Stent-assisted Coiling of Acutely Ruptured Cerebral Aneurysms

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Purpose: The usefulness of stent-assisted coiling (SAC) of ruptured cerebral aneurysms has been reported, but a consensus has not yet been reached. We review the merits and limitations of this procedure based on our series.

Subjects and Methods: Out of 96 ruptured cerebral aneurysms treated by endovascular treatment between July 2010 and July 2016, five (5%) had SAC. We investigated this group’s clinical characteristics, postoperative complications, and modified Rankin Scale (mRS) score after 6 months.

Results: In all five patients, it was possible to insert a stent without difficulties, and there were no procedure-related complications. Diffusion-weighted brain MR images showed high-signal-intensity “spot-like” areas in all patients, remaining as asymptomatic cerebral infarctions and all stents remained completely patent. A hemorrhagic complication was observed in one patient who underwent later ventricle drainage. The mRS scores after 6 months were 0 in one patient, 1 in one patient, 3 in one patient, 4 in one patient, and 6 in one patient.

Conclusion: SAC of ruptured cerebral aneurysms could be considered a useful treatment option although indicated for a limited number of patients with adequate use of antiplatelet treatment and cerebral spinal fluid (CSF) drainage for the subarachnoid hemorrhage (SAH).

Keywords ▶ ruptured cerebral aneurysms, stent-assisted coiling

Introduction

Intracranial stent use during coiling of unruptured wide-neck-type cerebral aneurysms, which are difficult to treat by coiling alone, is covered by health insurance in Japan. However, in some cases, stent-assisted endovascular treatment must be used for ruptured cerebral aneurysms. Previous studies reported the usefulness of stent-assisted coiling (SAC) of acutely ruptured cerebral aneurysms. Criteria for use and methods of stent deployment have often been determined based on each institution’s evaluation; a consensus has not yet been reached. In this study, we examined the merits and limitations of SAC of acutely ruptured cerebral aneurysms based on our series.

Subjects and Methods

Of 96 ruptured cerebral aneurysms treated by cerebral endovascular treatment in our hospital between July 2010 and July 2016, five (5%) had SAC. As the use of a stent for ruptured cerebral aneurysms is not covered by health insurance, the subjects were limited to patients in whom surgery was difficult, and coiling alone was considered difficult even when adopting adjunctive techniques, such as the double catheter technique (DCT) and balloon assist technique (BAT). After explaining that stent use is not covered by health insurance, informed consent was obtained from the patients’ families.

The subjects group included one male and four females. The mean age at the time of treatment was 72.4 years (52–86 years). The aneurysm locations were within the anterior cerebral circulation in two patients (one saccular aneurysm and one dissecting aneurysm) and the posterior...
circulation in three (two saccular aneurysms, and one dissecting aneurysm). Enterprise VRD stents (Johnson & Johnson, Miami, FL, USA) were used in four patients, and a Neuroform EZ stent (Stryker, Kalamazoo, MI, USA) in one patient. As antiplatelet agents, aspirin at 100–200 mg and clopidogrel at 300 mg were administered through a nasogastric tube >30 minutes before stent use, excluding one patient who already was taking two antiplatelet agents before treatment. Surgery was performed under general anesthesia on the day of onset in all patients.

We examined the patients’ clinical status, postoperative complications (presence or absence of cerebral infarction or hemorrhagic complications), and modified Rankin Scale (mRS) score after 6 months.

**Results**

The results are shown in **Table 1**.

It was possible to insert a stent without technical difficulties in all patients, and there were no procedure-related complications. MRI of the head with diffusion weighted images (DWIs) was performed within 48 hours after surgery in all patients to confirm the presence or absence of thromboembolic complications or stent occlusion. Spots of high-signal-intensity were detected on DWIs in all patients, but they remained asymptomatic and stents remained patent. A hemorrhagic complication was observed in a patient who underwent ventricular drainage related to the severity of the subarachnoid hemorrhage (SAH) (Case 5). We had to control intracranial pressure by placing ventricular drains in three patients and lumbar drain in one patient.

