Endovascular implantation of covered stents in the extracranial carotid and vertebral arteries: Case series and review of the literature

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Abstract

**Background:** Covered stents are used endovascularly to seal arterial wall defects while preserving vessel patency. This report describes our experience with the use of covered stents to treat cervical pathology, and a review of the literature in regards to this topic is presented.

**Case Description:** Two patients presenting with the carotid blowout syndrome and one patient with a vertebrojugular fistula were treated with covered stents. This allowed for preservation of the vessel and was a treatment alternative to cerebral bypass.

**Conclusion:** Covered stents provide a viable means of preserving the cervical vessels in selected patients; however, long-term follow-up is necessary to determine stent patency and permanency of hemostasis.

**Key Words:** Covered stent, carotid blow-out, endovascular, vertebrojugular fistula

**INTRODUCTION**

Covered stents consist of a synthetic material that either covers or is attached to a metallic stent to create a graft endoprosthesis. The covering excludes breaches to the integrity of the arterial wall, while preserving vessel patency. Covered stents have been used to treat aneurysms,[43,53,58] traumatic arterial injuries,[79,102,108] and arteriovenous fistulas (AVF)[43,79,102,108] of the axillary, subclavian, iliac, femoral, and popliteal arteries.

The emergence of neuroendovascular techniques offers an alternative treatment for patients in whom surgery is contraindicated. Advantages of an endovascular approach include: an easier access, less invasiveness, performance under local anesthesia, less post-procedural pain and disability, and less expense.[79] The Food and Drug Administration (FDA) has not approved the use of covered stents for neuroendovascular interventions; however, these devices offer a potentially less morbid alternative in the treatment of complex, extracranial disease where surgical options are limited. We describe our experience with the placement of covered stents in the treatment of the carotid blowout syndrome (CBS) and a vertebrojugular fistula (VJF). We also review the present literature regarding the use of covered stents in extracranial cerebral circulation.

**CASE REPORTS**

The Institutional Review Board approval was obtained for the retrospective review of all extracranial neuroendovascular interventions between January 2006 and June 2009. Three patients treated with a covered...
A 53-year-old female with a history of stage II squamous cell carcinoma of the larynx was treated with radical laryngectomy with bilateral neck dissection, tracheostomy, and adjuvant radiation therapy. The patient suffered tumor recurrence in the pharynx, and was being treated with palliative chemotherapy. He presented with severe, acute bleeding from the mouth and bilateral nares, which required emergent intubation and extensive packing of the nasal and oral cavities. Angiography demonstrated left common carotid artery (CCA) blowout with a pseudoaneurysm at the carotid bifurcation [Figure 2a]. Cerebral angiography showed complete exclusion of the pseudoaneurysm as well as the external carotid artery [Figure 2b].

A Fluency Plus stent-graft was also deployed across the right carotid bifurcation. During advancement of the stent, dissection of the proximal CCA was noted. Subsequently, two Precise Nitinol stents (Cordis Corporation; Miami Lakes, FL) were successfully deployed across the iatrogenic dissection. Control angiography demonstrated the near-normal caliber of the right common carotid artery with the three stents in tandem. Systemic heparinization was continued for 24 hours, after which the patient was maintained on dual anti-platelet therapy. Post-procedurally no new neurological deficits were identified. He was ultimately discharged to a nursing home and was lost to follow-up.

Case 3
A 51-year-old woman presented with a ten-week history of persistent left-sided neck pain and pulsatile tinnitus. Cerebral angiography demonstrated a large, high-flow AVF originating from the left vertebral artery (VA) and draining into the internal jugular veins bilaterally [Figure 1a]. Retrograde flow from the right VA also supplied the fistula [Figure 1b]. Diffuse, advanced fibromuscular dysplasia was observed in the cervical segments of both the vertebral arteries and was the presumed underlying etiology. Flow measurements with quantitative magnetic resonance angiography (Q-MRA) using the Non-invasive Optimal Vessel Analysis (NOVA) software (VasSol Inc., Chicago, IL) demonstrated that the fistula was supplied by 744 ml / minute of antegrade flow through the left VA and 55 ml / minute of retrograde flow through the right VA.

