping or endovascular therapy.\(^1\)\(^{30}\) In the present series, the anatomical results of both patients with posttreatment rebleeding were residual neck. The CARAT (Cerebral Aneurysm Rerupture After Treatment) study reported that the risk of posttreatment rebleeding was closely associated with the degree of aneurysm occlusion. Particularly, partially occluded aneurysms carry a high risk of posttreatment rebleeding.\(^9\) It must be kept in mind that incompletely occluded aneurysms still have the risk of rebleeding after endovascular therapy.

The IPH did not influence the clinical outcomes in our series. Although the aneurysms with IPH showed a low rate of satisfactory aneurysm occlusion, they also showed a high rate of unchanged/improved outcome and a low rate of recurrence. The reason for this remains unknown, but we speculate that the mass effect of the IPH may prevent sufficiently dense packing of the aneurysm and may cause flow stagnation within the aneurysm leading to the progress of the thrombosis and the prevention of recurrence. However, a larger number of patients are needed to verify our speculation.

The effect of treatment modality for symptomatic vasospasm and shunt-dependent hydrocephalus after SAH remains controversial.\(^7\)\(^{19}\) Although the risk of symptomatic vasospasm and/or shunt-dependent hydrocephalus in the patients with H/H grades 1–3 was very low in the present series, the number of subjects is too small to evaluate the effect of endovascular therapy.

As the present study included retrospective data acquisition, a prospective study with a more rigorous technical and follow-up strategy is warranted. The patients in the present series are not representative of the whole population of patients with ruptured DACA aneurysms because surgically treated or untreated patients were not included in this study. Decisions regarding treatment indications may induce an inclusion bias.

In conclusion, the endovascular therapy of ruptured DACA aneurysms is feasible and effective. The risks of recurrence and posttreatment rebleeding are remaining issues that must be resolved.

Acknowledgment

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Conflicts of Interest Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper. All authors who are members of The Japan Neurosurgical Society (JNS) have registered online Self-reported COI Disclosure Statement Forms through the website for JNS members.

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