The dosage of antiplatelet/antithrombotic agents for perioperative therapy and its timing are presented in **Table 2**. All patients received loading with aspirin and clopidogrel before surgery and the intraoperative dose of heparin was controlled so that the activated clotting time (ACT) finally ranged from 250 to 300. Immediately after surgery, three patients remained on anticoagulants (heparin and argatroban). Postoperative antiplatelet therapy included aspirin and clopidogrel for two patients, clopidogrel alone to one patient (due to hemorrhage), and one of the two agents was switched to cilostazol in two patients to reduce cerebral vasospasm.

The mRS scores after 6 months were as follows: 6 in a patient with stage IV renal carcinoma after surgery, 4 in a patient in advanced without rehabilitation in the absence of new neurologic deficits, 3 in a patient with

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**Table 1** Clinical summary of patients with stent-assisted coiling for ruptured aneurysms

<table>
<thead>
<tr>
<th>Case</th>
<th>Age/Sex</th>
<th>Location</th>
<th>AN size</th>
<th>SAH grading</th>
<th>Stent device</th>
<th>NR, CO, BF post-OP DWI Drainage</th>
<th>Hemorrhagic complication</th>
<th>SVS</th>
<th>mRS at 6 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>84/Male</td>
<td>BA</td>
<td>6.66</td>
<td>2</td>
<td>EP</td>
<td>NR</td>
<td>None</td>
<td>None</td>
<td>6</td>
</tr>
<tr>
<td>Case 2</td>
<td>75/Female</td>
<td>ICA</td>
<td>3.58</td>
<td>1</td>
<td>BF</td>
<td>Spasm</td>
<td>None</td>
<td>None</td>
<td>3</td>
</tr>
<tr>
<td>Case 3</td>
<td>52/Female</td>
<td>PCA</td>
<td>11.74</td>
<td>2</td>
<td>EP</td>
<td>NR</td>
<td>Lumbar drainage</td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Case 4</td>
<td>86/Female</td>
<td>VA</td>
<td>7</td>
<td>5</td>
<td>NF</td>
<td>NR</td>
<td>Ventricle drainage</td>
<td>None</td>
<td>4</td>
</tr>
<tr>
<td>Case 5</td>
<td>65/Female</td>
<td>ICA</td>
<td>3.13</td>
<td>2</td>
<td>EP</td>
<td>NR</td>
<td>Ventricle drainage</td>
<td>Thalamic hemorrhage</td>
<td>1</td>
</tr>
</tbody>
</table>

Stent-assisted Coiling of Acutely Ruptured Cerebral Aneurysms

1 after rehabilitation in a patient with postoperative hemorrhage, and 0 in a patient showing a favorable course.

Representative Cases

Case 1
An 84-year-old male was admitted with SAH World Federation of Neurosurgical Societies (WFNS) grade 2. A ruptured cerebral aneurysm was detected on the basilar artery at the origin of the anterior inferior cerebellar artery (AICA), which emerged from the aneurysmal neck (Fig. 1a–1c). Surgical approaches were considered to be quite invasive, but also the wide-neck-type aneurysm was expected to make stent-free endovascular treatment difficult. A 6 Fr Shuttle sheath (Cook Medical, Bloomington, IN, USA) was inserted into the left vertebral artery, and an SL-10 preshaped 90° (Stryker) micro-catheter was inserted into the aneurysm. Using the BAT, a Matrix 2 360 Soft 3 mm × 8 cm (Stryker) coil was inserted as the framing one, but the coil remained unstable, which required to proceed with SAC. After anti-platelet agents were administered through a nasogastric tube, an Enterprise VRD stent measuring 4.5 × 22 mm was inserted, and the aneurysm was filled with nine coils while preserving the anterior inferior cerebellar artery. The procedure was completed leaving a neck remnant (Fig. 1d–1f).

