www.jkns.or.kr 10.3340/jkns.2009.46.6.572
J Korean Neurosurg Soc 46 : 572-576, 2009

Print ISSN 2005-3711 On-line ISSN 1598-7876

Case Report

Endovascular Graft-Stent Placement for Treatment of Traumatic Carotid Cavernous Fistulas

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Detachable balloon-based endovascular fistula occlusion is a widely accepted treatment for traumatic carotid cavernous fistulas (CCF). However, more recently coils have been used to obliterate the lesion, especially in case detachable balloon is not available. We failed balloon-assisted coil embolization for CCF because of large fistulas and herniation of coil loops into the parent artery. The authors describe our experiences of balloon-expandable graft-stents to treat CCF, and place emphasis on arterial wall reconstruction. Three traumatic CCF patients were treated using a graft-stent with/without coils, and underwent angiographic follow-up to evaluate the patency of the internal carotid artery (ICA). In all cases, symptoms related to CCF regressed after stent deployment and did not recur during follow-up. Follow-up angiography revealed good patency of the ICA in all patients. Graft-stents should be considered as an alternative means of treating CCF and preserving the parent artery by arterial wall reconstruction especially in patients with a fistula that cannot be successfully occluded with detachable balloons or coils.

KEY WORDS : Carotid cavernous fistulas · Graft-stent · Endovascular treatment.

INTRODUCTION

Detachable coils have proven to be an excellent therapeutic option for traumatic carotid cavernous fistula (CCF) occlusion under circumstances when detachable balloons cannot be used because of technical limitations or a lack of availability. Nevertheless, detachable coils have their limitations of parent artery occlusion or thromboembolism by herniation or jumping of coils into the parent vessel. In the three described cases, we were unable to obtain complete and permanent occlusion using coils alone, and thus, we attempted endovascular graft-stent placement. Here, we describe these three cases of traumatic CCFs that were treated with balloon expandable graft-stents.

CASE REPORT

Patient 1

This 42-year-old woman was involved in a motor vehicle accident and suffered from multiple right rib fractures, hemothorax, liver laceration, and right supratentorial subdural hemorrhage. After two weeks of hospitalization, she was discharged with no neurologic deficit. However, two weeks later, right exophthalmos, ptosis, and conjunctival injection developed. Magnetic resonance imaging (MRI) of the orbits confirmed the presence of a markedly ectatic right superior ophthalmic vein and multiple signal voids within the right cavernous sinus, suggesting CCF. Digital subtraction angiography (DSA) confirmed the presence of a right traumatic CCF draining via the superior ophthalmic vein, pterygoid plexus, and petrosal sinus (Fig. 1A). No intracranial blood flow distal to the fistula was observed in a right ICA angiogram, but collateral flow through the posterior communicating artery was sufficient angiographically and clinically.

The patient was fully awake during the procedure, and her electrocardiogram, arterial oxygen saturation, and blood pressure were appropriately monitored. Baseline activated clotting times (ACT) were obtained before the procedure. Percutaneuos access was obtained via the right femoral artery, and a 6F sheath was inserted. Systemic heparinization and a bolus injection of heparin (3,000 IU) were administered just before the therapeutic procedure, and an additional 1,000-IU bolus of heparin was administered every

• Received : February 20, 2009 • Revised : April 3, 2009
• Accepted : October 26, 2009
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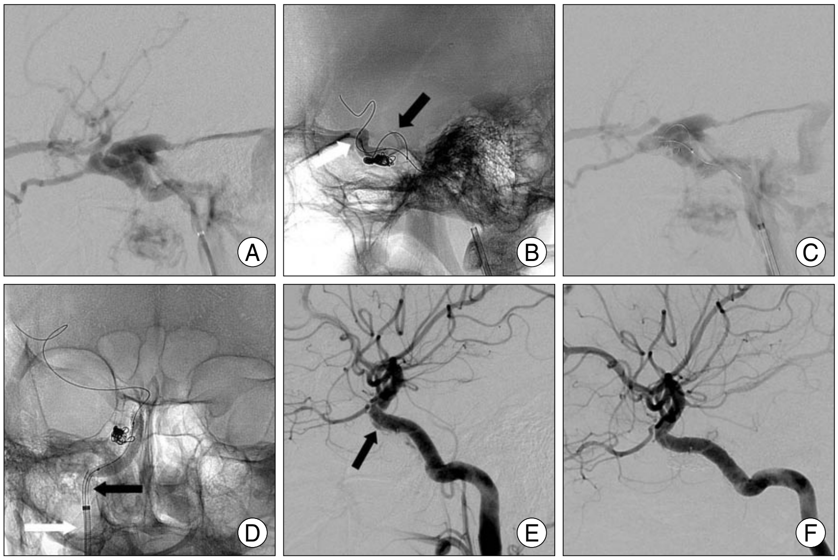

