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Endovascular treatment of extracranial carotid artery aneurysms using self-expandable covered stent grafts: A single center retrospective study

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Abstract

Objectives: This study was aimed to evaluate the safety and efficacy of endovascular treatment of extracranial carotid artery aneurysms (ECAAs) using self-expandable covered stent grafts.

Methods: All patients with ECAA at a single institution were reviewed from February 2014 to February 2020. Eight consecutive patients (three men, mean age 64.5 years) treated with endovascular repair with self-expandable covered stent graft were retrospectively reviewed. Patient characteristics, angiographic results, and follow-up outcomes were retrospectively recorded. Access to ECAA was gained via a femoral approach or a direct puncture of common carotid artery after surgical exposure because of kinking of the aortic arch and common carotid artery. A self-expandable covered stent graft (Viabahn; W. L. Gore, Flagstaff, AZ) was deployed to exclude the aneurysm.

Results: Based on imaging features, there were five peudoaneurysms and three true aneurysms. The technical success rate was 100%. Cerebral protection devices were not used in all the patients during the procedures. Immediate absolute obliteration of the ECAA with no endoleak was documented in all the patients. Perioperative complications included one internal carotid-cavernous sinus fistula, one bleeding at the puncture site, and one stroke. The mean follow-up period was 35.5 months (range, 9–72 months). All the patients were alive, with an obligation rate of 100%. No transient ischemia attack, stroke, or reoccurrence of symptoms was identified during the follow-up period. Radiological examinations identified patency of the stent grafts and revealed no endoleaks, stent fracture, stent migration, or aneurysm rupture.

Conclusions: Endovascular treatment of ECAAs with self-expandable covered stent grafts appears to be a safe and feasible alternative for traditional open surgery, especially in the challenging anatomy and instable physical conditions. Although cerebrovascular accidents can occur as the result of hemodynamic changes during the perioperative period, the minimal alternative can yield satisfactory midterm follow-up clinical outcomes.

Keywords

Extracranial carotid artery aneurysm, endovascular treatment, covered stent

Introduction

Extracranial carotid artery aneurysm (ECAA) is a relatively rare condition, comprising about 0.4% to 4% of all peripheral arterial aneurysm.[1–4] The natural history of ECAA is still unknown even now. Most ECAAs might remain clinically asymptomatic and are often discovered incidentally during other radiological findings. The aneurysms usually present as pulsating cervical mass or cranial nerve dysfunction due to local compression. However, the lesions are also associated

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with high risks of neurologic deficits including transient ischemia attack (TIA) and ischemic stroke in more than 50% patients if left untreated.[1,2,5–8]

The optimal treatment strategy is still on debate mainly because of small numbers of experiences and lack of guidelines.[1–3,5,8–12] Conservative management comprising of anticoagulation or antiplatelet medication might be justified in lower risks of cerebral stroke in asymptomatic patients, but seems ineffective in relieving symptom burden, and the risks of thrombus formation and cerebrovascular accidents still remain.[2,9,13] Surgical exclusion of aneurysm with restoration of blood flow has been regarded as the primary strategy in symptomatic or growing ECAAs.[3,8,12,13] However, the surgical approach is associated with a high risk of cranial nerve injury especially in the lesion close to the base of skull and longer hospital stays.[8,10] With advances in catheter technology and increasing experiences, endovascular treatment has emerged as a minimally invasive alternative to open surgery, particularly in highly positioned aneurysms, hostile neck, or surgically high-risk patients.[1,2,6–8,10,14] Nevertheless, a variety of stent types and assisted techniques were used in the previous studies. No consensus was reached regarding the choice of stents.[1,6–8,14]

This study aimed to evaluate the safety and efficacy of endovascular treatment of ECAAs with self-expandable covered stent grafts.

