Innovations in Endovascular Treatment Strategies for Large Carotid Cavernous Aneurysms—The Safety and Efficacy of a Flow Diverter

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Background: The efficacy for the treatment of large carotid cavernous aneurysms (CCAs) was compared between conventional endovascular treatments, stent-assisted coiling (SAC), parent artery occlusion (PAO), and the flow diverter (FD). *Methods:* Between January 2001 and December 2015, 49 patients with large, broad-necked, unruptured CCA underwent endovascular treatment at our institution. We performed PAO in 22 patients, SAC in 18 patients, and FD in 9 patients. Safety and efficacy were assessed in all patients by periodic clinical and radiological examinations during a 6-month follow-up. *Results:* All 22 aneurysms treated with PAO disappeared immediately after treatment, but in the SAC-treated group, complete occlusion was obtained in only 5 of the 18 patients. All aneurysms in the FD group resulted in body filling. Perioperative ipsilateral temporary ischemic events occurred in 6 cases (PAO 4, SAC 2, FD 0). Delayed deterioration or new onset of cranial nerve symptoms was observed in 10 cases (PAO 3, SAC 3, FD 4), almost all of which recovered within 3 months. During the 6-month follow-up, all aneurysms treated with PAO showed a decrease in size without recanalization. In the SAC group, 12 aneurysms showed neck remnants, and marked recanalization occurred in 4 cases. Six of the 9 aneurysms in the FD group were completely occluded. *Conclusions:* The FD provided excellent final results despite transient worsening of symptoms. Although further long-term follow-up is essential, from a cost-effective and time-saving viewpoint, FD is a relatively safe and reliable method for the treatment of large CCAs. **Key Words:** Carotid cavernous aneurysm—flow diverter—parent artery occlusion—stent-assisted coiling—complication.
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Introduction

Carotid cavernous aneurysms (CCAs) tend to grow gradually without any symptoms until they manifest a mass effect due to cranial nerve compression, and they rarely rupture with a subarachnoid hemorrhage. The present consensus is that simple coil packing for large or giant symptomatic aneurysms has limited effects against the decompression of cranial nerves because of the filled coil mass in the sac; moreover, this coil packing occasionally worsens the symptoms owing to a failure to stop the aneurysm's regrowth.

An advanced embolization with adjunctive technique was thus developed to stabilize the coils and obtain high packing density. Stent-assisted coiling (SAC) in particular

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has been expected to have a stable radical effect with a reduction of inflow due to some rectification and better neck coverage.[1] Over the past few years, it has been thought that the most effective way to achieve recovery from cranial nerve palsy due to large CCAs is parent artery occlusion (PAO). It can stop all inflow to the aneurysm in exchange for the loss of 1 carotid artery. However, in cases of poor collaterals, extra-intracranial (EC-IC) arterial bypass surgery is absolutely required.[2,3]

Flow diverter (FD) has been introduced as an alternative option for large CCAs. FD can promote aneurysm occlusion through a process of endoluminal reconstruction of the parent artery and by rectifying blood flow away from the aneurysm sac.[4] The safety and efficacy of a Pipeline embolization device (PED) (Medtronic/Covidien, Irvine, CA) has been demonstrated in several recent series, but most of these series did not include a control group of patients treated with conventional embolization strategies.[4-7] In the present study, we compared the 3 treatment modalities, PAO, SAC, and FD, in terms of safety and efficacy against CCAs.

Materials and Methods

Patient Cohort

An endovascular approach was used to treat 93 patients with unruptured CCAs between January 2001 and December 2015 at Nagoya University and Osaka Medical College. After obtaining the institutional review board approval from each institution, we searched our prospectively maintained database for all patients with unruptured CCAs. Then, we extracted the patients whose cases were consistent with the following conditions: (1) having a large or giant aneurysm (max. dia. ≥10 mm), (2) treated with PAO, SAC, or FD, and (3) followed up clinically and radiologically for at least 6 months after the treatment. Forty-four patients with small aneurysms and who underwent simple or balloon-assisted coiling were excluded. A total of 49 aneurysms in 49 patients (43 women and 6 men; 36-83 years old; mean age 63.4 years) were included in this retrospective study. We retrospectively reviewed the patients' medical charts to determine the patient profiles, aneurysm characteristics, procedural specifics, and procedural complications. Only clinically relevant procedural complications are reported here. Radiological studies including angiography, magnetic resonance imaging (MRI), and computed tomography (CT) were carefully reviewed pre- and postoperatively and at 6 months' follow-up. All of the treatments were performed by 3 trained endovascular neurosurgeons (S.M., H.O., and T.I.). Of the 49 aneurysms, we found that 22 were treated with PAO including internal trapping, 18 were treated with SAC, and 9 patients were treated with FD.

Aneurysm Characteristics

Regarding the aneurysmal profile laterality, the maximum diameter and size were determined on angiogram. Of the 49 aneurysms, 25 were located on the right side, and the mean size of maximum diameter was 18.2 mm. There were 40 large aneurysms and 9 giant aneurysms. Thirty-five patients had a single aneurysm, and 14 patients had another aneurysm in addition to a CCA, including 5 mirror-type bilateral CCA aneurysms. Four aneurysms were preceded with saccular coil packing, and 1 patient with bilateral CCAs was treated with bilateral EC-IC bypass in advance.

Antithrombotic Management

All 49 patients were premedicated with antiplatelet agents for 7 days before the intervention. The patients treated with PAO received 100 mg of aspirin daily, and those who underwent SAC or FD were preloaded with 75 mg of clopidogrel and 100 mg of aspirin daily. Treatment was performed with an initial 5000 IU of heparin bolus and the intraoperative maintenance of an activated clotting time of 2× the patient's baseline value. Heparin was discontinued at the conclusion of the procedure. Dual antiplatelet therapy was continued for ≥6 months after the procedure.

Treatment Methods

Parent Artery Occlusion (22 Patients)

In all 22 of the patients who underwent PAO, the collateral circulation was evaluated with a balloon occlusion test (BOT) of the ipsilateral carotid artery in advance. The tolerance of PAO was judged using the following criteria under the condition of ipsilateral carotid artery occlusion[8]: (1) sufficient collateral flow via communicating or leptomeningeal pathways on the contralateral carotid or vertebral angiogram, (2) no delay or a small delay of the perfusion time on parenchymogram and dynamic CT, (3) stump pressure measured in the guiding balloon catheter up to one half of the mean systemic blood pressure, and (4) no neurological deficits during 20 minutes of simple occlusion and 10 minutes of hypotension load with nicardipine (an intentional reduction of the mean pressure by >20 mm Hg).

One patient (case 4) with bilateral CCAs without tolerance for a BOT underwent a high-flow EC-IC bypass on both sides of the carotid territory. All 21 of the remaining patients were judged to have sufficient collateral supply, and they underwent PAO without bypass surgery. In all 22 patients, internal trapping was attempted for both sides, that is, distal and proximal to the aneurysm of the parent artery. However, in cases in which it was difficult to access the distal side, only proximal occlusion was performed. The use of intra-aneurysmal coiling was avoided because the coil mass might disturb the shrinkage of the aneurysmal sac. However, the aneurysmal sac was packed with minimum coils in particular cases with the intracavernous meningeal feeders directly

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