Fig. 1. 42-year-old woman with right-sided exophthalmos and ptosis in one month after a motor vehicle accident. A : Lateral angiographic image of the right internal carotid artery demonstrating the presence of a traumatic carotid cavernous fistula draining via the superior ophthalmic vein, pterygoid plexus, and petrosal sinuses. B and C : A microcatheter (black arrow) was placed at the fistula point, and an attempt made to close the fistula using four detachable platinum coils using the balloon-assisted technique (white arrow) (B). However, this failed to occlude the fistula because of a large linear tear and herniation of coil loops into the parent artery (C). D : Anteroposterior radiograph showing deployment of a balloon expandable graft-stent at the right internal carotid artery. To advance a stiff graft-stent delivery system in an intracranial vessel, the coaxial guiding catheter (black arrow) within the shuttle sheath (white arrow) was positioned distal to the lesion. E : Immediate post-procedural angiogram showing normal patency of the internal carotid artery with some residual carotid cavernous fistula flow through an endoleak (black arrow). F : Thirteen-month follow-up angiogram demonstrating complete occlusion of the traumatic carotid cavernous fistula without in-stent stenosis or an endoleak.

hour to maintain an ACT of longer than 250 seconds throughout the procedure. A 6F guiding catheter (Envoy; Cordis Endovascular Corporation, Miami, FL, USA) was positioned in the distal cervical ICA, and preprocedural angiograms were then obtained in orthogonal planes. A 0.014-inch microcatheter (Echelon, EV3 Neurovascular Irvine, CA, USA) over a 0.014-inch microwire (Synchro, Boston Scientific, USA) was placed at the fistula point, and an attempt was made to close the fistula using four detachable platinum coils and the balloon-assisted technique (Fig. 1B). However, we failed to occlude the fistula because of a large linear tear and herniation of coil loops into the parent artery (Fig. 1C). Therefore, we decided to utilize balloon expandable graft-stent deployment to occlude the fistula and preserve the parent artery. After removing all devices including the guiding catheter, microcatheter, balloon catheter, and sheath, an 80 cm long 6F long sheath (Shuttle sheath, Cook, Bloomington, IN, USA) was inserted via the right femoral artery. The shuttle sheath was positioned in the distal cervical ICA segment, and then a 6F guiding catheter (Envoy, Cordis, Miami Lakes, FL, USA) was coaxially inserted into the sheath and navigated into the cavernous ICA segment (Fig. 1D). A 160-cm long 0.014-in microwire (Transend 14; Target/Boston Scientific, Natick, MA, USA) was then navigated into the third segment of the MCA (M3) (these techniques allowed the balloon-mounted graft-stent catheter to be tracked). A 4/26mm-sized graft-stent (GraftMaster, Abbott Vascular Devices, Amersfoort, Netherlands) was then advanced over the microwire and positioned across the fistula segment by using roadmap imaging and external stent markings, and its position angiographically confirmed. We then began to deploy the stent using the roadmap image. Following stent deployment, an endoleak was identified in the control angiogram, and balloon re-inflation was performed in an attempt to close the endoleak. However, despite multiple balloon inflations at over burst pressure, the endoleak did not disappear. Final angiograms confirmed normal patency of the ICA with some residual CCF flow through the endoleak (Fig. 1E).

After the procedure, ophthalmic symptoms were much reduced, and completely resolved soon after. The patient was discharged four days after the procedure and was placed on 100 mg aspirin and 75 mg clopidogrel daily for one year.

Follow-up angiography at 13 months postoperatively demonstrated complete occlusion of the traumatic CCF with-out in-stent stenosis or an endoleak (Fig. 1F).

