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Clinical Experience with Treatment of Carotid Artery Lesions with Stent-Graft

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INTRODUCTION

Pseudoaneurysms (PAs) and arteriovenous fistulas (AVFs) that develop in the carotid artery (CA) after a blunt or penetrating neck injury, carotid endarterectomy, or neck tumor are uncommon but may result in serious neurologic deficits. Conventional surgical treatment of these lesions is associated with high mortality and morbidity related to blood loss, cranial nerve injury, and stroke. Thus, a great deal of interest in using endovascular techniques to treat CA PAs and AVFs has emerged. These techniques include permanent balloon occlusion of the CA, combined stent and endovascular coil placement, and stent-grafting with preservation of flow of the parent vessel.

The first clinical use of stent-grafting, described by Parodi et al in 1991, was for treatment of abdominal aortic aneurysms.[1] Stent-grafting has since been employed in several other applications, including treatment of PAs and AVFs in various sites. Use of many types of stent-grafts, from homemade to commercially available devices, has been described in numerous case reports and reports on small series of patients.[2-11] In 1992, we began to employ homemade covered stents and then stent-grafts from several manufacturers to treat PAs and AVFs in the CA. We here describe our results with this treatment in a multicenter series in which the maximum follow-up time was 13 years.

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METHODS

Between July 1992 and September 2005, 22 patients (16 men; 6 women) with an AVF or PA in the CA were treated with percutaneous placement of stent-grafts. All cases done in the United States employed devices approved by the US Food and Drug Administration (FDA) for other than CA applications. They were used "off label" in the CA with approval from our local institutional review boards and the patients' consent. The location, cause, type, and presentation of the vascular lesions treated are shown in Table 1. Diagnoses were made by using computerized tomographic angiography (CTA) and digital substraction angiography (DSA). Access to the artery was obtained by means of a percutaneous femoral approach in 21 patients and surgical cut-down of the common CA in one patient.

The stent-grafts used, their manufacturers, and the number of patients in whom each device was implanted are shown in Table 2. Five different prostheses were employed. The Wallgraft device is a self-expandable stent covered with polyester fabric that is available in 6- to 14-mm diameters and 20-, 30-, 50-, and 70-mm lengths. The delivery catheter has a working length of 90 cm and a profile ranging from 9 to 12 Fr. The Viabahn endoprosthesis is a self-expandable nitinol stent with a thin inner lining made of expanded polytetrafluoroethylene (ePTFE). It is available in lengths ranging from 25 to 150 mm and diameters of 5 to 130 mm and has a profile of 8 to 12 Fr. The Viabahn delivery catheter is 110 cm long, which allows CA lesions to be easily treated through a percutaneous femoral approach. The Corvita endoluminal graft, a self-expandable stent covered with a biocompatible elastomeric polycarbonate urethane, was used outside the United States only and is now not available anywhere. The Jostent coronary stent-graft, which was used in this series to treat a PA in the internal CA and a posttraumatic cavernous carotid fistula, is an ePTFE-covered, balloon-expandable device that is supplied already mounted over monorail coronary angioplasty balloon catheters. The stent is available in diameters of 2.75 to 5 mm and can be delivered through a 6 Fr guiding catheter. The Jostent peripheral stent-graft which was used in this series to treat a PA in the common CA (Figure 5) is still not available in US. The stent is composed by a sandwich construction of two bare peripheral Jostent slotted stents with a thin layer of ePTFE wrapped between them.

In two patients, one with acquired immunodeficiency syndrome and a giant PA that developed in the common CA after a gunshot wound and the other with a posttraumatic PA in the internal CA, Palmaz stents covered with autologous vein were implanted. The vein was har-

Table 1. Characteristics of Carotid Artery Injuries Treated with Stent-Grafting

Characteristic	No. of Patients
Injury location	
Common carotid artery	14
Internal carotid artery	8
Cause of injury	
Gunshot wound	8
Carotid endarterectomy	4
Blunt trauma	3
Neck tumor	2
Spontaneous carotid dissection	2
Stab wound	2
Central venous catheter access	1
Type of lesion	
Pseudoaneurysm	17
Arteriovenous fistula	5
Clinical presentation	
Neck mass	8
Bruit	5
Headache	4
Mouth and tracheotomy bleeding	2
Transitory hemiparesis	2
Seizure	1
Stroke	1

vested from the arm and attached to the stent with four 6-0 polypropylene "U" stitches placed two at each end of the graft at 180˚ to each another. To obtain secure fixation, the stent-vein device was mounted on an angioplasty balloon catheter with a diameter that exceeded the diameter of the artery by 10% to 15%. The entire device (balloon and stent-vein) was compressed into an 11 Fr, 100-cm-long introducer sheath. A homemade tapered tip was used to avoid arterial damage during introduction and progression into the vessel. One case was performed through a surgical cut-down to the common CA; the other used a percutaneous common femoral artery approach.