Due to the complexity of the fistula, surgery and endovascular coiling were not feasible. Additionally, preservation of the VA was preferred given the presence of fibromuscular dysplasia. The procedure was performed under general anesthesia. Loading doses of intravenous Heparin (5000 U) and eptifibatide (180 µg / kg) were administered initially and eptifibatide (2 µg / kg / minute) was continued throughout the procedure. A Fluency Plus covered stent (Bard Inc.; Karlsruhe, Germany) was deployed successfully across the fistula. Control angiography of the left VA demonstrated complete closure of the fistula with preservation of flow to the intracranial circulation [Figure 1c], and reversal of the contralateral flow from the right VA [Figure 1d]. Post-procedural Q-MRA demonstrated normalization of the antegrade flow through the left VA distal to the fistula at 143 ml / minute, with a combined total of 261 ml / minute within both vertebral arteries, (the normal range of combined vertebral flow was 99 – 281 mg / minute) [Figures 1e and f].

Postoperatively the patient remained neurologically intact and was started on dual anti-platelet therapy with daily aspirin (325 mg) and clopidogrel (75 mg). Eptifibatide was discontinued the morning after the procedure. On follow-up, the patient’s tinnitus had resolved, and angiography at four months demonstrated complete exclusion of the VJF and patency of the covered stent.

**Review of the Literature**

We conducted a systematic review of the English-speaking medical literature using the PubMed service of the National Library of Medicine / National Institutes of Health and OVID.
Medline databases to identify all publications documenting the use of covered stents in the extracranial cerebral circulation. The search included the keywords ‘Stents’[Mesh] AND ‘Vertebral Artery’[Mesh] OR ‘Carotid Artery Injuries’[Mesh] NOT ‘Intracranial Arterial Diseases’[Mesh] NOT ‘Subclavian artery’[MESH] NOT ‘Carotid-Cavernous Sinus Fistula’[Mesh]. Additionally, the reference lists of the relevant articles were checked until no further publications were found. These publications are summarized in Table 1.

DISCUSSION

Indications for covered stents

A total of 150 patients, including the present cases, were endovascularly implanted with 164 covered stents for the treatment of extracranial disease of the carotid or vertebral arteries [Table 1]. Publication bias may have resulted in the underestimation of these figures, as failed procedures are occasionally not publicized. The most commonly reported indications included 81 pseudoaneurysms, 27 cases of CBS, and 23 AVFs. Additional reported indications included

Figure 2: (a) Left CCA angiogram showing a pseudoaneurysm at the carotid bifurcation; (b) exclusion of the pseudoaneurysm after deployment of the covered stent

Figure 1: (a) Left VA angiogram showing an AVF draining into bilateral internal jugular veins and diffuse fibromuscular dysplastic change; (b) Right VA injection showing retrograde filling of the distal left VA into the right VA-jugular vein fistula, and diffuse fibromuscular dysplastic change; (c) after deployment of the stent-graft showing complete occlusion of the AVF with normalization of the antegrade flow within the intracranial portion of the left VA; (d) Right VA injection showing no cross flow of contrast into the left intracranial VA; (e) 3D-imaging from a Q-MRA, showing reconstitution of the left VA with no opacification of the fistula; (f) Q-MRA flow maps indicating 151 ml/minute of antegrade blood flow within the left VA compared to 744 ml/minute at the baseline
Table 1: Extracranial neurovascular interventions with covered stents: bibliography review