Case 5
A 65-year-old female was admitted with WFNS grade 2 SAH. During a follow-up for unruptured multiple cerebral aneurysms at the outpatient clinic, SAH occurred. The distribution of SAH suggested that the right internal carotid artery aneurysm at the origin of superior hypophyseal arteries had ruptured (Fig. 2a and 2b). The patient required ventricular drainage for intracranial pressure control before aneurysm embolization treatment. An 8 Fr OPTIMO (Tokai Medical Products, Aichi, Japan) was inserted into the right internal carotid artery, and an SL-10 micro-catheter was guided into the aneurysm. The aneurysm was small, with a wide neck. When applying BAT, the framing coil was unstable, making insertion difficult. Therefore, after administering antiplatelet agents through a nasogastric tube, an Enterprise VRD stent measuring 4.5 × 22 mm (Cordis) was deployed (Fig. 2c and 2d). The aneurysm was filled with two Target coils (Stryker), and the procedure was completed leaving a neck remnant. Immediately after surgery, C-arm CT did not reveal postoperative hemorrhage, and heparin was continuously administered.

<table>
<thead>
<tr>
<th>Case</th>
<th>Intra-operative antiplatelet agents</th>
<th>Postoperative antiplatelet agents</th>
<th>ACT (final)</th>
<th>Pre-stenting antiplatelet agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Asp 100 mg, Clo 300 mg</td>
<td>Yes</td>
<td>Activated clotting time: 4000U</td>
<td>Yes</td>
</tr>
<tr>
<td>Case 2</td>
<td>Asp 100 mg, Clo 75 mg</td>
<td>No</td>
<td>Activated clotting time: 2000U</td>
<td>No</td>
</tr>
<tr>
<td>Case 3</td>
<td>Asp 200 mg, Clo 300 mg</td>
<td>Yes</td>
<td>Activated clotting time: 3000U</td>
<td>Yes</td>
</tr>
<tr>
<td>Case 4</td>
<td>Asp 200 mg, Clo 300 mg</td>
<td>No</td>
<td>Activated clotting time: 5000U</td>
<td>No</td>
</tr>
<tr>
<td>Case 5</td>
<td>Asp 100 mg, Clo 300 mg</td>
<td>Yes</td>
<td>Activated clotting time: 2000U</td>
<td>Yes</td>
</tr>
</tbody>
</table>

ACT: activated clotting time; Asp: aspirin; Cil: cilostazol; Clo: clopidogrel

Table 2: Clinical summary for perioperative management of antiplatelet agents and anticoagulants
In this study, we report five patients who underwent SAC of ruptured cerebral aneurysms. There were no stent-coiling-associated technical or thromboembolic complications. SAC of ruptured cerebral aneurysms can be an effective treatment option for ruptured cerebral aneurysm although the inconvenience of not being covered by health insurance remains. However, this procedure has many limitations to be overcome, such as the use of antiplatelet agents/anticoagulants together with possible drainage-related hemorrhagic complications. Careful decision on its indications is warranted.

Many studies reported results of SAC in ruptured cerebral aneurysms. One study clearly indicated the usefulness of stent deployment, whereas more studies reported adverse events, such as ischemic or hemorrhagic complications. This procedure should be carefully indicated. A stent should be used only in patients for whom embolization cannot be accomplished using adjunctive techniques.

Concerning the timing of antiplatelet drug administration for SAC of ruptured cerebral aneurysms, the incidence of thromboembolism was higher in patients treated with antiplatelet agents postoperatively. Based on this, we administered antiplatelet agents as loading doses (aspirin

\[Fig. 1\] (a–c) A ruptured basilar artery trunk cerebral aneurysm with the anterior inferior cerebellar artery branching out from the aneurysmal neck. (d–f) The aneurysm was filled with nine coils while preserving the anterior inferior cerebellar artery. White arrow: anterior inferior cerebellar artery.

administered. The patient was extubated immediately after surgery. There was no new neurologic deficit, but aphasia and right hemiparesis suddenly appeared 6 hours after surgery. The urgent CT showed left thalamic hemorrhage and ventricular penetration of hematoma (Fig. 2e and 2f). Therefore, the administration of heparin and oral aspirin (from the day after surgery) was discontinued, maintaining treatment only with clopidogrel. CTA of intracranial vessels 10 days after surgery did not show any new aneurysm, but cerebral angiography revealed an irregular aneurysm on the anterior wall of the internal carotid artery, which was not detected on initial angiography, 20 days after surgery (Fig. 2g). We could not rule out the possibility that this aneurysm may have caused the first rupture, and immediately performed embolization of this aneurysm. As the Enterprise VRD stent inserted on initial treatment covered the neck of this aneurysm, an SL-10 micro-catheter was guided into the aneurysm using a trans-cell approach, and the aneurysm was embolized with four coils. The procedure was completed also leaving a neck remnant (Fig. 2h–2j). The right incomplete hemiplegia and memory disturbances remained. The patient was referred to another hospital 57 days after surgery with mRS score of 3. After rehabilitation, the score improved to 1.