Patient 2

This 16-year-old man was involved in a high-speed motorbike accident and was admitted to the intensive care unit. Signs of traumatic subarachnoid hemorrhage, mandibular fracture, left femoral fracture, and right 3rd nerve palsy were apparent. About 50 days after the accident, he complained of mild left side motor weakness and decreased right side visual acuity. MRI and MR angiography of the brain confirmed the presence of a right side traumatic CCF and a subacute stage infarction at the right frontal lobe, the temporal lobe, and insula. DSA of the ICA confirmed the presence of a right side traumatic CCF with retrograde cortical venous drainage and no ICA flow distal to the fistula (Fig. 2A). Furthermore, the right ICA did not contribute to supply of the right hemisphere, which received extensive cross-flow from the left anterior circulation. DSA of the

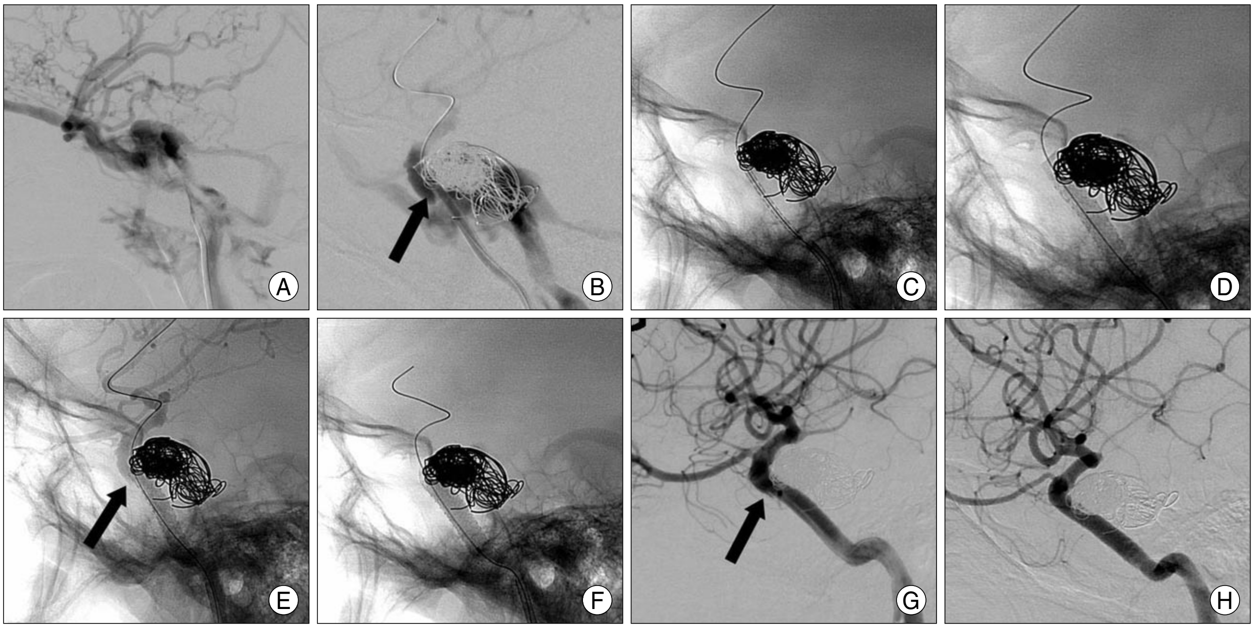

Fig. 2. 16-year-old man with mild left-sided motor weakness and decreased right-sided visual acuity in 50 days after a high-speed motorbike accident. A : Lateral angiogram of the right internal carotid artery demonstrating the presence of a traumatic carotid cavernous fistula with retrograde cortical venous drainage. B : After a failure of the transarterial approach using 7 detachable coils, the guiding catheter (black arrow) was positioned distal to anterior genu of the cavernous internal carotid artery to ease navigation. C : After the graft-stent had been positioned across the fistula segment, the guiding catheter was pulled back to the petrous internal carotid artery. D : Lateral radiograph showing deployment of a balloon expandable graft-stent at the fistula. E : The graft-stent was repeatedly dilated with a balloon to over its burst pressure. However, and endoleak (black arrow) persisted between the parent artery and the distal end of the graft-stent. F : Additional balloon angioplasty using 5 mm-sized balloon was performed to close the endoleak. G : Immediate post-procedural angiogram showing normal patency of the internal carotid artery with some residual carotid cavernous fistula flow through an endoleak (black arrow). H : Nine-month follow-up angiogram demonstrating a complete occlusion of the traumatic cavernous fistula without in-stent stenosis or an endoleak (H).

right ECA confirmed the presence of a retrograde CCF flow through the ophthalmic artery.