| Authors (first) | Year | Age/Sex | Indication | Device or Stent/Graft | Outcome | Complications | Follow-up |
|-----------------|------|---------|------------|----------------------|---------|---------------|-----------|
| Nicholson       | 1995 | 59/M    | PSA of the left | CCACraggstent | Lesion excluded | None     | 8 w: patent   |
| Singer          | 1997 | 34/F    | VJF involving the left VA | Palmez/Gortex | Lesion excluded | None     | 17 mo: patent |
| May             | 1997 | 70/M    | PSA of the right ICA | Passager endograft | Lesion excluded | Embolic stroke | 6 mo: asymptomatic occlusion |
| Reiter          | 1998 | 72/M    | PSA of the left ICA | Palmez/PTFE | Lesion excluded | None     | 6 mo: patent   |
| Von Nieuwenhove | 1998 | 67/M    | PSA of the left CCA | Palmez/Saphenous vein | Lesion excluded | None     | 2 mo: patent   |
| Waldman         | 1998 | 44/M    | Dissection of the left VA | CEG | Lesion excluded | None     | 1 wk: patent |
| Marotta         | 1998 | 20/M    | PSA of the left ICA | Palmaz 154/saphenous vein | Lesion excluded | None     | 1 mo: patent   |
| Parodi          | 1999 | 23/M    | PSA of the CCA | Palmaz/Saphenous vein | Lesion excluded | None     | 18 mo: asymptomatic occlusion |
|                 |      | 37/M    | PSA of the ICA | Palmaz/Saphenous vein | Lesion excluded | None     | 36 mo: patent   |
|                 |      | 22/M    | CJP involving the CCA | CEG | Lesion excluded | None     | 24 mo: patent |
|                 |      | 21/M    | CJP involving the CCA | CEG | Lesion excluded | None     | 6 mo: patent   |
|                 |      | 53/M    | CJP involving the ICA | CEG | Lesion excluded | None     | 4 mo: patent   |
|                 |      | 23/M    | CJP involving the CCA | CEG | Lesion excluded | None     | 8 mo: patent   |
|                 |      | 12/M    | PSA of the ICA | Wallgraft | Lesion excluded | None     | 1 mo: patent   |
| Smith           | 2000 | 28/W    | PSA of the left ICA | Palmaz/PTFE x 2 | Lesion excluded | None     | 6 mo: patent (PSA filling) |
| Martin          | 2000 | 59/M    | PSA of the right CCA | Palmaz/Saphenous vein | Lesion excluded | None     | 8 mo: patent   |
| Simionato       | 2000 | 50/M    | PSA of the right CCA | Jostent x 2 | Lesion excluded | None     | 12 mo: patent |
| Macdonald       | 2001 | 61/M    | CBS of the right CCA | Jostent | Lesion excluded | None     | -           |
| Kwok            | 2001 | 63/M    | CBS of the right CCA | Jostent | Vessel rupture | -        | -           |
| Ruckert         | 2001 | 13/F    | VJF involving the right VA | Jostent | Lesion excluded | None     | 15 mo: patent |
| Gonzalez        | 2001 | 57/F    | VJF involving the right VA | Wallgraft | Lesion excluded | None     | 9 mo: patent |
| Scavee          | 2001 | 53/M    | PSA of the right ICA | Jostent | Lesion excluded | None     | 6 mo: patent   |
| Redekop         | 2001 | 20/M    | PSA of the ICA | Palmaz/Saphenous vein | Lesion excluded | None     | 3 mo: patent   |
|                 |      | 60/F    | VVF | Palmaz/Saphenous vein | Lesion excluded | None     | 6 mo: patent   |
| Patel           | 2002 | 16/M    | CJP involving the left ICA | Palmaz/PTFE x 3 | Lesion excluded | None     | 3 mo: patent   |
| Ellis           | 2002 | 29/M    | PSA of the left CCA | Wallgraft | Lesion excluded | None     | 6 mo: patent   |
| Mukherjee       | 2002 | 43/M    | PSA of the left ICA | Wallgraft | Lesion excluded | None     | 9 mo: patent   |
|                 | 65/M | PSA of the right ICA | Wallgraft | Lesion excluded | None     | 8 mo: patent   |
|                 | 64/M | PSA of the right CCA/ICA | Wallgraft x 2 | Lesion excluded | None     | 9 mo: patent   |
| Lesley          | 2002 | 46/M    | CBS of the ICA | Wallgraft | Hemostasis | None     | -           |
|                 | 41/F | CBS of the ECA | Wallgraft | Hemostasis | None     | -           |

