Technical Failure of Giant Supraclinoid Aneurysm after Internal Carotid Artery Occlusion

A Report of Three Cases

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Summary

We describe three cases of technical failure in patients with giant supraclinoid aneurysm treated with internal carotid artery (ICA) occlusion.

Case 1 was a 65-year-old woman who presented with a two-month history of headache accompanied by blurred vision of the left eye. Case 2 was a 43-year-old woman who presented with a six-month history of headache accompanied by blurred vision of the right eye. Case 3 was a 21-year-old man admitted due to headache and blurred vision of the left eye, accompanied by left oculomotor nerve palsy for three months. Cerebral angiography revealed giant supraclinoid aneurysms in these patients. All of them were treated with ICA occlusion.

One case had recurrent headache symptoms after the first procedure and was retreated. Two cases suffered from post-procedural intracranial hemorrhagic complications.

Before ICA occlusion for giant supraclinoid aneurysm, balloon occlusion test was used to evaluate the collateral anastomosis between the external carotid artery (ECA) and the ICA, and still plays an important role in preventing treatment failure.

Introduction

Endovascular treatment by occlusion of the parent artery (PAO) is considered a safe and effective treatment option for large or giant carotid siphon aneurysms^{1,2}. A balloon occlusion test (BOT) performed prior to the procedure

allows for clinical and angiographic evaluation of the tolerance to PAO, ensuring the presence of a patent or adequate circle of Willis that would reduce the probability of ischemic complications following sacrifice of the ICA involved. Several papers have discussed cases involving ischemic complications due to hypoperfusion following ICA permanent occlusion, even in patients who have passed BOT uneventfully³⁻⁵. However, there have been only infrequent reports of hemorrhagic complications after PAO. This article describes three unusual cases involving patients with giant carotid siphon aneurysms treated with PAO, one of whom had recurrent headache symptoms after the first procedure and underwent a second one, while the other two suffered from post-procedural intracranial hemorrhagic complications.

Case 1

A 65-year-old woman presented with a two-month history of headache accompanied by blurred vision of the left eye. During the procedure, she received boluses of intravenous heparin to maintain an activated clotting time of two to three times baseline. Digital subtraction angiography (DSA) examination showed a giant aneurysm at the left supraclinoid ICA, as well as a primitive trigeminal artery (Figure 1A). The BOT demonstrated patent anterior communicating artery and left posterior communicating artery, and clinical evaluation revealed tolerance to BOT (Figure 1B). Occlusion of the left ICA was subsequently per-

Figure 1 DSA presentations of Case 1. A) Lateral DSA view of the left ICA demonstrating the giant supraclinoid aneurysm and the primitive trigeminal artery (white arrow). B) Frontal DSA view of the right ICA (top) and lateral DSA view of the right vertebral artery (bottom) performed during BOT of the left ICA demonstrating collateral support of the left hemispheric circulation through the circle of Willis. C) The left ICA was occluded by 3 detachable balloons. The first balloon (white arrow) was placed into the aneurysm cavity unintentionally. D) Postoperative DSA image of the left ECA demonstrates the aneurysm opacified via the internal maxillary artery-ophthalmic artery anastomosis. E) DSA re-examination of the left ECA 10 months later revealing that the ophthalmic artery fed the aneurysm (left) and then the distal ICA (right). F) Lateral microcatheter angiography during coiling the aneurysm showing the microcatheter route from the vertebrobasilar artery, via the left posterior communicating artery, to the aneurysm cavity. G) Lateral mask showing the coil mass packed into the aneurysm cavity and the origin of the left ophthalmic artery. H) Postoperative angiography of the left ECA, showing the aneurysm was not opacifying.

Figure 2 DSA and CT images of Case 2. A) Lateral DSA view of the left ICA demonstrating a small aneurysm at the supraclinoid segment. B) Frontal (left) and lateral (right) DSA views of the right ICA demonstrating a giant aneurysm at the supraclinoid segment. C) Postoperative lateral DSA view of the left ICA showing that the small aneurysm was embolized with detachable coils. D) DSA re-examination of the left ICA 2 months later showing no recanalization of the small aneurysm. E) Lateral mask showing that the right ICA was occluded with 3 detachable balloons after the BOT. The arrow indicates the coil mass in the contralateral aneurysm. F) The mid (left) and late (right) phases of the lateral DSA of the right ECA revealing that the aneurysm was perfused by reversal of flow through the ophthalmic artery anastomosing with the collaterals of the internal maxillary artery. G) Emergent CT scan on the third postoperative day, showing intracranial hemorrhage resulting from rupture of the right supraclinoid aneurysm. H) Lateral view of DSA re-examination of the right ECA, showing absence of aneurysm opacification, possibly due to thrombosis within the cavity of the right supraclinoid aneurysm after rupture.