Stent-graft size selection was based on angiography in 20 cases and on angiography and intravascular ultrasonography in two, with 15% to 20% over sizing used to ensure effective anchoring and sealing. In six patients in whom the stent-graft extended from the internal to common CA, selective embolization with coils (five patients) or detachable balloon (one patient) was performed before the prosthesis was implanted. In these patients, the size of the stent-graft was selected according to the size of the common CA.

Follow-up in the series included clinical, CTA, Doppler ultrasound, and angiographic evaluations.

RESULTS

Resolution of the PA or AVF was achieved in all patients. In one patient with a large petrous PA, acute occlusion of the CA developed after placement of three Jostent stent-grafts. However, because the circle of Willis was functional, the patient had no neurologic complications. In another patient with a large distal common carotid PA, fever developed after stent-graft exclusion of the lesion. The PA was drained percutaneously under CT guidance and the fluid sent to the lab for cultures which resulted negative. Antibiotics and anti-inflammatory medication were administered, and the fever resolved.

One patient with a history of radical neck surgery for squamous cell carcinoma of the larynx who presented with active bleeding through the mouth and tracheostomy due to a PA rupture was treated with a Wallgraft device. A type IV endoleak associated with high graft porosity occurred, and a second Wallgraft prosthesis was deployed, overlapping the first device. Despite remodeling of the stent-graft with an angioplasty balloon and reversal of heparin with protamine, the hemorrhage through the mouth and tracheostomy did not stop. Direct ultrasound-guided puncture of the PA was then performed by using an 18-gauge needle, and 5000 units of bovine thrombin procoagulant (Duett, Vascular Solutions Inc, Minneapolis, MN) was injected, obtaining complete occlusion of the PA. The final angiogram showed no filling of the PA, normal blood flow through the stent-graft, and normal intracranial patency of the internal CA and its branches.

The follow-up time in the series ranged from 2 months to 13 years. In one patient with an autologous vein-covered, balloon-expandable stent in the internal CA, Doppler ultrasonography and angiography showed asymptomatic 90% stenosis due to stent compression 13 months after implantation of the device. Reintervention was offered but the patient refused further treatment. Three patients died during follow-up of causes unrelated to stent-graft placement (cancer, 2 patients; brain surgery, 1 patient). The other 17 patients remained asymptomatic with patent stent-grafts and no neurologic deficits. Angiograms from representative cases in which Viabahn,

Jostent, and Wallgraft devices were used are shown in Figures 1 to 6.

DISCUSSION

Injuries to the CA, which are relatively rare but can have serious neurologic sequelae, may be diagnosed initially by using Doppler ultrasonography, CTA,[12] or magnetic resonance angiography.[13] The diagnosis is usually confirmed by DSA.[14] Surgical treatment of CA injuries has high morbidity and mortality rates. For example, elective CA resection for advanced squamous cell carcinoma of the neck has a 29% mortality rate, and 40% of survivors have a major neurologic deficit.[11,15] Chronic AVFs in the CA are associated with enlarged, friable veins under high pressure. Inadvertent laceration of these thin-walled vessels can lead to catastrophic complications, including massive hemorrhage and nerve damage.[16]

Several endovascular treatments for CA injuries have been described. Permanent balloon occlusion of the CA was shown to be effective in carotid blowout syndrome. Despite the effectiveness of this endovascular technique, however, there is concern regarding its potential for producing delayed cerebral ischemic complications in 15% to 20% of patients.[17]