Contd....
| Authors (first) | Year | Age/Sex | Indication                  | Device or Stent/Graft | Outcome                  | Complications | Follow-up |
|---------------|------|---------|-----------------------------|----------------------|--------------------------|---------------|-----------|
| McNeil        | 2002 | 18/M    | PSA of the left ICA         | Wallgraft            | Lesion excluded          | None          | 10 mo: 50% stenosis |
| Durante       | 2002 | 31/F    | PSA of the left ICA         | Wallgraft            | Lesion excluded          | ICA dissection | 6 wk: ICA occlusion |
| Amar          | 2002 | 47/M    | CBS of the right CCA        | Wallgraft x 2        | Lesion excluded          | None          |          |
|              |      | 38/F    | VVF involving the right VA  | Wallgraft            | Lesion excluded          | None          | 6 d: patent |
|              |      | 35/M    | PSA of the left ICA         | Wallgraft            | Lesion excluded          | None          |          |
| Duncan        | 2003 | 22/M    | CJSF involving the right ICA| Wallgraft            | Lesion excluded          | None          | 6 mo: patent |
| Tseng         | 2003 | 68/M    | PSA of the left ICA         | Jostent x 2          | Lesion excluded          | None          | 9 mo: patent |
| Ahn           | 2003 | 32/M    | CJSF and PSA of the left ICA| Jostent              | Lesions excluded         | None          | 1 wk: patent |
| Hertz         | 2003 | 80/M    | PSA of the right CCA        | Wallgraft x 2        | Lesion excluded          | None          |          |
| Lupattelli    | 2003 | 40/M    | PSA of the left ICA         | Jostent              | Lesion excluded          | None          | 20 mo: patent |
| du Toit       | 2003 | -       | CJSF involving the CCA      | -                    | -                        | -             |          |
|              |      | -       | CJSF involving the CCA      | -                    | -                        | -             |          |
|              |      | -       | CJSF involving the CCA      | -                    | -                        | -             |          |
| Koenigsberg   | 2003 | 33/M    | PSA of the left CCA         | Wallgraft            | Lesion excluded          | None          | 1 yr: clinically asymptomatic |
| Sadato        | 2003 | 24/F    | VVF involving the right VA  | Palmaz/PTFE          | Lesion excluded          | None          | 5 mo: patent |
| Surber        | 2003 | 42/F    | VVF involving the right VA  | Wallgraft            | Lesion excluded          | None          | 12 mo: patent |
| Lin           | 2003 | 74/M    | PSA of the right CCA/ICA    | Wallgraft            | Lesion excluded          | None          | 18 mo: patent |
| Kubaska       | 2003 | 39/M    | PSA of the left ICA         | Wallgraft            | Lesion excluded          | None          | 2 yr: clinically asymptomatic |
|              |      | 40/M    | PSA of the left ICA         | Wallgraft            | Lesion excluded          | None          | 1 mo: patent |
|              |      | 34/W    | PSA of the right ICA        | Wallgraft            | Lesion excluded          | None          | 14 mo: patent |
|              |      | 67/M    | PSA of the left ICA         | Wallgraft x 2        | Lesion excluded          | None          | 6 mo: patent |
| Powell        | 2003 | 54/M    | Vein-graft aneurysm of right CCA | Viabahn            | Lesion excluded          | None          | 4 mo: patent |
| Priestley     | 2003 | 45/M    | VVF involving the right VA  | Hemobahn             | Lesion excluded          | VA dissection | 6 mo: patent |
| Assadian      | 2004 | 43/F    | Dissection of the ICA       | Hemobahn             | Lesion excluded          | None          | 45 mo: patent |
|              |      | 49/F    | Dissection of the ICA       | Hemobahn             | Lesion excluded          | None          | 54 mo: patent |
|              |      | 34/M    | Dissection of the ICA       | Hemobahn             | Lesion excluded          | None          | 6 mo: patent |
|              |      | 78/M    | Dissection of the ICA       | Hemobahn             | Lesion excluded          | None          | 35 mo: patent |
