Covered Stents for the Endovascular Treatment of a Direct Carotid Cavernous Fistula: Single Center Experiences with 10 Cases

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Objective: Covered stent has been recently reported as an effective alternative treatment for direct carotid cavernous fistulas (DCCFs). The purpose of this study is to describe our experiences with the treatment of DCCF with covered stents and to evaluate whether a covered stent has a potential to be used as the first choice in selected cases.

Methods: From February 2009 through July 2013, 10 patients underwent covered stent placement for a DCCF occlusion. Clinical and angiographic data were retrospectively reviewed.

Results: Covered stent placement was performed for five patients primarily as the first choice and in the other five as an alternative option. Access and deployment of a covered stent was successful in all patients (100%) and total occlusion of the fistula was achieved in nine (90%). Complete occlusion immediately after the procedure was obtained in five patients (50%). Endoleak persisted in five patients and the fistulae were found to be completely occluded by one month control angiography in four. The other patient underwent additional coil embolization by a transvenous approach. Balloon inflation-related arterial dissection during the procedure was noted in two cases: healing was noted at follow-up angiography. One patient suffered an asymptomatic internal carotid artery occlusion noted seven months post-treatment.

Conclusion: Although endoleak is currently a common roadblock, our experience demonstrates that a covered stent has the potential to be used as the first choice in DCCF; this potential is likely to increase as experience with this device accumulates and the materials continue to improve.

Key Words: Carotid cavernous fistula · Covered stent · Endovascular treatment.

INTRODUCTION

Direct carotid cavernous fistula (DCCF) results from head and facial injuries or cavernous internal carotid artery (ICA) aneurysm rupture. The direct communication between the ICA and the cavernous sinus produces a series of symptoms including exophthalmos, conjunctival injection, bruit, and cranial nerve impairment.

At present, the endovascular approach is the mainstay for treatment of a DCCF: The treatment options include: detachable balloons, coils, other embolic material, and stents through a transarterial or transvenous approach.1,3,11-14 In recent years, covered stents have been applied for the treatment of DCCF with encouraging short-to-midterm clinical results, thus, showing that a covered stent is an effective alternative after failure of conventional endovascular therapy.15-17 However, there are few reports regarding the application of covered stents in DCCF treatment as the first choice. The purpose of this study was to evaluate whether covered stent placement could be a preferred first-line method for DCCF patients. We present 10 cases of DCCF treated with covered stents: in five, a covered stent was the first choice.

MATERIALS AND METHODS

Patient population
From January 2009 through July 2013, a total of 13 cases of DCCF were treated by the endovascular approach at our institution. Therapeutic alternatives were discussed with both neu-
Endovascular procedure

All procedures were performed under local anesthesia. The angi-architectures were evaluated by using the Integris V (Philips Medical System, Best, the Netherlands) biplane system, including three-dimensional (3D) rotational angiography. Angiographic evaluation included ipsilateral and contralateral carotid and vertebral angiographies with neck three-dimensional (3D) rotational angiography were also reviewed. Angiographic segments of the cavernous ICA to demonstrate the fistula point were classified as follows: vertical, genu, and horizontal portion.

Prior to the interventional procedures, most of the patients were given dual antiplatelet medication. Heparin (3000 IU) was administered as a bolus after femoral arterial sheath placement and intermittently thereafter 1000 IU bolus per hour with monitoring of activated clotting time to maintain 250–300 seconds.

After arterial access, a double coaxial guide system was used. A 7-F Shuttle (Cook, Bloomington, IN, USA) was advanced to the level of the common carotid artery, and then a 7-F Softip guide catheter (Boston Scientific, Natick, MA, USA) was advanced coaxially into the cavernous ICA near the carotid canal. After selection of the middle cerebral artery with the aid of a microcatheter through the true lumen of the cavernous ICA, the covered stent was placed at the fistula point of the cavernous ICA along an exchange microguide wire. Then, the stent was released with staged-balooning. At first, the stent was deployed by low-pressure balloon inflation until the balloon-waist disappeared. Then, the balloon inflation was repeated with gradually-increasing pressure to ensure good apposition of the stent to the vessel wall; the balloon was gently moved into the proximal position to avoid arterial dissection. If endoleak with large amount persisted despite balloon inflation up to the bursting pressure, a larger balloon