The use of a combination of stent implantation and endovascular coil placement (stent/coil technique) was initially described as a treatment for intracranial aneurysms with a wide neck. A technical and feasibility study of endovascular stent/coil treatment of fusiform aneurysms in a swine model was reported in 1995.[18] Klein et al[19] described successful treatment, after a failed surgical repair, of a posttraumatic extracranial PA in the internal CA by placement of a Wallstent prosthesis and embolization using Guglielmi detachable coils. Bush et al[20] reported five cases in which a PA in the CA was treated with insertion of an endovascular stent to exclude the PA, followed by filling of the cavity with multiple detachable coils. Successful PA exclusion was achieved in all five patients. However, although the stent/coil technique has been found to be effective in the short term, there are concerns about its long-term results. Specifically, the aneurysm sac is not completely excluded from the circulation and could still enlarge as a result of continued transmission of arterial pressure and thrombus reabsorption.[6]

Endovascular treatment using stent-grafting to exclude PAs and AVFs while preserving blood flow appears to be a better alternative. In 1991, Becker et al[21] reported the first use of a stent-graft to treat a patient with a life-threatening subclavian posttraumatic hemorrhage. Subsequently, many cases in which an endovascular technique was used to treat vascular trauma were described.[2-5,22] Our team began using stent-grafts to treat traumatic lesions in 1992, and we reported our initial experience with this technique in 1999.[16]

The first cases in our series were done with homemade devices combining a balloon-expandable stent and autologous vein. We initially used vein instead of polyester or ePTFE in the CA because of surgical experience indicating that veins are less likely to develop thrombosis and infection. Balloon-expandable covered stents have been employed by

TABLE 2 Stent-Grafts Used to Treat Carotid Artery Pseudoaneurysms and Arteriovenous Fistulas

Stent-Graft (Manufacturer)	No. of Patients
Wallgraft Endoprosthesis (Boston Scientific, Natick, MA)	6
Gore Viabahn Endoprosthesis (WL Gore & Associates, Flagstaff, AZ)	6
Corvita Endoluminal Graft (Corvita, Miami, FL)	5
Jostent Graftmaster Coronary Stent Graft (Abbott Vascular Devices, Redwood City, CA)	3
Palmaz stent (Johnson & Johnson Interventional Systems, Warren, NJ)*	2

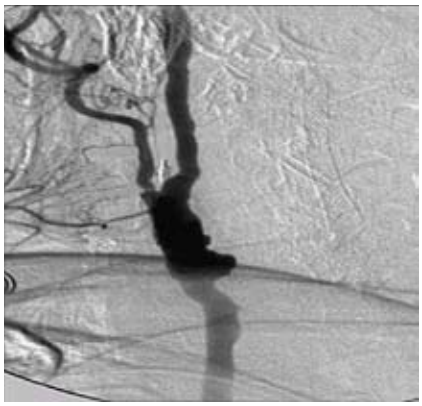

Figure 1. Selective carotid artery (CA) angiogram from a 67-year-old patient with neck cancer and active bleeding through the mouth and tracheostomy shows a pseudoaneurysm (PA) in the distal common CA.

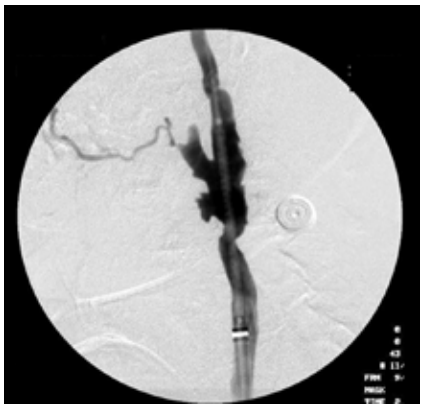

Figure 2. Angiogram from the same patient as in Figure 1, obtained after selective coil embolization of the external CA, shows extravasation from the PA that correlated with bleeding from the patient's mouth.