|              |      | 64/M    | Dissection of the ICA       | Hemobahn             | Lesion excluded          | None          | 48 mo: patent |
|              |      | 49/M    | Dissection of the ICA       | Hemobahn             | Lesion excluded          | TIA           | 42 mo: patent |
| Fusonie       | 2004 | 37/M    | PSA of the right ICA        | Wallgraft            | Lesion excluded          | None          | 3 mo: patent |
| Saket         | 2004 | 18/M    | PSA of the right ICA        | Palmaz/PTFE          | Lesion excluded          | Type I endoleak | None |
|              |      | 28/M    | PSA of the left ICA         | Hemobahn             | Lesion excluded          | None          | 46 mo: patent |
|              |      | 33/W    | VVF involving the right VA  | Jostent              | Lesion excluded          | None          | 14 mo: patent |
| Authors (first) | Year | Age/Sex | Indication | Device or Stent/Graft | Outcome | Complications | Follow-up |
|----------------|------|---------|------------|-----------------------|---------|---------------|-----------|
| Felber         | 2004 | 46/M    | PSA of the right ICA | Jostent | Lesion excluded | None | 14 mo: patent |
|                |      | 92/W    | PSA of the left CCA | Viabahn | Lesion excluded | None | - |
| ul Haq         | 2004 | 39/M    | PSA of the left ICA | Jostent | Lesion excluded | None | 6 mo: patent |
|                |      | 12/M    | PSA of the left CCA | Jostent | Lesion excluded | None | 3 mo: patent |
| Huttl          | 2004 | 24/M    | PSA and VVF of the left VA | Jostent | Lesion excluded | None | 18 mo: LVA occlusion |
| Baril          | 2004 | 79/W    | Infected PSA of the right CCA | Viabahn | Lesion excluded | None | 12 mo: patent |
| Self           | 2004 | 32/M    | PSA and CJF of the right CCA | Wallgraft | Lesion excluded | None | - |
| Layton         | 2004 | 31/F    | PSA of the left ICA | - | Lesion excluded | None | 27 mo: patent |
|                |      | 23/M    | PSA of the left ICA | - | Lesion excluded | None | 8 mo: patent |
|                |      | 63/F    | In-stent stenosis of the right CCA | - | Lesion excluded | None | 3 yr: patent |
| Zingler        | 2004 | 63/M    | VVF involving the right VA | Jostent | Lesion excluded | None | - |
| Cil            | 2004 | 57/M    | Stenosis of the left ICA | Palmaz/PTFE | - | None | 6 mo: patent |
|                |      | 47/M    | Stenosis of the left ICA | Palmaz/PTFE | - | None | 6 mo: patent |
|                |      | 67/M    | Stenosis of the right ICA | Palmaz/PTFE | - | None | 6 mo: patent |
| Joo            | 2004 | 32/M    | PSA and CJF of the left ICA | Jostent | Lesion excluded | None | 10 mo: patent |
| McCready       | 2004 | 58/M    | PSA of the left ICA | Wallgraft x 2 | Lesion excluded | TIA | 12 mo: asymptomatic occlusion |
|                |      | -       | PSA | Wallgraft | Lesion excluded | TIA | 12 mo: patent |
|                |      | -       | PSA | Wallgraft | Lesion excluded | None | 12 mo: patent |
|                |      | -       | PSA | Wallgraft | Lesion excluded | None | - |
| Szopinski      | 2005 | 37/M    | PSA of the right ICA | Jostent | Lesion excluded | None | 5 yr: clinically asymptomatic |
|                |      | 64/M    | PSA of the right ICA | Jostent | Lesion excluded | None | 3 yr: clinically asymptomatic |
|                |      | 56/M    | Aneurysm of the left CCA/ICA | Wallgraft | Lesion excluded | None | 2 yr: clinically asymptomatic |
| Mousa          | 2005 | 82/W    | PSA of the right CCA/ICA | Wallgraft | Lesion excluded | None | 6 mo: patent |
| Dieter         | 2005 | 67/M    | Perforation of the right ICA | Jostent | Lesion excluded | None | 1 mo: patent |
| Heye           | 2005 | 44/M    | PSA of the right ICA | Symbiot | Lesion excluded | None | 4 mo: patent |
| Akiyama        | 2005 | 48/M    | PSA of the right CCA | Jostent | Lesion excluded | None | 6 mo: patent |
| Witz           | 2005 | 16/M    | PSA of the left CCA | Jostent | Lesion excluded | None | 1 yr: patent |
| Maras          | 2006 | 22/M    | PSA of the left ICA | Jostent | Lesion excluded | None | 18 mo: patent |
| Hagspiel       | 2006 | 54/W    | CBF involving the left CCA | iCAST x 2 | Lesion excluded | None | 6 wk: clinically asymptomatic |
| Katsaridis     | 2006 | 74/M    | PSA of the right VA | Symbiot | Lesion excluded | None | 6 mo: patent |
