Tailored Flow Alteration Treatment for Intracranial Internal Carotid Artery Aneurysms: Strategy Beyond Parent Artery Occlusion With Bypass
—Case Report—

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Abstract
A 58-year-old woman with multiple right internal carotid artery (ICA) aneurysms detected incidentally was referred to us. Three-dimensional computed tomography (CT) angiography revealed a broad-necked paraclinoid aneurysm and an aneurysm on the C1 segment. Aneurysm clipping with preservation of the anterior choroidal artery and posterior communicating artery was not possible because these vessels could not be adequately identified. Intraoperative digital subtraction angiography during obliteration of the cervical portion of the ICA confirmed retrograde flow from the extracranial-intracranial (EC-IC) bypass to the right ophthalmic artery and stagnation of flow in the aneurysms. The cervical portion of the ICA was ligated. Postoperative three-dimensional CT angiography confirmed complete occlusion of both aneurysms and absence of ischemic lesions involving branches of the ICA. Reversal of the blood flow in the ICA via the EC-IC bypass primarily into the ophthalmic artery as the flow outlet by obliterating the cervical portion of the ICA was successful. To prevent ischemia in the territory fed by the perforating arteries of the ICA, tailored flow alteration treatment may be superior to simple parent artery occlusion of the ICA with/without bypass. The pattern of flow alteration should be deliberately based on individual anatomic variations, especially the preservation of flow outlets.

Key words: balloon test occlusion, extracranial-intracranial bypass, flow alteration, internal carotid artery aneurysm, parent artery occlusion

Introduction
Complete aneurysm occlusion and preservation of the anterior choroidal artery (ACHoA) and posterior communicating artery (PCoA) is of the utmost importance in the treatment of intracranial internal carotid artery (ICA) aneurysms. Parent artery occlusion with/without bypass is an alternative surgical strategy to address ICA aneurysms that cannot be treated by clipping or coil embolization, but ischemic complications involving the perforating arteries may cause serious problems.4,5 We treated a patient with complex ICA aneurysms using tailored flow alteration treatment to reduce the risk of perforator impairment.

Case Report
A 58-year-old woman was referred to our department after multiple right ICA aneurysms were detected incidentally by magnetic resonance imaging. Three-dimensional computed tomography (CT) angiography revealed a 13-mm diameter paraclinoid aneurysm with inferior projection; and another aneurysm on the C1 segment measured 6 mm and projected infero-medially (Fig. 1). No intra-aneurysmal thrombosis was observed. During balloon test occlusion (BTO) of the right ICA, she became restlessness and we judged her to be intolerant of carotid artery occlusion. The venous drainage delay in the right hemisphere exceeded 4 seconds, indicative of poor cross-filling via the anterior communicating artery (Fig. 2A, B).1 The right PCoA was not detected even after injection into the vertebral artery during BTO of the right ICA (Fig. 2C). Based on the anatomical features of the broad-necked paraclinoid aneurysm and the unclear relationships between the aneurysm of the C1 segment and the origins of the AChoA and PCoA, we judged her ineligible for coil embolization.

External carotid artery (ECA)-saphenous vein graft (SVG)-middle cerebral artery (MCA) bypass was performed through the pterional approach on the right side after superficial temporal artery-MCA (M4) bypass. After trapping the cervical portion of the ICA and a site just distal to the paraclinoid aneurysm, blood was manually aspirated by puncturing the cervical portion of the ICA for suction decompression of the aneurysm. However, this procedure failed to produce sufficient deflation of the
Fig. 1 Three-dimensional computed tomography angiogram showing a 13-mm diameter paraclinoid aneurysm projecting inferiorly and a 6-mm aneurysm on the C1 portion of the internal carotid artery projecting infero-medially.

Fig. 2 A, B: Left internal carotid angiograms obtained during balloon test occlusion (BTO) of the right internal carotid artery (ICA), anteroposterior view, arterial phase (A) and venous phase (B), showing the asymmetry of the bilateral hemispheres. C: Right vertebral angiogram showing the right posterior communicating artery not visualized even after injection into the vertebral artery during BTO of the right ICA.

Fig. 3 Intraoperative digital subtraction angiograms of the right internal carotid artery (ICA), lateral view, arterial phase (A) and venous phase (B), showing retrograde blood flow via the external carotid artery-saphenous vein graft-middle cerebral artery bypass to the right ophthalmic artery (arrows) during obliteration of the cervical portion of the ICA (A). Note stagnant blood flow in both aneurysms (B).

