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Prevention of Retrograde Blood Flow Into Large or Giant Internal Carotid Artery Aneurysms by Endovascular Coil Embolization with High-Flow Bypass: Surgical Technique and Long-Term Results

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Key words
- Coil embolization
- Giant aneurysm
- High-flow bypass
- Internal carotid artery
- Retrograde blood flow

Abbreviations and Acronyms
BTO: Balloon test occlusion
CCA: Common carotid artery
ECA: Extracranial artery
EC–IC: Extracranial-to-intracranial
ICA: Internal carotid artery
ISUIA: International Study of Unruptured Intracranial Aneurysms
M2: Middle cerebral artery second portion
MCA: Middle cerebral artery
MHT: Meningohypophyseal trunk
MRA: Magnetic resonance angiography
MRI: Magnetic resonance imaging
OphA: Ophthalmic artery
RA: Radial artery
STA: Superficial temporal artery

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■ BACKGROUND: **Recanalization has been reported in large or giant aneurysms of the internal carotid artery (ICA) addressed by high-flow bypass and endovascular treatment. Aneurysmal recanalization may be attributable to retrograde blood flow into the aneurysm through the ICA branches, such as the ophthalmic artery or the meningohypophyseal trunk, or through the surgically created bypass. We modified the endovascular treatment of aneurysms to prevent retrograde flow and evaluated the long-term efficacy of our method.**

■ METHODS: **We used a hybrid operative/endovascular technique to treat 5 patients with large or giant aneurysms arising from the C2–C4 segment of the ICA who presented with visual symptoms due to the mass effect of the aneurysm. To prevent retrograde flow into the aneurysm our modified endovascular treatment involves coil embolization of the aneurysmal orifice and the ICA, including the origin of the ophthalmic artery and meningohypophyseal trunk, and placement of a high-flow bypass using a radial artery graft.**

■ RESULTS: **During the 5- to 12-year follow-up period, 4 aneurysms disappeared, and the other decreased in size. There were no subarachnoid hemorrhages. All bypass grafts remained patent. Visual preservation was achieved in 2 patients; 1 patient manifested visual improvement. Although 2 patients experienced transient neurological deficits we encountered no permanent complications in this series. The final modified Rankin scale of the 5 patients was 0 or 1.**

■ CONCLUSIONS: **Prevention of retrograde flow into the aneurysm by coil embolization with high-flow bypass is a safe and effective method. It prevents the recanalization of large or giant ICA aneurysms.**

INTRODUCTION

Various treatment options have been reported for patients with large or giant complex aneurysms arising from the C2–C4 segment of the internal carotid artery (ICA). However, because of their large size, difficult location, wide atheromatous neck, and calcified dome, some aneurysms are unclippable and the intracranial approach is contraindicated. Endovascular techniques to address cerebral aneurysm are available and stent-assisted coil embolization and special stents including covered and flow-diverting stents, such as pipeline stents, are useful for treating giant ICA aneurysms (5, 21). Becske et al. (5) showed that at 1-year follow-up, 87% of their large or giant ICA aneurysms were completely occluded. However, unstable scaffolding, intraparenchymal hemorrhage unrelated to rupture of the target aneurysms, and thromboembolic complication requiring prolonged dual antiplatelet therapy remain an unsolved problem (20).

Although ligation of the cervical ICA with or without extracranial-to-intracranial (EC–IC) bypass is available to address unclippable aneurysms, their recanalization and rupture have been reported (10, 12, 13, 15, 17). Proximal ICA occlusion does not exclude aneurysms from the flow stream and retrograde flow into the aneurysm may be related to aneurysmal recanalization. There are two collateral pathways into aneurysms, the intrinsic collateral routes between the extracranial artery (ECA) and the ICA through ICA branches, such as the ophthalmic artery (OphA) or the meningohypophyseal trunk (MHT), and retrograde flow from the surgically created bypass graft.

To avoid recanalization due to retrograde flow into the aneurysms, in our 5 patients we performed endovascular coil occlusion of the aneurysmal orifice and the ICA, including the origin of the OphA and MHT. We placed a bypass (radial artery [RA] to second portion [M2] of the middle cerebral artery) before endovascular coil occlusion. We report our operative techniques and the long-term outcomes in these 5 patients.

METHODS

Patients

Between January 1996 and June 2011, 18 consecutive patients with large or giant ICA aneurysms were treated in our department. The treatment strategy for each patient was decided by neurovascular surgeons and endovascular specialists. Of the 18 patients, 5 underwent coil embolization of the aneurysmal orifice and the ICA including the origin of the OphA and MHT and placement of a high-flow bypass using an RA graft.

The 5 patients presented with large or giant ICA aneurysms (C3–C4 cavernous aneurysms, n = 3; C2–C3 paraclinoid aneurysms, n = 2) and dysfunction of cranial nerve II (n = 2), III (n = 2), and/or VI (n = 3) due to compression by the aneurysms. One patient (case 2) had a past history of subarachnoid hemorrhage due to rupture of a contralateral ICA aneurysm that had been clipped earlier. The aneurysms were giant in 4 patients and large in 1; their sizes ranged from 15–43 mm.

