Large Paraclinoid Aneurysm With a Calcified Neck Treated by Tailored Multimodality Procedures
—Case Report—

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Abstract
A 68-year-old woman presented with a large paraclinoid aneurysm with a calcified neck causing visual symptoms. Direct clipping was hazardous because of severe calcification of the neck. Endovascular internal trapping was difficult because of the short distance between the neck and the origin of the posterior communicating artery. Proximal occlusion was likely to be less effective because of large collateral back flow to the aneurysm via the ophthalmic artery (OphA). The aneurysm was successfully treated by a combination of a high-flow bypass, intraoperative coil embolization of the parent artery including the origin of the OphA, and clipping of the internal carotid artery distal to the aneurysm. Paraclinoid aneurysms may be difficult to treat by the simple application of direct clipping, endovascular coiling, or trapping. Multimodality procedures can be tailored to treat such aneurysms.

Key words: paraclinoid aneurysm, mass effect, calcification, high-flow bypass, direct clipping, intraoperative embolization

Introduction
Large or giant aneurysms in the paraclinoid segment of the internal carotid artery (ICA) remain some of the most difficult aneurysms to obliterate. Recent advances in skull base surgery have enabled direct clipping of the aneurysm. The use of endovascular surgery has also increased, but the results of endosaccular coil embolization may be less satisfactory for wide-necked aneurysms or aneurysms causing a mass effect. Direct clipping sometimes results in incomplete obliteration of the aneurysm or compromise of the patency of the ICA if severe sclerotic change is present in the wall of the aneurysm neck or the parent artery. We report a case of large paraclinoid aneurysm with a calcified neck treated by a tailored combination of multimodality procedures.

Case Report
A 68-year-old woman with a 1-year history of progressive vision loss in the left eye presented to the neurosurgical clinic at Kyoto University Hospital. On admission, visual acuity had decreased to 0.04 with upper nasal quadrant hemianopsia. Magnetic resonance (MR) imaging revealed a non-thrombosed aneurysm compressing the left optic nerve (Fig. 1A). Cerebral digital subtraction angiography (DSA) disclosed a 15-mm wide-necked aneurysm at the paraclinoid segment of the left ICA (Fig. 2A, B). A Matas test revealed that the collateral blood flow via the anterior communicating artery and posterior communicating artery (PcomA) was insufficient for permanent occlusion of the left ICA, even with reconstruction by superficial temporal artery to middle cerebral artery anastomosis. Considerable retrograde blood flow from the external carotid artery (ECA) to the aneurysm was observed via a maxilloophthalmic anastomosis. Three-dimensional DSA showed the aneurysm neck was close to the origin of the PcomA (Fig. 2C). Three-dimensional computed tomography (CT) demonstrated severe calcification at the aneurysm neck (Fig. 2D). Three-dimensional CT angiography could not clearly demonstrate the margin between the anterior clinoid process and the aneurysm (Fig. 2E).
Neck clipping was not indicated for this aneurysm because of the calcified neck. Drilling of the anterior clinoid process carried some risk of deterioration of the visual function including blindness of the left eye because preoperative visual loss was highly advanced. Drilling of the anterior clinoid process also carried the risk of injury to the aneurysm wall because the margin between the anterior clinoid process and the aneurysm was unclear. Therefore, direct trapping with drilling of the anterior clinoid process was avoided. Endosaccular coil embolization was also unsuitable because of the mass effect and wide neck of the aneurysm. The short distance between the neck and the origin of the PcomA hindered endovascular internal trapping with preservation of the PcomA. Endovascular proximal occlusion was suspected to be ineffective because of the large collateral back flow to the aneurysm from the ophthalmic artery (OphA).\(^1,7\)