Fig. 4 Postoperative three-dimensional computed tomography angiograms, anterior view (A) and posterior view (B), showing complete occlusion of both aneurysms.

Discussion

Flow alteration treatment is a tailored flow reduction strategy that promotes thrombosis of cerebral aneurysms by altering the blood flow around them.3,6) Blood flow can be tailored with interventions from simple proximal obliteration to deliberate artery ligation with flow reversal bypass, depending on the individual anatomic variations and flow characteristics. To induce aneurysm thrombosis by blood flow stagnation, reduction of the in- and out-flow may be important.12) In our patient, intraoperative DSA demonstrated out-flow to the ophthalmic artery (Fig. 3A) and stagnant blood flow in the aneurysms after flow reversal (Fig. 3B), resulting in immediate aneurysm thrombosis (Fig. 4).

The clipping of intracranial ICA aneurysms, especially large or giant aneurysms, is technically demanding and often requires suction decompression. Patients intolerant of carotid artery occlusion require placement of a high-flow bypass to prevent ischemia during suction decompression. We were unable to adequately identify the critical branches of the ICA even after suction decompression of the aneurysm. However, the flow alteration procedure achieved immediate aneurysm occlusion without the need for clipping that would have raised the risk of sacrificing dome of the paraclinoid aneurysm. We judged that aneurysm clipping with preservation of the AChoA and PCoA was not possible as these arteries could not be adequately identified. Intraoperative digital subtraction angiography (DSA) during obliteration of the cervical portion of the ICA confirmed retrograde flow from the ECA-SVG-MCA bypass to the right ophthalmic artery (Fig. 3A) and stagnation of flow in the aneurysms (Fig. 3B). Therefore, we selected another strategy of flow alteration which had been planned preoperatively. After ascertaining that the motor, somatosensory, and visual evoked potentials (MEP, SEP, VEP) were stable during 20-minute obliteration of the cervical portion of the ICA, ligation was performed.

Postoperative three-dimensional CT angiography confirmed complete occlusion of both aneurysms (Fig. 4), and absence of ischemic lesions involving branches of the ICA. The patient was discharged home 2 weeks after treatment and 2-year follow-up examination detected no evidence of aneurysm recanalization.
ICA branches.

Therapeutic parent artery occlusion with revascularization resulted in postoperative perforator infarction in 31% of patients with complex ICA aneurysms, but the surgical methods of parent artery occlusion with/without low- or high-flow bypass had no statistically significant effect. Postoperative single photon emission computed tomography showed no evidence of decreased blood flow in the hemisphere, so the mechanism underlying perforator impairment was thought to be thrombotic or embolic rather than hemodynamic hypoperfusion. A patient with a ruptured ICA anterior wall aneurysm was treated with a high flow bypass and proximal arterial occlusion of the ICA just proximal to the aneurysm, but infarction occurred in the AChoA territory several days later despite thrombosis of the aneurysm. The ipsilateral AChoA and PCoA were not visualized on preoperative carotid angiography. Flow outlets may be preserved to reduce the risk of perforator impairment in patients treated with parent artery occlusion for intracranial ICA aneurysms. To maintain blood flow to the perforators, the occlusion site and flow outlet must be chosen based on individual anatomic variations. If normal-sized AChoA and PCoA can serve as outlets for the reversed blood flow, the ICA could be trapped at the cervical portion of the ICA and at a site just proximal to the PCoA (Fig. 5). However, if these flow outlets are small, as in our patient and the previous patient, simple occlusion of the cervical portion of the internal carotid artery (ICA) should be performed to leave the ophthalmic artery open as the other important flow outlet (Fig. 6).

The present procedure carries the risk of ischemia in brain areas supplied by small perforating arteries adjacent to the aneurysm, even if the appropriate occlusion site is carefully identified based on individual anatomic features. Postoperative perforator occlusion occurred in 1 of 7 patients treated by flow alteration treatment. We stress the importance of intraoperative monitoring of MEP, SEP, and VEP to avoid postoperative complications, particularly in patients with aneurysms involving the anterior circulation, although such monitoring cannot predict the occurrence of delayed thrombotic complications.

The success in the present patient cannot provide general insights into the safety or efficacy of treatment, but accumulation of experience with intracranial ICA aneurysms treated by tailored flow alteration will increase our understanding of this strategy. Parameters that confirm adequate blood flow to perforating arteries can help ensure the safety of this treatment. Studies on large patient populations must be performed to assess long-term clinical and angiographic outcomes.

References

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