Posttraumatic Carotid-Cavernous Fistulae Treated by Internal Carotid Artery Trapping and High-Flow Bypass Using a Radial Artery Graft
—Two Case Reports—

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Abstract
Two patients presented with post-traumatic carotid-cavernous sinus fistulae (CCFs) that were successfully treated by high-flow bypass using a radial artery graft after initial unsuccessful attempts at obliteration by intravascular embolization. Case 1 was a 20-year-old man with a CCF detected by magnetic resonance imaging and angiography following an accident. Although the CCF appeared partially occluded by intravascular embolization, serial angiography revealed CCF recurrence. The CCF was trapped by placing a high-flow bypass. Case 2 was a 21-year-old man who presented with bilateral CCFs after sustaining face trauma. The bilateral CCFs were directly treated because of recurrence after balloon occlusion. At present, intravascular surgery is the first treatment choice, but placing a high-flow bypass with trapping of the CCF gained time to treat the CCF and may be useful for treating post-traumatic CCF that cannot be effectively eliminated by intravascular techniques.

Key words: high-flow bypass, internal carotid artery trapping, radial artery graft, traumatic carotid-cavernous fistula

Introduction
Traumatic carotid-cavernous fistula (CCF) may develop as a result of trauma to the face or head. Traumatic CCF is usually treated by intravascular procedures such as balloon and/or coil embolization.1,2,10,18) Spontaneous healing or disappearance were reported in 19.4% of cases of traumatic aneurysms, including some traumatic CCFs, indicating that these patients should be followed up angiographically at regular intervals up to 6–8 weeks if there is no evidence of healing.3) Fistulae usually occlude within a few weeks to a few months because of progressive fibrosis of the cavernous sinus even in patients with partial CCF occlusion following embolization.9) On the other hand, post-traumatic CCF that cannot be embolized completely in one procedure require a second attempt after 1 to 2 weeks.10) If this approach fails, direct surgery is indicated.

Here we report two cases of CCF that were successfully treated by trapping and placing a high-flow bypass using a radial artery (RA) graft after failure of obliteration using intravascular treatment.

Case Reports
Case 1: A 19-year-old man was admitted to our hospital after a car he was repairing fell on him. On admission, his neurological condition was Glasgow Coma Scale (GCS) 3 (E1V1M1). His left pupil was mydriatic, and left direct and indirect light reflexes were absent. Computed tomography (CT) demonstrated pneumocephalus and cerebral contusion with subarachnoid hemorrhage (SAH). Magnetic resonance (MR) imaging, obtained on day 6 after the accident, showed cerebral contusion and a flow void in the left cavernous sinus (Fig. 1 left). Cerebral angiography of the left internal carotid artery (ICA) demonstrated a CCF that drained into a markedly dilated superior ophthalmic vein, petrosal vein, and the pterygoid venous plexus (Fig. 2 upper left). Reflux of blood flow to the cerebral cortical veins was also noted.

The patient’s consciousness gradually improved, and on the 13th day after the accident, his GCS score was 5T (E2VTM3), so intravascular treatment was performed via a transfemoral approach. Two detachable balloons were placed in the fistula. In addition, Guglielmi detachable coils were introduced to block the fistula because the CCF was not occluded by only the balloons. Although the fistu-
on the 28th day after the accident, his consciousness declined to GCS score 5T (E2VTM3).

CT revealed SAH, intraventricular hemorrhage, and hydrocephalus (Fig. 1 right). Cerebral angiography showed enlargement of the CCF (Fig. 2 lower left) and he underwent trapping of the ICA between the proximal and distal CCF at 43 days after the accident. To reconstruct the cerebral circulation in the left ICA after trapping, we placed a left external carotid artery (ECA) graft using a RA and anastomosed the proximal portion of the middle cerebral artery (MCA) to the intradural portion. Because of the consciousness disturbance and SAH, balloon test occlusion or multi-stage procedure with intravascular ICA occlusion were not viable treatment options. To prevent ischemia during the high-flow bypass, a left superficial temporal artery (STA)-distal MCA anastomosis was performed. After completing the bypass surgery, the perfusion pressure was measured from the parietal branch of the STA through the STA-MCA anastomosis. The arterial pressure of the MCA before ICA ligation was 30–40 mmHg. After occlusion of the ICA at the cervical portion, MCA pressure fell below 10 mmHg. After opening the high-flow bypass, MCA pressure was 60–70 mmHg, and after ICA trapping it rose to 100 mmHg.

Following placement of a ventriculoperitoneal shunt on the 62nd day after the accident, the patient became alert, but with reduced visual acuity compared to the first visual acuity test on the 86th day after the accident. No improvement and some worsening of left oculomotor paresis and abducens palsy had occurred from the time of the injury to after surgery. Postoperative angiography showed no evidence of residual shunt and the left MCA territory was perfused via the anastomosis from the ECA-RA graft (Fig. 2 lower right). The patient was discharged 3 months after the operation with post-traumatic hypopituitarism.

**Case 2:** A 21-year-old man was transferred to our hospital because chemosis and exophthalmos persisted 7 months after he had sustained face and head trauma in a traffic accident. On admission, he was alert. The left eyeball protruded, the bilateral conjunctivae were red, and bruit was detected. He had lost hearing in his right ear after the accident. MR imaging showed dilation of the bilateral cavernous sinuses and superior ophthalmic veins (Fig. 3 upper left). Cerebral angiography of the left ICA revealed a CCF draining into a markedly dilated superior ophthalmic vein, petrosal vein, and pterygoid venous plexus, with venous cortical reflux (Fig. 3 lower left). The left MCA was poorly supplied from the ipsilateral ICA. Cerebral angiography of the right ICA also showed a CCF draining into a markedly dilated superior ophthalmic vein and inferior petrosal vein, without venous cortical reflux (Fig. 3 upper right). The territory of the right MCA was not filled from the ICA because of an arteriovenous shunt. Balloon occlusion test of the left ICA, analyzed with single photon emission CT imaging, demonstrated no clinical symptoms and severe hypoperfusion of the left hemisphere. To restrain the influence of the arteriovenous shunt on the balloon test occlusion, a balloon was inflated at the cavernous fistula. These findings indicated that trapping of the ICA without revascularization surgery would not be possible.
Therefore, we planned reconstructive surgery of the left CCF.