Therefore, the aneurysm was treated with a tailored combination of multimodality procedures as follows. A left frontotemporal craniotomy was performed simultaneously with harvesting of a radial artery graft from the left forearm and exposure of the cervical ECA. A high-flow bypass with a radial artery graft between the ECA and
M2 segment of the middle cerebral artery was performed after systemic heparinization with barbiturate brain protection as described previously.\textsuperscript{15\textsuperscript{)} Then, a 7-Fr guiding catheter with an inflatable balloon (PATLIVE; Clinical Supply Co., Ltd., Osaka) was introduced to the left cervical ICA via the transfemoral approach. Temporary trapping of the aneurysm was obtained by inflating the balloon and clipping the distal side ICA just proximal to the origin of the PcomA after navigation of a microcatheter (Prowler Plus 18; Cordis, Johnson & Johnson, Miami Lakes, Fla., U.S.A.) into the aneurysm. Intraoperative coil embolization of the left carotid siphon including the origin of the OphA was performed with Guglielmi detachable coils (Target Therapeutics/Boston Scientific, Fremont, Calif., U.S.A.) and fibered platinum coils under intraoperative DSA guidance. The amount of coils within the aneurysm could be minimized because clipping of the distal ICA had provided a blind pouch in the distal side ICA serving as an anchoring site for coils (Fig. 1C, D). After finishing embolization, the origin of the cervical ICA was ligated with 1-0 silk sutures as a stumpectomy.\textsuperscript{18\textsuperscript{)} Complete obliteration of the aneurysm and patency of the graft were confirmed by intraoperative DSA. Somatosensory evoked potential monitoring showed no abnormal findings throughout the procedure.

Postoperative DSA confirmed complete obliteration of the aneurysm and extensive blood supply to the left cerebral hemisphere via the radial artery graft (Fig. 3A–C). The blood supply to the left eye was preserved via the maxilloophthalmic anastomosis from the ECA (Fig. 3D). MR imaging on day 62 after surgery showed complete thrombosis and shrinking of the aneurysm (Fig. 1B). Her left visual acuity had improved to 0.4 without ischemic retinopathy by 3 months after surgery.

**Discussion**

Recent advances in skull base surgery have enabled direct clipping of paraclinoid aneurysms with drilling of the anterior clinoid process.\textsuperscript{2,4,6,8,17\textsuperscript{)} However, occlusion or stenosis of the ipsilateral ICA sometimes occurs after direct clipping and a high degree of mural sclerosis of the aneurysms and the parent artery is suspected to be one of the most crucial predictors of this phenomenon.\textsuperscript{13,14,16,24\textsuperscript{)} In our case, the severe calcification of the aneurysm neck led us to avoid direct clipping. Drilling of the anterior clinoid process often induces postoperative aggravation of the visual loss or visual field defect due to mechanical or heat injury.\textsuperscript{16\textsuperscript{)} Drilling of the anterior clinoid process caused fatal aneurysm rupture in one case because the aneurysm dome had migrated within the process.\textsuperscript{19\textsuperscript{)} In our case, the preoperative visual loss was highly advanced and three-dimensional CT angiography could not clearly demonstrate the margin between the calcified aneurysm neck and the anterior clinoid process. Therefore, clinoidal drilling was thought to be hazardous and avoided.

The results of endosaccular coil embolization may be less satisfactory for the treatment of paraclinoid aneurysms with a wide neck or mass effect.\textsuperscript{3,9,11,20,21\textsuperscript{)} Less than 50\% of large and giant aneurysms and less than 60\% of small but wide-necked aneurysms can be obliterated by endosaccular coiling.\textsuperscript{11\textsuperscript{)} Postoperative aggravation of visual symptoms after endosaccular coil embolization also occasionally necessitates additional surgical debulking of the aneurysm.\textsuperscript{8,20,21\textsuperscript{)} In this case, the neck and size of the aneurysm suggested that endosaccular coil embolization could not relieve the mass effect of the
aneurysm. Proximal occlusion or trapping of the aneurysm is reported to be effective, especially using endovascular surgery.\textsuperscript{7,14,23} In our case, the short distance between the aneurysm neck and the origin of the PcomA prevented endovascular internal trapping with preservation of the PcomA. Residual back flow into the aneurysm via the maxilloophthalmic anastomosis suggested that endovascular proximal occlusion with extracranial-intracranial bypass or surgical trapping with extracranial-intracranial bypass would be less effective.\textsuperscript{1,7,13}

Intraoperative endovascular occlusion of the parent artery including the origin of the OphA could have effectively interrupted the retrograde influx of blood flow into the aneurysm in our case. Clipping of the ICA between the aneurysm neck and the origin of the PcomA were important to reduce the risk of distal embolism and to avoid excessive endosaccular coil placement causing aggravation of the aneurysmal mass effect (Fig. 1D). This case illustrates the effective use of intraoperative endovascular surgery as an adjunct to open surgical treatment for a paraclinoid aneurysm.

Tailoring of the combination of these modalities according to the individual case based on the nature of the aneurysm and the cerebral hemodynamics is important for successful treatment of a paraclinoid aneurysm.

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