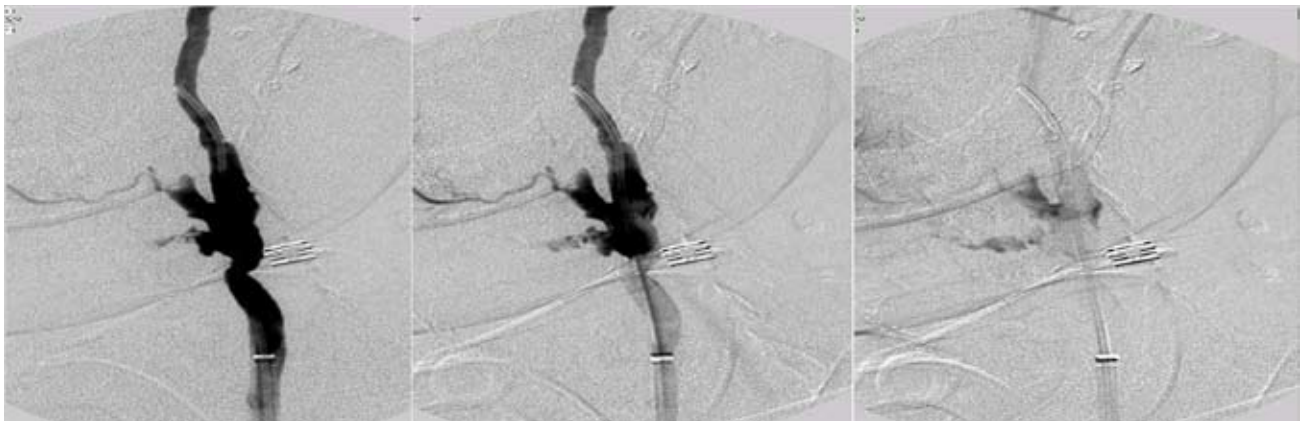

Figure 3. In the same patient as in Figures 1 and 2, a Viabahn device (8 mm x 50 mm) is deployed from the internal to common CA.

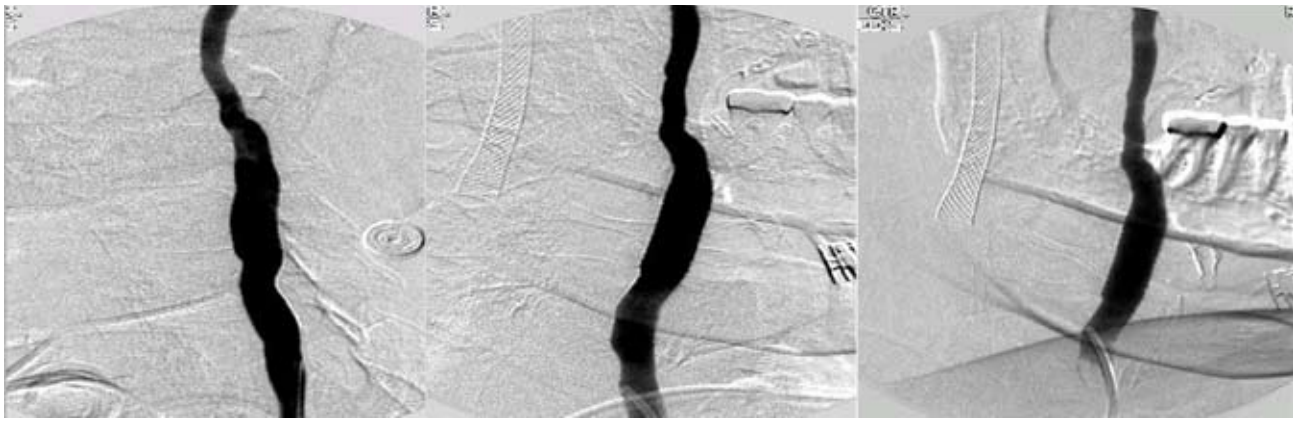

Figure 4. In the same patient as in Figures 1 to 3, a final angiogram (different views) shows complete exclusion of the PA and preservation of blood flow through the vessel.

other groups,[5,7] but compared with self-expandable stent-grafts, they are more prone to collapse, crushing, and occlusion.[23] One patient in our series with an autologous vein-covered stent in the internal CA was found to have asymptomatic 90% stenosis due to stent compression at follow-up 13 months after the device was implanted.

Although the Corvita device was used successfully in our series, it is very porous; therefore, high-flow AVFs remained patent for up to 24 hours after insertion and heparin reversal. The Wallgraft device is also porous and may not achieve efficient sealing in patients with a high-flow AVF or active bleeding. Self et al[10] described a case of a posttraumatic common CA-internal jugular vein fistula treated with a Wallgraft stent-graft in which the final arteriogram showed extravasation from a type IV endoleak. Kubaska et al[22] observed blushing of the PA, representing a type IV endoleak, in two of four patients treated with a Wallgraft device. Therefore, when immediate sealing is essential, it may be necessary to insert a second Wallgraft stent-graft within the previously inserted device or to employ supplementary coil or thrombin embolization. In contrast to the Corvita and Wallgraft devices, the Viabahn endoprosthesis is nonporous, allowing immediate sealing, with no foreshortening. The Viabahn delivery catheter is 110 cm long, and CA lesions can be easily treated through a percutaneous femoral approach, even in tall patients and those with vessel tortuosity.