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Table 1. Summary of the patient data

| No. | Age | Sex | Cause | Time gap | Time interval | Previous treatment | Procedural balloon inflation | Procedure result | Outcome (GOS) |
|-----|-----|-----|------|---------|--------------|-------------------|--------------------------|-----------------|---------------|
| 1   | 26  | F   | V    | NA      | NA           | NA                | None                     | None            | 5             |
| 2   | 54  | M   | G    | 3 mo    | 1 mo        | NA                | Re-dilation with larger balloon | Near-total occlusion | NA            |
| 3   | 37  | M   | H    | 1 mo    | 1 mo        | NA                | Re-dilation with same balloon | Near-total occlusion | NA            |
| 4   | 30  | M   | G    | 2 mo    | 0          | NA                | Re-dilation with same balloon | Near-total occlusion | NA            |
| 5   | 61  | F   | V    | 1 mo    | NA          | NA                | Re-dilation with larger balloon | Near-total occlusion | NA            |
| 6   | 48  | F   | V    | 3 mo    | 3 mo        | TA coil           | Re-dilation with same balloon | Near-total occlusion | 3 mo          |
| 7   | 46  | M   | H    | 4 mo    | 6 mo        | TA coil           | Re-dilation with same balloon | Total occlusion   | 6 mo          |
| 8   | 43  | F   | V    | 1 mo    | 1 mo        | TA coil           | Re-dilation with same balloon | Total occlusion   | 7 days        |
| 9   | 26  | F   | V    | 1 mo    | 14 days     | TA coil           | Re-dilation with same balloon | Total occlusion   | 14 days       |

*Time gap means the interval between initial trauma and treatment with covered stent. Time interval means the interval between previous treatment and treatment with covered stent. F: female, M: male, H: horizontal, V: vertical, PS: post-surgery, PT: post-trauma, TA: trans-arterial, TV: trans-venous, Cx: complication, F/U: follow-up, GOS: Glasgow outcome scale, ICA: internal carotid artery.
was found to be helpful for reduction of the endoleak. Dual antiplatelet medication was maintained for at least three month after the procedure, and a single agent was maintained for at least one year.

**Immediate and final outcome**

The degree of DCCF occlusion was assessed by completion angiography with a 3-point scale: total occlusion (no residual shunt), near-total occlusion (minimal residual shunt), and subtotal occlusion (high flow residual shunt).

**Clinical and radiological follow-up**

In patients with total occlusion of the fistula, clinical follow-up was recommended at one and three months after the procedure. Only if the patient showed aggravation of the clinical symptoms, imaging follow-up, such as DSA or MRA, was recommended. In patients with near-total or subtotal occlusion after the procedure, a follow-up DSA was recommended one month post procedure to confirm the progressive occlusion, or to decide if further treatment was necessary.

**RESULTS**

Covered stents were implanted in five patients (50%) as the first choice and in the other five patients (50%) after failure of transarterial embolization (n=4) or transvenous coil embolization (n=1). Stent delivery and deployment was technically successful in all cases. Total occlusion at the conclusion of the procedure was obtained for five patients (50%), near-total occlusion was for three, and subtotal occlusion was for the other two. Most patients receiving covered stents as the alternative option had total occlusion immediately after procedure, whereas four patients treated with covered stents as the first choice had a remnant fistula due to endoleak. All four patients with endoleak underwent one month control angiography, and complete occlusion was demonstrated in three. The remaining patient experienced increased shunt flow: additional coil embolization via transvenous approach was performed. The other patients were improved without evidence of fistula recurrence for clinical and radiologic follow-up period (range, 1–21 months; mean 5.3 months). Minimal stenosis at the proximal end of stent was detected in three cases (Fig. 1). In regard to procedure-related complications, balloon inflation-related arterial dissection occurred in two patients; it was noted to have healed at the follow-up angiography. One case of asymptomatic internal carotid artery occlusion was identified at seven month follow-up CT angiography.