Figure 3 DSA and CT images of Case 3. A) Oblique DSA view of the left ICA demonstrating a giant aneurysm at the cavernous segment and a smaller aneurysm at the supraclinoid segment. B) Frontal DSA view of the right ICA (left) and lateral DSA view of the left vertebral artery (right) during BOT of the left ICA, showing adequate collateral support of the left hemisphere circulation through the circle of Willis. C) Lateral DSA view of the left ECA during BOT of the left ICA, showing a faint anastomosis between the foramen rotundum artery (white arrow) and the ICA cavernous inferolateral trunk (black arrow). The intracavernous aneurysm opacified marginally via this anastomosis. D) The roadmap of the left ICA (left) showing that the supraclinoid aneurysm was coiled; subsequent oblique DSA view of the left ICA (right) demonstrating that the ophthalmic segment of the left ICA was occluded by the coils. E) Occlusion of the proximal ICA by two detachable balloons, as seen on roadmap of the left ICA. F) Postoperative lateral DSA of the common carotid artery showing trapping of the giant intracavernous aneurysm. G) CT scan on the postoperative 14th hour indicating intracranial bleeding. H) Faint opacification of the intracavernous aneurysm via the collaterals of the internal maxillary artery on lateral DSA view of the left ECA. I) Superselective microcatheter angiography of the left artery of the foramen rotundum on lateral projection revealed re-directed circulation from the artery of the foramen rotundum to the cavernous ICA, then to the ophthalmic artery whose origin was not completely occluded by coils. This circulation passed through the intracavernous aneurysm and caused its rupture. J) Lateral mask showing the Onyx 18 cast (arrow) within the artery of the foramen rotundum and the ICA cavernous inferolateral trunk. K) Aneurysm was no longer opacifying on postoperative lateral DSA view of the left ECA. L) Lateral DSA view of the left ECA 4 months later showing no recanalization of the aneurysm.

formed using detachable balloons (BALT/Goldbal2, Montmorency, France) (Figure 1C). Postoperative angiography of the ECA revealed collaterals between the internal maxillary artery and ophthalmic artery, and the aneurysm was perfused by reverse flow through the ophthalmic artery (Figure 1D). Ten months later the patient was readmitted due to refractory headache. DSA re-examination of the left ECA showed that the aneurysm, while decreased in size, was fed by the ophthalmic artery which in turn fed the distal ICA (Figure 1E). The patient underwent a second procedure during which the microcatheter was navigated through the vertebrobasilar artery and the left posterior communicating artery into the aneurysm (Figure 1F). The detachable coils were

packed into the aneurysm, and finally into the origin of the left ophthalmic artery (Figure 1G), after which the aneurysm no longer opacified (Figure 1H). Two-year follow-up was performed by telephone to confirm that her headache had disappeared and she lived independently.

Case 2

A 43-year-old woman presented with a six-month history of headache accompanied by blurred vision of the right eye. During the procedure, she received boluses of intravenous heparin to maintain an activated clotting time of two to three times baseline. DSA examina-

tion showed a small aneurysm at the left supraclinoid ICA (Figure 2A) and a giant aneurysm (Figure 2B) at the same site on the right. Detachable coils were used to embolize the small aneurysm on the left (Figure 2C, D). Two months later, PAO was performed on the right ICA using detachable balloons (BALT/Goldbal2, Montmorency, France) (Figure 2E). The first balloon failed to cover the origin of the right ophthalmic artery, resulting in persistent perfusion of the aneurysm via reversal of flow through the ophthalmic artery anastomosing with the collaterals of the internal maxillary artery (Figure 2F). On the third postoperative day, the patient died of intracranial hemorrhage secondary to rupture of the right supraclinoid aneurysm (Figure 2G). Before death, an emergency DSA re-examination showed absence of the aneurysm, possibly due to thrombosis within the cavity of the right supraclinoid aneurysm after rupture (Figure 2H).