Roth et al[24] reported a case in which direct percutaneous puncture and acrylic embolization of a PA were used after failure of CA stenting in a case of acute carotid blowout. In one of our patients, direct puncture and embolization of the PA with thrombin were necessary because of persistent bleeding after PA exclusion using a very porous stent-graft.

Embolization of the external CA in patients with lesions close to the carotid bifurcation and placement of a stent-graft extending from the internal to common CA are advisable to avoid persistent filling of the PA or AVF from the collateral circulation through branches of the contralateral external CA (type II endoleak). In six of our patients, the external CA was occluded (with coils in five patients

and a detachable balloon in one) before deployment of the stent-graft, and none of them subsequently had persistent flow through collaterals. The rationale for occlusion of the external CA in such cases is based on the practice of embolizing the internal iliac arteries to prevent type II endoleaks when treating abdominal aortic aneurysms extending to the common iliacs.[25,26]

Although stent-grafting in patients with CA injury may raise concerns about infection, only one patient in our series had onset of fever after stent-graft exclusion of the lesion. The PA in that patient was drained percutaneously under CT guidance, and the patient recovered uneventfully. Moreover, Baril et al[27] reported successful treatment with a Viabahn endoprosthesis of an infected PA that developed after carotid endarterectomy.
None of the devices employed in this series were designed to be used in carotid lesions. Future designs for covered stents intended for carotid applications should include a lower profile, a nonporous material, more device flexibility, and tapered configurations appropriate for the difference in size between the internal and common CA.

In conclusion, in a series of 22 patients treated during a 13-year period, we found that stent-grafting was safe and effective in resolving PAs and AVFs in the CA. This technique may well be offered as an alternative to surgical procedures.