**Illustrative cases**

**Patient 4**

A 30-year-old man with abducens nerve palsy and pulsatile tinnitus was admitted for treatment of DCCF, which developed after open reduction of a medial orbital wall fracture caused by blunt trauma. The fistula was located at the genu portion of the cavernous ICA. With a 7-F Shuttle flexor and 7-F guiding catheter co-axial system, a 2.3-F microw catheter was introduced into the left middle cerebral artery. Then, a covered stent (5.0×19 mm) was advanced to the fistula location and repeated balloon-dilatation was performed with gradually increasing pressure. Endoleak persisted; however, shunt flow markedly decreased. Balloon inflation-induced arterial dissection developed at the distal portion of the stented segment. After confirmation of ICA patency and absence of thrombus, the procedure was completed. At one-month control angiography, the fistula was completely occluded and the dissection was stable. Minimal stenosis at the proximal end of stent was detected; however, patency of the stented ICA was maintained. The patient fully recovered (Fig. 1).

**Patient 5**

A 61-year-old woman was admitted for endovascular treatment of a DCCF. She had diplopia due to oculomotor and abducens nerve palsies. On conventional angiography, the fistula was located at the vertical segment of cavernous ICA. After placement of a covered stent (4.5×19 mm) at the fistula location, the balloon was gradually inflated until its waist disappeared. Then, repeated inflation of the balloon with higher pressure was carried out. Although the flow of the shunt was notably decreased, endoleak remained. Additional balloon inflation was performed with a larger caliber balloon (5.0×12 mm), and the fistula was completely occluded. The patient was discharged the day after the procedure without complications (Fig. 2).

**DISCUSSION**

DCCF is frequently associated with poor neurological outcomes, necessitating surgical or endovascular repair. Due to its technical difficulty and associated morbidity, direct surgical closure has now been supplanted by endovascular methods.

Following its introduction in the 1970s, occlusion with a detachable balloon quickly became the method of choice to treat DCCF. Currently, the detachable balloon is still considered as the optimal therapeutic tool for DCCF. However, balloons do have some limitations: the fistula and cavernous sinus must be of appropriate size, premature deflation can result in fistula recurrence, and mass effect might occur. An additional shortcoming is their limited availability. Detachable or pushable coils have disadvantages similar to those of balloons: mass effect, fistula recurrence due to coil compaction, and higher cost.

During the past decade, the endovascular stent graft has been widely used for placement in the aorta, peripheral arteries and coronary arteries. Recently, covered stents have been utilized in the treatment of intracranial aneurysms and DCCF as well. A series of reports have been published regarding the feasibility, safety, and outcome of covered stents in the treatment of DCCF, thus, showing that a covered stent can be an effective and reliable alternative method. In our series of 10 cases treated with covered...
stents, the technical success rate was 100%. Complete fistula occlusion was obtained in nine cases (90%). According to the literatures, the technical success rate and complete occlusion rate at the conclusion of the procedure with a covered stent for DCCF ranges 90–100% and 75–100%, respectively. Our results are similar to those reports. One of the main advantages of graft stents may be that they do not exert any mass effect on the cranial nerves thus may enhance cranial nerve symptom recovery.

Given the limited availability of detachable balloons, we believe that covered stent placement could be a first-line method, as shown in five cases in our series. A covered stent immediately obliterates DCCF in a single step by placing an impermeable barrier at the site of abnormal communication. In addition, it decreases the risk of ischemic stroke by preserving the ICA patency, as compared to carotid trapping, which is the last resort in the treatment of DCCF. Treating DCCF with covered stents appears to be more reasonable because it does not require deployment of any embolization materials in the cavernous sinus that may complicate the procedure and enhance its associated risk. To the best of our knowledge, only Gomez et al. has reported two cases of a covered stent as the first choice, with complete fistula occlusion and good ICA patency at 7-month follow-up. In our stent-as-the-first-choice group, the total occlusion rate was 80% (4/5), including a patient with total occlusion immediately following the procedure and three patients with progressive occlusion noted at one month follow-up. Results of Gomez et al. and our experience show that a covered stent has the potential to be used as the first choice in DCCF treatment.