The procedure was performed under local anesthesia. An 80 cm long, 6F shuttle sheath was then positioned in the right proximal cervical ICA segment, and a 6F guiding catheter was coaxially inserted in the sheath and navigated into the petrous ICA segment. A microcatheter was then placed at the fistula point, and an attempt was made to close the fistula using the balloon-assisted technique and seven detachable platinum coils. However, this attempt at occlusion failed because of a large linear tear (Fig. 2B). Therefore, we decided on balloon expandable graft-stent deployment to occlude the fistula. Briefly, after removing the microcatheter and balloon catheter, the shuttle sheath was positioned in the distal cervical ICA segment, a 6F guiding catheter was navigated into cavernous ICA segment, and a 160 cm long microwire (Transend) was navigated into the insular segment of the MCA (Fig. 2B). A 4/26 mm-sized balloon-expandable graft-stent (GraftMaster, Abbott Vascular Devices, Amersfoort, Netherlands) was then advanced over the microwire and positioned across the fistula segment using roadmap imaging and external stent markings (Fig. 2C). The correct position of the stent was then angiographically confirmed, and stent deployment initiated using the roadmap image (Fig. 2D). After the graft-stent had been successfully deployed across the entire fistula, it was repeatedly dilated with a balloon to over burst pressure. However, an endoleak was observed between the parent artery and the graft-stent (Fig. 2E), and thus, angioplasty using another 5mm-sized balloon (US SV, Boston, USA) was performed to close the endoleak (Fig. 2F). After completing these procedures, DSA of bilateral ICAs and ECAs demonstrated near complete obliteration of the CCF with antegrade flow to the right anterior and middle cerebral arteries (Fig. 2G). After the procedure, right side visual acuity completely resolved, and the retrograde cortical venous drainage and right cerebral infarction recovered without a residual neurological deficit. The patient was discharged on 100 mg aspirin and 75 mg clopidogrel daily for one year.

At his 9-month follow-up, angiography demonstrated complete occlusion of the traumatic CCF without in-stent stenosis (Fig. 2H).

Patient 3

A 37-year-old man presented with a small amount of traumatic intracranial hemorrhage after falling on a street. Ten days after the accident, he complained of left eye redness, ocular pain, ptosis, and orbital bruit. At initial examination, his pupils were equal and reactive, but a left eyelid droop was obvious. He also demonstrated pronounced partial left 6th nerve palsy with diplopia to the affected side. However, visual acuity was not affected. He was referred to our center for diagnosis and treatment.

Cerebral angiography was performed to evaluate the causes of these symptoms and revealed a left-sided traumatic CCF. The left ICA was catheterized using a 6F, 80 cm shuttle and 6F guiding catheter coaxially. A microcatheter was placed at the fistula point, and an attempt was made to close the fistula by balloon-assisted coil embolization using a detachable coil, but herniation of coil loops into the parent vessel was observed, and thus, the coil was removed. We then decided to perform balloon expandable graft-stent placement. A 4/19 mm-sized balloon-expandable graft-stent (GraftMaster, Abbott Vascular Devices, Amersfoort, Netherlands) was advanced over the microwire and positioned across the fistula segment, and stent deployment initiated using a roadmap image. After the graft-stent had been successfully deployed across the entire fistula, the graft-stent was repeatedly dilated with a balloon to over burst pressure. An endoleak was observed between the parent artery and graft-stent, and this was closed by angioplasty using another 5 mm-sized balloon.

Final angiograms confirmed normal patency of the ICA and total exclusion of the fistula. After the procedure, no new neurological findings were found. Furthermore, the headache and ocular pain were much reduced and the orbital bruit had disappeared. Follow up angiography ten days postoperatively demonstrated stable, occlusion of the CCF and good ICA patency. The patient was discharged on 100 mg aspirin and 75 mg clopidogrel daily for one year.

DISCUSSION

Parent artery occlusion has been used to treat CCF with or without a bypass, but this approach has the disadvantage of the long-term risks often associated with carotid occlusion[10]. Ischemic complications after occlusion of the ICA occur in 5% to 22% of patients, despite a tolerant balloon occlusion test[3].

Despite the enormous progress made in endovascular techniques over the past few decades, detachable balloons remain the method of choice for the treatment of CCF with reported success rates of 75-88% in terms of preserving the patency of the parent ICA[4,12,13]. Although they are excellent therapeutic devices, there are some situations when detachable balloons cannot be used, if preservation of the parent artery is desired, particularly when the following are present : 1) a small orifice that does not allow the balloon passage, 2) a small cavernous sinus that causes the balloon to be herniated into the parent ICA, 3) sharp osseous fragments within the sinus that can cause rupture balloon on inflation, 4) a markedly enlarged cavernous sinus that cannot be completely filled by even multiple balloons, which leaves empty spaces that prevent complete occlusion and cure, and 5) transection of the cavernous ICA. In addition, the use of detachable balloons may also be limited by their availability[8].