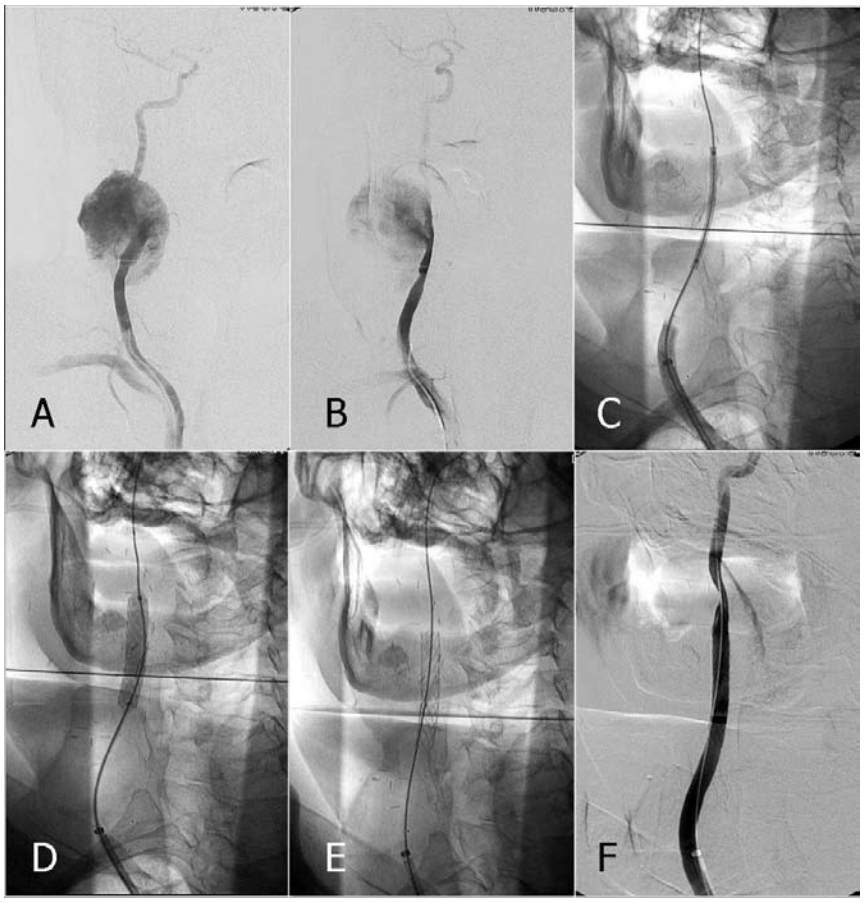

Figure 5. Angiograms from a 61-year-old patient who presented with a pulsatile neck mass after undergoing carotid endarterectomy. (A, B) Selective right CA angiograms show early and late phases, respectively, of a giant PA at the endarterectomy site. (C) A balloon-expandable Jostent stent-graft is positioned to cover the neck of the PA. (D) The balloon is inflated and the stent-graft deployed. (E) Stent-graft in position in the CA. (F) Final angiogram shows exclusion of the PA.

Summary

This paper reports on the safety and efficacy of stent-graft placement in the management of arteriovenous fistulas (AVFs) and pseudoaneurysms (PAs) involving the carotid artery (CA).

Twenty-two patients with a CA AVF or PA due to a gunshot or stab wound, carotid endarterectomy, blunt trauma, tumor, spontaneous dissection, or central venous catheter were treated with percutaneous placement of stent-grafts. The patients presented with tumor, bruit, headache, bleeding through the mouth and tracheotomy, transitory hemiparesis, seizure, or stroke. Diagnoses were made by using computerized tomography angiography (CTA) and digital subtraction angiography. Fourteen lesions were in the common CA; eight were in the internal CA. Homemade devices and stent-grafts from a variety of manufacturers were employed. Follow-up evaluations included clinical, CTA, and Doppler ultrasound assessments.

All patients had resolution of the PA or AVF. In one patient with a large petrous PA, an acute occlusion of the CA developed after placement of three balloon-expandable stent-grafts, but there were no neurologic complications because the circle of Willis was functional. During follow-up ranging from 2 months to 13 years, asymptomatic 90% stenosis due to stent compression was observed on Doppler ultrasound and angiographic examinations in a patient with an autologous vein-covered stent-graft in the internal CA. Three other patients died of causes unrelated to stent-graft placement. In all other patients, the stent-graft remained patent.

Our results indicate that stent-grafting is an acceptable alternative to surgery in the treatment of AVFs and PAs in the CA.

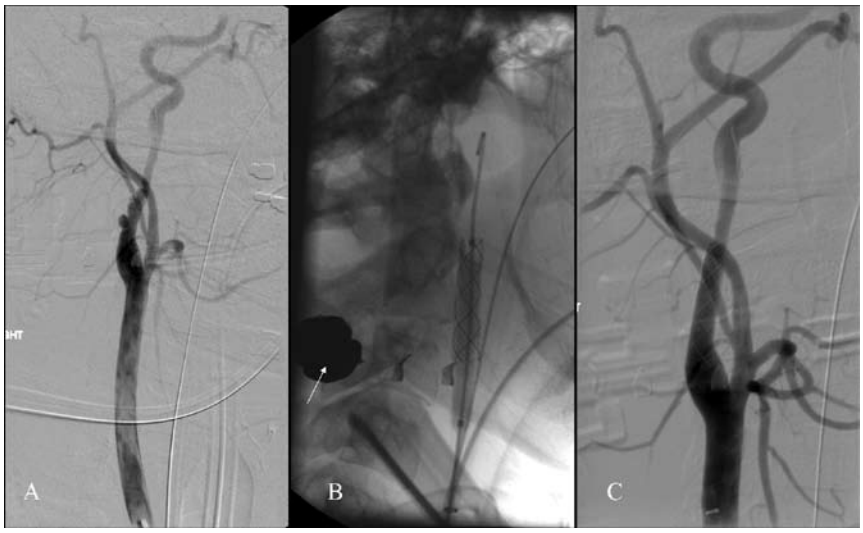

Figure 6. Angiograms from a 27-year-old patient with a gunshot wound in the neck. (A) Selective angiogram shows a traumatic lesion of the internal CA. (B) A Wallgraft device (7 mm x 30 mm) is deployed and a 5-mm balloon used for dilation. The bullet appears in this view (arrow). (C) Final angiogram shows complete coverage of the injured internal CA by the stent-graft.

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