All patients underwent ICA balloon test occlusion (BTO) to identify those at risk for acute ischemia related to the temporary occlusion of the middle cerebral artery (MCA) during the high-flow bypass procedure. Although all patients were BTO-tolerant, had our series including BTO-intolerant patients, we would have placed a double-insurance bypass (i.e., the superficial temporal artery [STA]–MCA bypass before the introduction of the high-flow bypass to reduce the risk of ischemic complications) (9). A high-flow bypass using an RA graft was placed in all patients to prevent hemodynamic ischemia in the ipsilateral hemisphere and the development of de novo aneurysms.

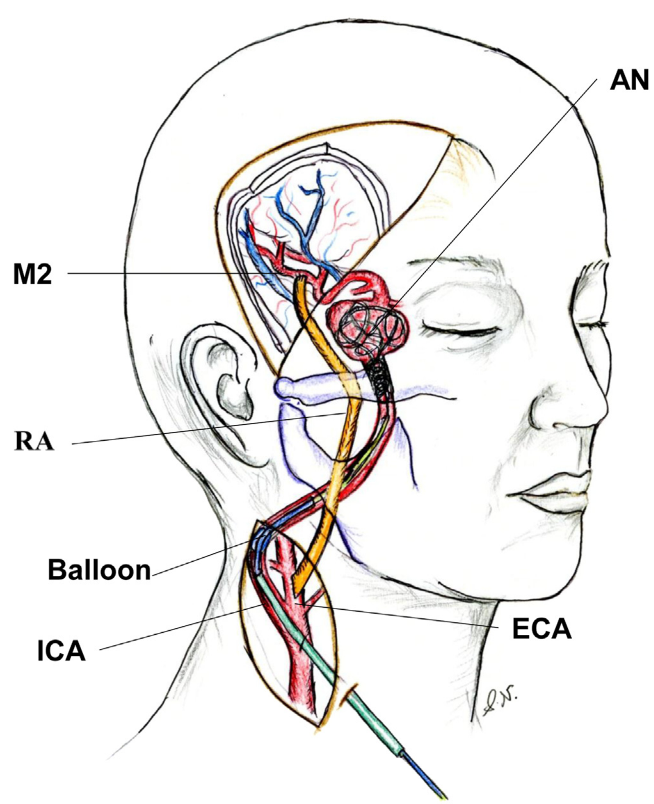

Figure 1. Illustration depicting the high-flow bypass using a radial artery (RA) graft between the external carotid artery (ECA) and the second portion (M2) of the segment of the middle cerebral artery. For intraoperative coil embolization of the internal carotid artery (ICA) proximal to the aneurysm (AN) a 7F sheath and a balloon catheter were inserted into the ICA.

Surgical Technique

Schematic drawings of our operative techniques and steps are shown in Figures 1 and 2. Neurophysiological monitoring to identify possible cerebral ischemic damage during temporary clipping included somatosensory-evoked and motor-evoked potentials. Craniotomy, exposure of the carotid artery, and harvesting of the RA were performed simultaneously by 3 teams of neurosurgeons. A 15- to 17-cm long segment of the RA was harvested between the wrist and the elbow. Before use, the harvested graft was distended in heparinized saline to avoid twisting and kinking. The common carotid artery (CCA), ICA, and ECA were exposed by making a cervical incision along the anterior aspect of the sternocleidomastoid muscle. Pterional craniotomy was performed with wide dissection of the Sylvian fissure.

Next, the harvested RA graft was passed from the cervical- to the craniotomy side through an 18-gauge chest tube in a tunnel created under the mandible and zygomatic arch (Figure 1). Distal anastomosis between the distal end of the RA and M2 was performed first in an end-to-side fashion with 9-0 monofilament nylon sutures. The proximal anastomosis was placed in an end-to-side manner to the ECA using 8-0 nylon continuous sutures. To retain patency of the bypass graft and to eliminate turbulent flow in the aneurysm, we then immediately proceeded to the endovascular procedure using a portable digital subtraction angiography instrument in the operating room. The exposed CCA was punctured directly and a 7F sheath ([Brite tip], Cordis, Miami, Florida, USA) was inserted from the CCA to the ICA (Figure 1). We injected radiopaque dye through the 7F sheath after temporary clipping of the cervical ICA to confirm bypass patency and to visualize the OphA and the aneurysmal supply by collaterals from the ECA (Figure 2A). Then we inserted a 7F balloon catheter ([PATLIVE], Clinical Supply, Gifu, Japan) into the ICA through the sheath. A microcatheter was inserted into the aneurysm under fluoroscopic guidance. After balloon dilation of the ICA proximal to the aneurysm to prevent distal embolism (Figures 1 and 2B) we inserted a few coils in the aneurysm to serve as anchors to