Methods

Study population

Between February 2014 and February 2020, 33 symptomatic ECAAs were found in 33 patients at our institution. ECAA was defined as a local dilation exceeding 50% of its expected normal diameter. Of these, 11 patients were treated conservatively, 12 patients with surgically, and 10 patients underwent endovascular treatment. In the endovascular group, two patients were excluded due to coil embolization in one patient and bare metal stent (BMS) implantation in another patient. Eight consecutive patients (three men, mean age 64.3 years) treated with endovascular repair with self-expandable covered stent graft were retrospectively reviewed. Choice of therapy strategy was based on patients' general conditions, aneurysm characteristics, the experience of the surgical team, and patients' preferences. Approval was obtained from our Institutional Review Board for a retrospective review of the patients' clinical data. Informed written consent was provided from all the patients.

Endovascular repair of ECAA was advised mainly according to the anatomical features of the aneurysm and the aortic arch and patients' conditions. Endovascular therapy was preferred for a high carotid bifurcation, carotid pseudoaneurysms, acute bleeding of carotid artery lesions, or patients with multiple comorbidities. While open surgery was usually performed in patients with hostile aortic arch, severe tortuosity of the carotid artery lesions, or with limited comorbidities. Indications of endovascular intervention for ECAAs include aneurysm diameter ≥ 2.0 cm, aneurysm rupture, neck pain, symptoms of compression of neighboring organs (i.e., hypoglossal nerve), and ipsilateral cerebral ischemia or infarction in this study. The clinical features of these patients who underwent endovascular therapy were collected. The features included age, gender, medical history, clinical presentation, etiology, size and shape of the aneurysm, aneurysm type according to Attigah classification, procedural details, postoperative complications, and follow-up outcomes. The Attigah classification was defined as follows: type I, aneurysm of the internal carotid artery distal to the carotid bifurcation; type II, aneurysm of the internal carotid artery; type III, aneurysm of the carotid bifurcation; type IV, aneurysm of the internal carotid artery and the common carotid artery; and type V, aneurysm of the common carotid artery.[15] Computed tomographic angiography (CTA) was performed in all the patients. Dural antiplatelet therapy with aspirin 100 mg/day and clopidogrel 75 mg/day was started before treatment.

Endovascular procedures

Procedures were performed under local anesthesia ($n = 3$) or general anesthesia ($n = 5$). Access to ECAA was gained via a femoral approach ($n = 6$) or a direct puncture of common carotid artery after surgical exposure ($n = 2$) because of kinking of the aortic arch and common carotid artery. A bolus of heparin was administered intravenously to achieve an activated coagulation time > 250 seconds. A 0.035-inch hydrophilic guidewire (Terumo Corp, Tokyo, Japan) was then carefully maneuvered to past the aneurysm. After that, a 0.035-inch stiff guidewire (Terumo stiff flex L, or Hi-Torque SupraCore guidewire) was exchanged and a self-expandable covered stent graft (Viabahn; W. L. Gore, Flagstaff, AZ) was selected based on aneurysm characteristics and diameter of the vessel. In general, the covered stent-graft oversizing goal was 5% to 15% greater than the outer diameter of the carotid artery landing zone. BMS might be used to ensure the covered stent stability if necessary. Vascular closure devices were used for all the femoral arterial access.

Follow-up

Technical success was defined as the complete exclusion of the aneurysm with no signs of endoleak or

Table 1. Clinical features of ECAA patients.

Case no.	Age (y)/sex	Past history	Presenting symptoms	Etiology	Side	Maximum diameter (cm)	Structure	Attigah classification
1	72/F	None	Pulsatile mass	Unknown	L	1.7	True	II
2	52/M	None	TIA	Trauma	R	3.0	Pseudoaneurysm in carotid artery biefurcation	III
3	67/F	None	Pulsatile mass, pain	Unknown	R	3.0	Pseudoaneurysm	II
4	60/F	HT, CHD, CVD	Dizziness	Atherosclerosis	L	4.0	True	I
5	64/M	DM, CHD, neck radiotherapy and implantation of ^{125}I-radioactive particles for thyroid cancer	Bleeding ulcer, swelling	Radiotherapy	L	3.0	Pseudoaneurysm	V
6	74/F	CHD with stable angina	Pulsatile mass	Unknown	L	4.0	True	II
7	63/M	None	TIA, hoarseness, pulsatile mass, pain	Unknown	L	4. 8	Pseudoaneurysm	V
8	52/M	Neck radiotherapy, HT	Bleeding ulcer	Radiotherapy	L	1.97	Pseudoaneurysm	III

F: female; M: male; DM: diabetes mellitus; CHD: coronary heart disease; HT: hypertension; CVD: cerebrovascular disease; L: left; R: right; TIA: transient ischemia attack.

embolization of distal runoff, which was assessed by final angiography after stent-graft deployment.