| Cox            | 2007 | -       | PSA of the VA | iCAST | Lesion excluded | None | - |
|                |      | -       | PSA of the ICA | Wallgraft | Lesion excluded | None | - |
| Authors (first) | Year | Age/Sex | Indication | Device or Stent/Graft | Outcome | Complications | Follow-up |
|----------------|------|---------|------------|----------------------|---------|---------------|-----------|
| Riesenman      | 2007 | 86/F    | PSA of the right ECA | Jostent | Lesion excluded | None | 2 mo: patent   |
| Briguori       | 2007 | 76/M    | PSA of the left CCA | Fluency | Lesion excluded | None | 3 mo: patent   |
| Lim            | 2007 | 26/F    | PSA of the left ICA x 2 | Symbiot | Lesion excluded | ICH | Died: ruptured aortic aneurysm |
| Chang          | 2007 | 35/M    | CBS of the CCA/ICA | Wallgraft | Hemostasis | None | Rebled 19 days post-procedure |
| Chang          | 2007 | 43/M    | CBS of the CCA | Wallgraft | Hemostasis | None | Rebled two days post-procedure |
| Chang          | 2007 | 52/M    | CBS of the ICA | Wallgraft | Hemostasis | ICA occlusion | Rebled 6 mo post-procedure |
| Chang          | 2007 | 49/M    | CBS of the CCA/ICA | Wallgraft | Hemostasis | Embolic stroke | 1 mo: patent |
| Chang          | 2007 | 65/M    | CBS of the CCA/ICA | Wallgraft | Hemostasis | Brain abscess | 4 mo: septic carotid thrombosis |
| Chang          | 2007 | 44/M    | CBS of the CCA | Wallgraft | Hemostasis | None | 2 wk: patent |
| Chang          | 2007 | 54/M    | CBS of the CCA | Wallgraft | Hemostasis | None | 2 wk: patent |
| Barkhordarian  | 2007 | 63/M    | PSA and VJF of the right VA | Jostent | Lesions excluded | None | 6 mo: patent |
| Feugier        | 2007 | 44/M    | Dissection of the right ICA | Advanta V12 | Lesion excluded | None | 2 yr: patent |
| Sancak         | 2008 | 22/M    | PSA and VJF of the left VA | Jostent x 2 | Lesion excluded | None | 18 mo: in-stent stenosis |
| Bellosta       | 2008 | 59/M    | PSA of the left CCA/ICA | Viabahn | Lesion excluded | None | 6 mo: patent |
| Yi             | 2008 | 44/M    | PSA of the left ICA | Fluency | Lesion excluded | None | 15 d: patent |
| Yi             | 2008 | 66/M    | PSA of the right ICA | Viabahn | Lesion excluded | None | - |
| Yi             | 2008 | 15/M    | PSA of the left CCA | Fluency | Lesion excluded | None | 25 mo: patent |
| Yi             | 2008 | 81/M    | PSA of the left CCA | Fluency | Lesion excluded | Embolic stroke | - |
| Yi             | 2008 | 17/F    | PSA of the left ICA | iCAST | Lesion excluded | None | 20 mo: patent |
| Yi             | 2008 | 62/M    | PSA of the left CCA | Fluency | Lesion excluded | None | 5 d: patent |
| Yi             | 2008 | 24/M    | PSA of the left CCA | Fluency | Lesion excluded | None | 13 d: patent |
| Hoppe          | 2008 | 61/F    | CBS of the right CCA/ICA | Palmaz/PTFE | Hemostasis | None | 1 mo: asymptomatic occlusion |
| Hoppe          | 2008 | 86/F    | CBS of the left CCA | Palmaz/PTFE | Hemostasis | CCA dissection | - |
| Hoppe          | 2008 | 75/M    | CBS of bilateral CCAs | Palmaz/PTFE x 2 | Hemostasis | None | Rebled 9 days post-procedure |
| Hoppe          | 2008 | 67/F    | CBS of the left CCA | Fluency | Hemostasis | None | 4 mo: patent |
| Hoppe          | 2008 | 62/F    | CBS of the right CCA/ICA | Fluency | Hemostasis | None | 6 mo: patent |
| Hoppe          | 2008 | 33/M    | CBS of the right CCA | Wallgraft | Hemostasis | None | Rebled 24 hrs post-procedure |
| Hoppe          | 2008 | 87/F    | CBS of the left ICA | Wallgraft | Hemostasis | None | - |
| Hoppe          | 2008 | 63/M    | CBS of the left CCA/ICA | Wallgraft | Hemostasis | None | - |
| Hoppe          | 2008 | 61/M    | CAF involving the right CCA | Fluency | Lesion excluded | None | - |
| Hoppe          | 2008 | 64/F    | CAF involving the right CCA | Viabahn | Lesion excluded | None | - |
| Hoppe          | 2008 | 52/M    | CAF involving the right CCA | Viabahn | Lesion excluded | None | - |
| Hoppe          | 2008 | 68/M    | PSA of the left CCA/ICA | Fluency | Lesion excluded | None | - |
| Hoppe          | 2008 | 20/F    | PSA of the left ICA | Viabahn | Lesion excluded | None | 6 mo: patent |
| Hoppe          | 2008 | 67/M    | PSA of the right ICA | Viabahn | Lesion excluded | None | 33 mo: patent |