Endoleak, defined as persistent perfusion of the space between the stent graft and the parent vessel wall, is the most common procedural failure of endovascular repair. Hoit et al. reported their experience with a covered stent for DCCF and a traumatic pseudoaneurysm. According to the report, transient endoleak occurred in 83% (5/6); the endoleaks were related to poor stent vessel apposition or size mismatch. In two patients, they were able to completely appose the stent to the vessel wall with an additional angioplasty; however, three patients required deployment of an additional graft stent. Saatci et al. found that 32% (8/25) had an endoleak immediately after intracranial covered stent deployment for aneurysm treatment. However, 75% (6/8) of the endoleaks disappeared by balloon re-inflation at the proximal and distal ends of the stent grafts. In our series, transient endoleaks were observed in 67% (6/9) immediately after stent deployment. To decrease the flow of the endoleak, we applied two

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**Fig. 1.** A: Left ICA angiography shows that steal of the flow toward the cavernous sinus and primary flow drained into ophthalmic vein, superior petrosal sinus, and inferior petrosal sinus. B: Left ICA angiography performed under ipsilateral carotid compression shows that the fistula was located at the genu portion of the cavernous ICA. C: Coronal source image of 3D rotational angiography shows the connection between the ICA and the cavernous sinus. D: Repeated balloon inflation with higher pressure to augment apposition of the stent to the vessel wall was performed. E: Final angiography shows that the fistula with decreased shunt flow persisted and balloon-induced arterial dissection was observed. F: The fistula was completely occluded and arterial dissection was stable at one month follow-up angiography. Minimal stenosis at the proximal end of stent was detected. ICA: internal carotid artery, 3D: three-dimensional.
methods in consecutive order: 1) repeated-dilation with gradually-increasing pressure (initially), and 2) use of a balloon with a larger caliber (if endoleak persisted). The former method induced successful occlusion in three cases, and subtotal occlusion with remarkably decreased shunt flow with remnant in one case. The latter method also induced the similar results. Both methods were effective to decrease or halt shunt flow, improving the approximation of the stent to the fistula point.

Although four out of five cases with endoleak immediately after the procedure were found to have progressive occlusion at follow-up, the endoleak acted as a structural limitation to the covered stent. All of the endoleak, which persisted after completion of the procedure, were located at the posterior genu portion of cavernous ICA. The curvature of the posterior genu, combined with the limited flexibility of covered stent, may lead to poor apposition of the stent to the vessel wall, especially at the lesser curve of covered stent. In addition, this sectional shape mismatch might cause stent migration and incomplete coverage of the fistula during inflation; thus, enhancing the risk of endoleak, for which the staged ballooning technique mentioned above, offers a feasible solution. Of course, the endoleak may also be caused by a size mismatch between the covered stent and the parent ves-

Fig. 2. A: Right ICA angiography shows that steal of the flow toward the cavernous sinus and intracranial flow was diminished. B: Left ICA angiography performed under ipsilateral carotid compression shows that the fistula was located at the vertical portion of the cavernous ICA. C: After placement of the covered stent at the fistula location, initial balloon inflation was performed to detach the covered stent from the balloon. D: High shunt flow remained; however, velocity was lessened. E: Repeated balloon inflation with higher pressure was carried out. F: The endoleak with more decreased shunt flow remained. G: Additional balloon inflation with a larger sized-balloon was performed. H: The fistula was totally occluded. ICA: internal carotid artery.
covered stent graft as an alternative option were found to have better results than the ‘first choice group’ as well as lower rates of complications. One major advantage of covered stent grafts is their ability to achieve good initial results in DCCF treatment. However, it has the potential to be used as first-line therapy in selected cases because it may offer a more definitive reconstructive treatment than the conventional endovascular approach. Further progress can be anticipated as technology and materials continue to improve, and more data are accumulated.

CONCLUSION

Our experience shows that a covered stent graft can serve as an effective and safe micro-invasive technique in DCCF treatment. The group using the covered stent as an alternative option were found to have better results than the ‘first choice group’ as well as lower rates of complications. One major advantage of covered stent grafts is their ability to achieve good initial results in DCCF treatment. However, it has the potential to be used as first-line therapy in selected cases because it may offer a more definitive reconstructive treatment than the conventional endovascular approach. Further progress can be anticipated as technology and materials continue to improve, and more data are accumulated.

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