Discussion

In this study, we report five patients who underwent SAC of ruptured cerebral aneurysms. There were no stent-coiling-associated technical or thromboembolic complications. SAC of ruptured cerebral aneurysms can be an effective treatment option for ruptured cerebral aneurysm although the inconvenience of not being covered by health insurance remains. However, this procedure has many limitations to be overcome, such as the use of antiplatelet agents/anticoagulants together with possible drainage-related hemorrhagic complications. Careful decision on its indications is warranted.
Fig. 2  (a and b) An aneurysm of the right internal carotid at the origin of the superior hypophyseal arteries may have ruptured.
(c and d) SAC with use of Enterprise VRD stent (4.5 × 22 mm) was performed. (e and f) Left thalamic hemorrhage with ventricular penetration was observed. (g) A de novo irregularly shaped aneurysm was detected on the anterior wall of the internal carotid artery. (h–j) An SL-10 catheter was guided into the aneurysm using the trans-cell approach, and the aneurysm was filled with four coils. The procedure was completed leaving neck remnant. SAC: stent-assisted coiling; VRD: vascular reconstruction device.
at 100–200 mg + clopidogrel at 300 mg) during surgery (especially before stent insertion).

Several studies indicated the usefulness of the intraoperative drip infusion of tirofiban although this agent has not been approved in Japan. Some studies suggested that the intraoperative use of tirofiban followed by the oral administration of two agents after surgery is the best method to reduce the risk of hemorrhagic/ischemic complications.\textsuperscript{9,10} If this agent is approved in Japan in the future, it may reduce the incidence of complications related to SAC in the acute phase of ruptured cerebral aneurysms.

As another limitation of SAC of ruptured cerebral aneurysms, the risk of ventricle drainage-associated hemorrhagic complications has been demonstrated.\textsuperscript{7,11} Actually, we also encountered a patient with ventricle drainage-associated cerebral hemorrhage (Case 5). Before surgery, a ventricular drainage tube was inserted, and there was no fresh hemorrhage at this point. However, after surgery, hemorrhage was observed at an area adjacent to the drainage tube end, suggesting an influence of antiplatelet drug administration. When stent insertion is required, the selection of drainage procedures (lumbar/ventricle drainage) and their timing must be reviewed thoroughly. As ventricular drainage is associated with intracranial hemorrhage, lumbar drainage, which may lead to an improvement through a conservative course despite the risk of epidural hematomas, should be considered. Due to the above-mentioned reasons, a drainage tube should be inserted before stenting considering the effects of antiplatelet therapy.

In our series, we selected various stents (Enterprise VRD or Neuroform EZ) in accordance with the characteristics of aneurysms/blood vessels. However, currently, Elvis (MicroVention Terumo, Tustin, CA, USA) and Atlas (Stryker) stents are available as alternative options. A consensus regarding the stent types appropriate for use in the acute phase of ruptured cerebral aneurysms has not been reached. We consider that laser-cut stents containing a small volume of metal are appropriate regarding thromboembolism or blood flow-diverting effects.

\section*{Conclusion}

The incidence of perioperative complications in SAC for acutely ruptured cerebral aneurysms is higher than for unruptured cerebral aneurysms. However, this procedure may become an effective treatment option if selectively indicated for patients in whom surgery could be difficult, and endovascular treatment cannot be accomplished even when applying BAT or DCT. In particular, methods of administering antiplatelet agents and drainage-related complications must be thoroughly considered.

\section*{Disclosure Statement}

There is no conflict of interest regarding this article.

\section*{References}