The patient underwent frontotemporal craniotomy 8 months after the accident. Anastomosis was performed between the frontal branch of the STA and the distal portion of the MCA, then an ECA-RA-proximal MCA graft was performed. The pressure of the MCA via the parietal branch of the STA was 30–40 mmHg. After cervical ICA occlusion, this pressure fell to below 10 mmHg and increased to only 30–40 mmHg after opening the high-flow bypass. The ICA was trapped between the cervical portion and just distal to the ophthalmic artery, and the ophthalmic artery was also clipped. The MCA pressure improved to 90–100 mmHg after ICA trapping.

The patient’s left exophthalmos gradually improved and his left eye bruit and chemosis were reduced. Follow-up angiography found no evidence of residual shunt on the left ICA (Fig. 3 lower right). Cerebral blood flow to the territory of the left ICA was provided by the ECA-RA graft and MCA anastomosis. The patient underwent balloon occlusion of the right CCF via the transfemoral approach 13 months after the accident. Two detachable balloons were placed in the CCF. Post-embolization angiography showed that the arteriovenous shunt flow had disappeared and the patency of the left ICA was preserved (Fig. 4 upper left). Angiography obtained 4 months after embolization showed no evidence of CCF. However, the patient developed right abducens nerve palsy 6 months after embolization. Angiography of the right ICA showed that one balloon had become deflated and that the right CCF and pseudoaneurysm had recurred (Fig. 4 upper right and lower left).

The patient underwent open surgery 19 months after the accident because he refused to undergo intravascular treatment for the recurrent CCF. After right frontotemporal craniotomy, a right STA-distal MCA anastomosis was performed. Right proximal ECA-RA graft and MCA anastomosis were performed. Measurement of the perfusion pressure on the parietal branch of the STA after STA-MCA anastomosis showed that the initial pressure of the MCA was 60–70 mmHg. After occlusion of the cervical ICA, this pressure decreased to 10 mmHg and increased to only 50–60 mmHg after opening the high-flow bypass due to the steal phenomenon via the CCF. The pressure increased to 90–100 mmHg after opening the high-flow bypass and ICA trapping. The ICA was trapped between the cervical portion and just distal to the ophthalmic artery. The patient’s postoperative course was uneventful. Follow-up angiography found no evidence of residual shunt and the bilateral ICA territories were supplied by the ECA-RA graft and the MCA anastomosis (Fig. 4 lower right).
Both of our patients underwent intravascular treatment with detachable balloons and/or coils, but the fistulae were not completely eliminated. More intense follow-up examinations, including serial angiography, following the incomplete embolization of the CCF and SAH may have led us to perform direct surgery earlier in the clinical course of Case 1. From our experience, we recommend a direct surgical approach if no healing is indicated by angiography, after failed endovascular surgery, or if new clinical symptoms such as cranial nerve palsy or intracerebral hemorrhage are observed after failed endovascular surgery. However, intravascular treatment is absolutely the recommended first-line treatment.

A direct surgical approach is indicated \(^{16,17}\) if interventional approaches fail. Five of 100 patients with traumatic CCF required surgical treatment. \(^{10}\) Different approaches and methods, such as neck clipping to retain the patency of the parent artery, have been used to close the fistula directly in patients with post-traumatic CCF. \(^{4,8,11,12,14,15}\)

On the other hand, proximal ligation or trapping of the parent artery may be useful \(^{16,17}\) if direct surgical treatment of post-traumatic aneurysms is difficult because the fibrous wall is friable and the aneurysm neck is broad. \(^{1,3,13}\) Simultaneously, ICA ligation may result in complications such as cerebral infarction, visual loss, and CCF recurrence, even if the Matas test is negative. \(^{18}\)

In our cases, the fistula could not be completely closed intravascularly. Only ICA ligation may not avoid ischemic insult and may cause complications. In addition, there is no preoperative assurance that the STA can supply enough blood to compensate for the occluded ICA. \(^{6,18}\)

Therefore, we trapped part of the CCF and placed a high-flow bypass using a RA graft to prevent ischemic complications, because the intraoperative MCA perfusion pressure was very low after occlusion of the parent artery. However, ICA and ophthalmic artery trapping may lead to vision loss. \(^{18}\) To preserve the blood flow of the ophthalmic artery, intravascular treatment should be selected as the primary treatment. In our cases, proximal clipping of the ophthalmic artery was performed to occlude the feeding artery of CCF, as the ophthalmic arteries were supplied from the ECA. To ensure a safe and favorable outcome, we recommend intraoperative monitoring of visual evoked potentials if possible.

Our experience with these two patients provides some valuable hints for developing a successful strategy for such cases. Although the perfusion pressure in the territory of the MCA was not restored after proximal ICA ligation with placement of a high-flow bypass because of the arteriovenous shunt in the remaining CCF, the MCA pressure increased sufficiently after ICA trapping and introduction of a high-flow bypass. Only the ICA was ligated after placement of a high-flow bypass in a case of giant aneurysm of the ICA. \(^{71}\) However, our experience suggests that trapping rather than ligation of the ICA is required in patients undergoing bypass surgery for the treatment of CCF.

### References


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