Case 3

A 21-year-old man was admitted due to headache and blurred vision of the left eye, accompanied by left oculomotor nerve palsy for three months. During the procedure, he received boluses of intravenous heparin to maintain an activated clotting time of two to three times baseline. DSA examination of the left ICA showed a giant aneurysm at the cavernous segment and a smaller aneurysm at the supraclinoid segment (Figure 3A). BOT of the left ICA showed adequate collateral support of the left hemispheric circulation through the circle of Willis (Figure 3B). DSA examination of the left ECA performed during the BOT demonstrated faint anastomosis between the artery of the foramen rotundum (a terminal branch of the internal maxillary artery) and the inferolateral trunk arising from the cavernous segment of the internal carotid artery. The intracavernous aneurysm opacified slightly via this anastomosis (Figure 3C). Coil embolization of the supraclinoid aneurysm was performed, followed by occlusion of the ophthalmic segment of the left ICA using coils (Figure 3D). Two detachable balloons (BALT/Goldbal2, Montmorency, France) were subsequently used to occlude the proximal ICA (Figure 3E), trapping the giant intracavernous aneurysm (Figure 3F). Fourteen hours later, the patient presented with sudden onset seizure and fell into a coma. Emergent

CT scan showed subarachnoid hemorrhage around the mesencephalic region (Figure 3G), suggesting rupture of the left intracavernous aneurysm. Emergent DSA re-examination of the left ECA revealed faint opacification of the intracavernous aneurysm via the collaterals of the internal maxillary artery (Figure 3H). The microcatheter was navigated into the left foramen rotundum artery, and superselective microcatheter angiography showed incomplete occlusion of the ophthalmic segment of the left ICA, with persistent flow from the foramen rotundum artery into the ophthalmic artery via the aneurysm (Figure 3I). Onyx was used to occlude the foramen rotundum (Figure 3J), after which the aneurysm was no longer opacifying (Figure 3K). Four months later the DSA re-examination demonstrated no recanalization of the aneurysm (Figure 3L). The patient had partial recovery of the blurred vision and oculomotor dysfunction.

Discussion

We focus on the cavernous and supraclinoid portions of the carotid siphon, which are locations where large or giant intracranial aneurysms tend to develop. Giant intracranial aneurysms present great challenges to neurosurgeons and interventional neuroradiologists. Balloon-assisted or stent-assisted coiling makes it possible to obliterate wide-neck aneurysms and preserve the parent artery^{6,7}, while flow diversion has recently emerged as another important tool for the management of such intracranial aneurysms^{8,9}, but is not currently available in all markets. However, placing a stent or flow diverter device across the parent artery of an aneurysm is often challenging due to its large cavity and wide neck. Even if stent-assisted coil embolization is achieved, the patient will face a high incidence of future aneurysm recanalization. In such cases, sacrificing the ICA may be the most reasonable treatment alternative for these giant carotid siphon aneurysms¹.

It is widely accepted that BOT is necessary before performing a PAO, to determine the patency of the circle of Willis. In addition, another important function of BOT is to reveal the collateral anastomosis between the ECA and ICA, as well as the anatomical relationship between the anastomosis flow and the aneurysm. It is thus important to recognize that BOT not

Figure 4 Schematic illustration of the blood flow pattern within the aneurysm cavity in case 1. 1, ICA; 2, ophthalmic artery; 3, aneurysm cavity; solid arrow, the flow direction before PAO; empty arrow, the flow direction after PAO.

Figure 5 Schematic illustration of the blood flow pattern within the aneurysm cavity in case 2. 1, ICA; 2, ophthalmic artery; 3, aneurysm cavity; solid arrow, the flow direction before PAO; empty arrow, the flow direction after PAO.

Figure 6 Schematic illustration of the blood flow pattern within the aneurysm cavity in case 3. 1, ICA; 2, ophthalmic artery; 3, aneurysm cavity; solid arrow, the flow direction before PAO; empty arrow, the flow direction after PAO.

only determines the feasibility of PAO, but also influences how the procedure will be performed. We analyze below in detail what happened in the above-mentioned three cases, and how PAO-related hemorrhagic complications can be prevented.

The first question we seek to answer is, why were the carotid siphon aneurysms in all three cases still opacifying after the ICA was occluded? Indeed, in every case, the aneurysm remained supplied through flow from collateral anastomoses between the ECA and ICA.