Patients were discharged with oral antiplatelet therapy (100 mg/day aspirin indefinitely and 75 mg/day clopidogrel for at least three months) and statins (20 mg/day). Clinical examination and Doppler ultrasound were performed one, three, and six months after discharge and yearly thereafter. CTA was used when clinical suspicion or symptom recurrence were indicated.

Results

The clinical features of these patients who underwent endovascular therapy were summarized in Table 1. The etiology was fibrodysplasia in three patients, radiotherapy in two, blunt neck trauma due to blast injury in one, and unknown in the other two patients. Based on imaging features, five ECAAs were peudoaneurysms and the other three ECAAs were true aneurysms. The clinical symptoms included pulsatile masses in the neck in four patients, ECAA-related pains in two patients, TIA in two patients, and hoarseness in one patient. Bleeding ulcer and neck swelling were observed in two patients because of neck radiotherapy (cases 5 and 8). According to Attigah classification, there were one lesion of type I, three lesions of type II, two lesions of type III, and two lesions of type V. The maximum diameter of aneurysm averaged $3.2\,cm \pm 1.0\,cm$ (range, 1.7 cm to 4.8 cm). Emergency endovascular repair was performed in two cases (cases 5 and 7) because of progressive symptoms.

All the eight patients with ECAA successfully underwent endovascular stenting (Figure 1). As shown in Table 2, one covered stent graft was implanted in six patients, two covered stent grafts in one patient due to the involvement of carotid bifurcation, and two covered stent grafts plus one $9 \times 30\,mm$ bare metal Wallstent endoprosthesis (Boston Scientific, Marlborough, Mass) in the other patient because of the lengthy of the ECAA and stent-graft malapposition in the proximal segment of the internal carotid artery. Embolization of external carotid artery (ECA) was performed in two patients in order to reduce the potential risk of type II endoleak. Cerebral protection devices were not used in all the patients during the procedures. No post-dilation was performed after stent deployment. Immediate absolute obliteration of the ECAA with no endoleak was documented in all the patients. Internal carotid-cavernous sinus fistula (CCF) was found in one patient (case 3), and disappeared soon after strict blood pressure control. Exophthalmos, ocular motor palsy, and decreased vision did not appear during the in-hospital period in this patient. Bleeding at the puncture site required surgical repair in one patient (case 2). Sudden cordial stroke presenting with partial vision loss occurred in case 1. No death