Transarterial or transvenous coil occlusion of CCFs is a therapeutic option in cases with a technical limitation, or when detachable balloons are not available. However, coil treatment is not always safe or effective, and it is expensive[9,14,16]. Furthermore, it has a risk of parent artery occlusion due to herniation of a coil loop into the parent artery.

Graft-stents were recently introduced as an alternative to provide support to coils or to obliterate fistulas directly. Gomez et al.[8] reported treating seven post-traumatic CCF patients with a graft-stent. One-month follow-up angiograms demonstrated occlusion of stented ICAs and the preservation of intracranial circulation via collateral flow in one patient who interrupted prescribed antiplatelet medication soon after discharge. The other six patients underwent angiographic follow-ups between 3 and 42 months postoperatively (mean, 18.4 months), which demonstrated persistent fistula occlusion, patent stent grafts, and no significant intimal hyperplasia. Additional encouraging experience of the intracranial graft-stents has been reported for the treatment of intracranial aneurysms and pseudoaneurysms[15,17]. In our series, 3 fistulas were successfully occluded using a graft-stents. In one patient, this was achieved using a graft-stent alone. The other two patients were treated with a graft-stent after failed transarterial coil embolization due to a presumed high risk of ICA occlusion.

There are several important concerns regarding the graft-stent placement for cavernous ICAs. The main problem is that, because they are stiff, it is difficult to navigate graft-stent into lesions. Currently, however, no perfect solution exists for the treatment of CCFs, and in fact, no manufacturer produces graft-stents designed or approved for neurovascular use[5]. To advance a stiff graft-stent delivery system in an intracranial vessel, the tip of the guidewire should be placed as distally as possible and the guiding catheter should be positioned as close to or distal to the lesion as possible for good support. The delivery system should not be given excessive force in advancing; instead, it should be gently navigated into the intracranial lesion. A Friction between the distal edge of a stent and the arterial wall prevents smooth navigation of stent delivery systems, but undue force may lead to serious complications, such as, dissection along the edge of a stent or deformation or migration of a stent. The former can cause a pseudoaneurysm, which may lead to hemorrhage or thromboembolism, and the latter may lead to abrupt closure of the intracranial artery and massive cerebral infarction. Therefore, a safe and smooth intracranial graft-stent navigation technique is required to enable this endovascular procedure to be performed without complications[11]. ICA sacrifice with/without bypass is considered in cases with technical limitations of graft-stent navigation and detachable coil embolization.

The second concern involves the prevention and management of an endoleak between a graft-stent and the parent artery. Gomez et al.[8] used an additional graft-stent or detachable coils to treat residual fistula filling, and Archondakis et al.[1] reported that postdilation using a coronary balloon of larger diameter is often needed to exclude an endoleak completely after graft-stent placement for traumatic CCF. In our cases, graft-stents were repeatedly dilated at high balloon inflation pressures to resolve this problem. In the case with a residual endoleak after repeated balloon dilation, we performed angioplasty using a larger diameter balloon to exclude the endoleak. Nevertheless, a minimal endoleak remained in two patients (1 and 2) by post-procedural angiography. However, their symptoms completely resolved after therapy and these endoleaks disappeared spontaneously at follow up angiography. Accordingly, our results suggest that small endoleaks heal spontaneously.

Short-and long-term artery patency is another important issue. Some have concluded that graft-stents reduce the risk of vessel occlusion after coronary intervention[2,6]. Although the long-term patency rate of graft-stents in cerebral arteries has not been determined, some available evidence indicate a positive long-term outcome in terms of parent artery patency[7,17].

Because of scarcity of reports on traumatic CCFs treated with graft-stents, larger series are necessary to ensure result reliability. Nevertheless, our clinical results show good outcomes without in-stent stenosis of the parent artery or CCF recurrence.

CONCLUSION

Our experience suggests that graft-stents are a safe and effective modality for the treatment of traumatic CCF in patients with a fistula that cannot be successfully occluded with detachable balloons or coils. In particular, graft-stents have the advantage of parent artery preservation in cases of contralateral ICA occlusion or with an intolerable balloon occlusion test. However, greater experience with the described technique would allow the role and long-term patency of graft-stent placement in the treatment of traumatic CCF to be better defined.

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