For the first two cases, after the proximal ICA was occluded, a new blood flow pathway was constructed from internal maxillary collaterals to the ophthalmic artery, continuing on to the supraclinoid ICA and further distal branches, and the aneurysm was seated in the flow pathway (Figures 1E and 2H). For the third case, after the supraclinoid ICA and the petrous ICA were occluded respectively, blood flow was redirected from the foramen rotundum artery, via the trapped cavernous ICA portion, to the ophthalmic artery whose origin

was not completely occluded by coils, and the cavernous aneurysm was in the pathway (Figure 3I). Of note, it has been estimated that collateral anastomosis between the internal maxillary artery and the ophthalmic artery is patent in more than eighty percent of the population under pathologic or iatrogenic occlusion of the ICA. In some patients, the ophthalmic artery originates from the middle meningeal artery rather than the supraclinoid ICA. However, the anastomosis between the foramen rotundum artery and the cavernous ICA is rarely encountered during angiography.

The second question is about the etiology of the hemorrhagic complications. We postulate that the hemorrhagic complications in Cases 2 and 3 may be explained by examining the anatomical relation between the anastomotic flow and the aneurysm, and the resulting hemodynamic changes in the aneurysm cavity^{10,11}. According to the dynamic angiography images, the direction and pattern of the blood flow in the aneurysm cavity post-PAO was identical to that observed pre-PAO in the first case (Figure 4). In the latter two cases, however, both were reversed post-PAO (Figures 5 and 6). In the first case, the ophthalmic artery, instead of the ICA, became the feeder of the aneurysm after PAO. Since the aneurysm was located proximal to the origin of the ophthalmic artery, the flow pattern within the aneurysm cavity was not changed by PAO (Figure 4). DSA re-examination ten months later demonstrated shrinkage of the aneurysm (Figure 1E), suggesting decreased blood flow, but to completely eliminate the risk of rupture, a second procedure was performed to obliterate the aneurysm. In the second case, the aneurysm was located distal to the origin of the ophthalmic artery. As a result, PAO reversed the flow pattern within the aneurysm cavity (Figure 5) and changed the location of higher shear stress that may lead to rupture. Indeed, we had anticipated the problem of flow reversal from the ophthalmic artery before performing the PAO, but the aneurysm remained perfused post-PAO since the first detachable balloon failed to cover the origin of the ophthalmic artery. Complementary treatment should have been conducted while the procedure was being done on the anastomosis component as the aneurysmal inflow is in the same direction. For the third case, having recognized the risk of flow reversal from the ophthalmic artery, we occluded the smaller supraclinoid aneurysm and

the supraclinoid ICA with coils. Otherwise, flow reversal from the ophthalmic artery would have entered the supraclinoid aneurysm following the petrosal ICA occlusion. We subsequently used detachable balloons to occlude the petrosal ICA, intending to trap the giant intracavernous aneurysm. During the BOT we had seen the faint anastomosis between the foramen rotundum artery and the cavernous ICA. During the procedure, treatment is incomplete and failure to completely occlude the origin of the ophthalmic artery allowed for an alternative pathway for blood flow, from the foramen rotundum artery to the cavernous ICA, then to the ophthalmic artery. The resulting flow from this circulation entered the intracavernous aneurysm and led to its rupture (Figure 6).

The third question is how to reduce the hemorrhagic complications. While performing BOT, we must be aware of potential collateral anastomosis between the ECA and ICA, while assessing the condition of the circle of Willis. If we fail to consider the flow supply from the anastomosis to the aneurysm, the PAO may result in unexpected flow patterns resulting in disastrous outcomes as presented in Cases 2 and 3. While this concern is of relative less importance for aneurysms at the communicating segment of the ICA, since PAO is seldom performed on the involved posterior communicating artery and the anterior choroidal artery, this practice must be emphasized in aneurysms at the supraclinoid and cavernous ICA. When performing PAO for the treatment of a giant supraclinoid aneurysm, we suggest using detachable coils to occlude both the aneurysm and the supraclinoid ICA. Using cheaper detachable balloons to occlude only the proximal ICA is not ideal, as that may redirect reversed flow from the ophthalmic artery to the unoccluded aneurysm, eventually leading to rupture. On the other hand, detachable balloons can be considered for the occlusion of the petrosal ICA when treating giant intracavernous aneurysms. Occlusion of the intracavernous aneurysm is not entirely necessary, since reversal of flow through the ophthalmic artery would be directed distally to the cerebral branches instead of proximally to the unoccluded aneurysm. However, we must not neglect to perform angiography of the ipsilateral ECA during the BOT and after PAO, to determine whether collateral anastomoses between the ECA terminals and the cavernous ICA are patent. Patent

anastomoses supplying the aneurysm must be interrupted with liquid embolic agents.

Conclusion

Before ICA occlusion for giant supraclinoid aneurysm, balloon occlusion test, used to evaluate the collateral anastomosis between ECA and ICA, still plays an important role in preventing treatment failure.

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