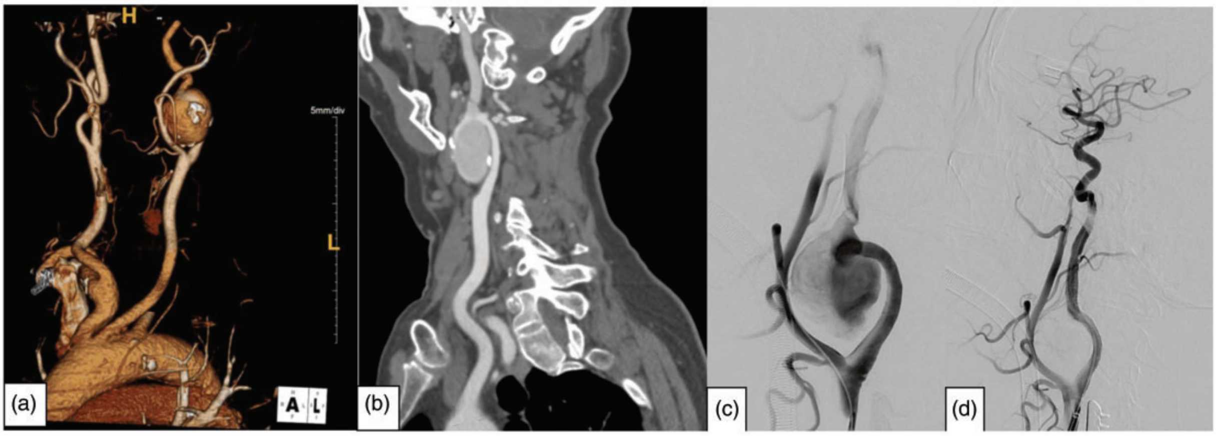

Figure 1. (a) Computed tomography angiography of left internal carotid artery aneurysm. (b) The Maximum intensity pixel reconstruction of the ECAA. (c) Preoperative angiogram showed aneurysm of the extracranial carotid artery. (d) Postoperative angiogram showed complete exclusion of the aneurysm and blood flow restore of the internal carotid artery.

or cardiovascular accidents occurred during the operation or within 30 days after intervention.

The mean follow-up period was 35.5 ± 21.6 months (range, 9–72 months). All the patients were alive, with no reoccurrence of symptoms. The obliteration rate of the ECAA was 100%. No TIA or stroke was identified during the follow-up period. Radiological examinations identified patency of the covered stents and revealed no endoleaks, stent fracture, stent migration, or aneurysm rupture.

Discussion

ECAA is an uncommon disease but needs more attention due to the high risks of cerebrovascular accidents and local compressions. [1,2,8] The present case series shows successful exclusion of aneurysm sac and restoration of brain blood flow with implantation of self-expandable covered stent grafts. Endovascular treatment of ECAA has an acceptable perioperative complication rate and can provide satisfactory follow-up clinical outcomes.

Etiology of these rare disorders involves multiple factors and is not well defined. Atherosclerosis and pseudoaneurysm formation are generally regarded as the most common causes of the aneurysms.[1,3,8] Nonetheless, several systematic reviews documented trauma accounted for approximately half of the cases.[8] Other causes includes infection, fibrodysplasia, connective tissue disorders, or radiotherapy.[1,2,8] Similarly with previous studies, more pseudoaneurysms (4/8) were found in this patient population. But the exact etiology of aneurysm formation remains unclear in several cases (4/8).

Endovascular repair of ECAA has been documented to be a safe and effective minimally invasive alternative to traditional open surgery.[8,14] The minimal approach could avoid the risk of cranial nerve injury, which occurs in 11.8% to 26% patients undergoing open surgery.[2,5,8] A systematic review conducted by Giannopoulos et al. aimed to investigate clinical and radiological outcomes of 162 ECAAs patients following endovascular repair in 68 reports and reported perioperative adverse events rate of 3.1% for stroke and 4.3% for mortality.[8] The clinical outcomes seem to be comparable with open surgery with a 30-day stroke rate of 5.16% and a mortality rate of 1.91%, which was reported in a total of 1,102 patients in 39 articles by Welleweerd et al.[2] But considering more cases with unstable circulation or hostile anatomy enrolled in the endovascular group, which is challenging for surgical operation, endovascular therapy seems to be a more attractive option.[8,10,12] As shown in our series, more cases were presented with spontaneous or secondary pseudoaneurysms. Two patients with cervical malignant cancers developed sudden onset of carotid artery rupture after several radiotherapy treatments, and was eventually treated with endovascular stenting of self-expandable covered stent grafts in order to avoid severe fibrous adhesion in surgical incision and possible impaired wound healing.

Cerebrovascular accident has been recognized as the most worried complications in both non-operated and perioperative periods. Patients with ECAA are at high risk of ischemic stroke due to distal embolic occlusion secondary to dislodgement of thrombus in the aneurysm sac.[16] In the present case series, 37.5% patients (3/8) suffered from cerebral ischemic symptoms. Moreover, internal CCF occurred in one patient after endovascular of ECAA in the present study, which indicated that cerebral hemodynamic changes also contributed to cerebrovascular accident.[17] The

Table 2. Endovascular treatment and follow-up of ECAA patients.

Case no.	Anesthesia	Access	Stent (mm)	ECA embolization	30 days complications	Follow-up month	Imaging follow-up	Clinical follow-up
1	Local	RFA	Viabahn 6 × 50	N	Stroke	72	Patent	Asymptomatic
2	General	RFA	Viabahn 8 × 50	N	Puncture site bleeding	60	Patent	Asymptomatic
3	General	RCA	Viabahn 6 × 50	N	Internal carotid-cavernous sinus fistula	28	Patent	Asymptomatic
4	Local	RFA	Viabahn 6 × 100 + Viabahn 6 × 50 + Wallstent 9 × 30	N	N	36	Patent	Asymptomatic
5	Local	RFA	Viabahn 7 × 100	N	N	40	Patent	Asymptomatic
6	General	RCA	Viabahn 7 × 50	N	N	24	Patent	Asymptomatic
7	General	RFA	Viabahn 8 × 50	Coil embolization	N	9	Patent	Asymptomatic
8	General	RFA	Viabahn 6 × 50 + Viabahn 8 × 50	Coil embolization	N	15	Patent	Asymptomatic

Note: Stent manufactures: Viabahn, Gore (Flagstaff, AZ); Wallstent, Boston Scientific (Natick, MA). RFA: right femoral artery; RCA: right carotid artery; ECA: external carotid artery; N: none.

hemodynamic changes including increase in cerebral perfusion pressure, loss of autoregulation, and reconstruction of extracranial carotid artery might be attributed to the cerebral overperfusion.

Several issues should be paid attention to ensure a successful procedure in the endovascular treatment of ECAA. First, BMSs, covered stents, overlapping multiple stents techniques, and stent-assisted coiling currently dominate the endovascular treatment paradigm for ECAAs.[1,5–8,11,14,18] However, covered stents have been shown to be more efficient in treating aneurysms due to better complete exclusion of blood flow into aneurysms sac.[5,8,19] Moreover, the use of covered stents is also associated with a significant decrease of reintervention and restenosis, an increase in exclusion of aneurysm sac, and less operative time required.[20] Second, the artery access should be based on patient's anatomic characteristics. Femoral access remains a major route for the treatment of ECAAs. In the cases with severe arterial tortuosity and kinks, the anterograde common carotid artery access can facilitate the pass-through of the guidewire and the covered stents, with less disturbance of intraluminal thrombus and following reduce of the distal embolization risk.[21] Furthermore, embolic protection devices (EPDs) have been the routine care in clinical practice of carotid stenting and can improve the safety of endovascular treatment of ECAAs. However, common EPDs should be delivered over a 0.014″ guidewire, which is not suitable for a covered stents requiring a greater profile and a good support guidewire, especially in challenging access situations.[7] The last but not the least, no tapered covered stents designed for carotid artery is available nowadays. As a result, the risk of endoleak might increase when the self-expandable covered stent grafts are applied in the lesions adjacent to the bifurcation. As shown in this study, embolization of the ECA was performed in two patients in order to reduce the type II endoleak. Moreover, different size of covered stents was overlapped when discrepancy in size was significant in order to reduce the risk of endoleak. In the present study, a BMS was deployed to accommodate the carotid bifurcation.

This study is limited by the retrospective design and a small number of patients enrolled because of the low incidence of ECAAs. The etiology and aneurysm type also differed in each case. Furthermore, transcarotid artery revascularization, a less-invasive alternative to open surgery for patients with carotid artery disease, has been used to successfully perform endovascular repair of symptomatic carotid pseudoaneurysm[22] but was not used in this cohort of patients.

In conclusion, the present study shows that endovascular treatment of ECAAs with self-expandable covered stent grafts appears to be a safe and feasible alternative for traditional open surgery, especially in the challenging anatomy and instable physical conditions. Arterial access sites should be based on patient's anatomic characteristics. Although cerebrovascular accidents can occur as the result of hemodynamic changes during the perioperative period, the minimal alternative can yield satisfactory midterm follow-up clinical outcomes. Further studies are warranted to assess long-term outcomes and improvements of endovascular technology.

Ethical approval

The acquisitions were performed with the approval of the Human Research Ethics Committee of Shandong Provincial Hospital Affiliated to Shandong First Medical University.

Informed consent

Written informed consents were obtained from all participants for their clinical records to be used in this study.

Declaration of conflicting interests

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