Contd...
A pseudoaneurysm forms secondary to vessel wall trauma that results in a periarterial hematoma contained in the ingrowth of the fibrotic tissue. As the center of the hematoma dissolves, a potential space for blood flow is created, which under arterial pressure gradually enlarges to form an aneurysmal sac. Blood may also dissect through the subintimal or subadventitial space narrowing the true lumen of the vessel. Pseudoaneurysms may be caused by blunt or penetrating craniocervical trauma, spontaneous dissection, and as a rare complication of carotid endarterectomy. The most common clinical presentations include thromboembolic symptoms or a pulsatile cervical mass or bruit on physical examination. Treatment is recommended to reduce the risk of stroke and rupture.

Arteriovenous fistulas involving the extracranial carotid and vertebral arteries are rare. Like pseudoaneurysms, these lesions most commonly occur secondary to blunt or penetrating neck trauma. Other causes include systemic diseases such as neurofibromatosis and fibromuscular dysplasia, which is the presumed etiology in our patient. Treatment is necessary, because shunting through the high-flow AVF may result in cardiac overload. Additionally, as seen in our patient, vertebral AVFs may produce a continuous or pulsatile tinnitus also necessitating treatment.

Carotid blowout syndrome is a term used to describe a rupture of the extracranial carotid artery or its branches. Patients commonly present with acute transoral or transcervical hemorrhage. CBS is a rare, but life-threatening complication of head and neck cancer occurring in 4.3% of these patients. The etiological factors related to previous surgery and adjuvant radiation therapy have been implicated. Our patients with CBS presented with life-threatening bleeding that necessitated packing and acute parent vessel reconstruction with covered stents.

**Table 1:**

| Authors (first) | Year | Age/Sex  | Device or Stent/Graft | Indication | Follow-up | Complications | Outcome |
|----------------|------|----------|-----------------------|------------|-----------|---------------|---------|
| Flood 2009     | 47/M | PSA of the right ICA | Viabahn    | Lesion excluded | 18 mo: patent | None            | Lesion excluded |
|                | 63/F | PSA of the left CCA  | Fluency    | Lesion excluded | 6 mo: patent | None            | Lesion excluded |
|                | 67/F | PSA of the left ICA  | Fluency    | Lesion excluded | 6 mo: patent | None            | Lesion excluded |
|                | 57/M | PSA of the left ICA  | Fluency    | Lesion excluded | 6 mo: patent | None            | Lesion excluded |
|                | 65/M | Stenosis of the left CCA/ICA | Fluency | Lumen expanded | 6 mo: patent | None            | Lumen expanded |
|                | 65/M | Stenosis of the right ICA | Fluency | Lumen expanded | 6 mo: patent | None            | Lumen expanded |
|                | 80/M | Stenosis of the left VA | Fluency | Lumen expanded | 6 mo: patent | None            | Lumen expanded |
|                | 62/M | CBS of the left CCA/ICA | Fluency | Lumen expanded | 6 mo: patent | None            | Lumen expanded |

**Table 1:** Contd...

| Authors (first) | Year | Age/Sex  | Device or Stent/Graft | Indication | Follow-up | Complications | Outcome |
|----------------|------|----------|-----------------------|------------|-----------|---------------|---------|
| Flood 2011     | 24/F | PSA of the right ICA | Jostent x 2 | Lesion excluded | 1 yr: in-stent restenosis | None    | Lesion excluded |
|                | 51/F | VJF involving the left VA | Fluency | Lesion excluded | 4 mo: patent | None            | Lesion excluded |
|                | 62/F | CAF of the left CCA/ICA | Fluency | Lesion excluded | - | None            | Lesion excluded |

**CCA = common carotid artery; ICA = internal carotid artery; ECA = external carotid artery; VA = vertebral artery; PSA = pseudoaneurysm; CJF = carotid-jugular fistula; VJF = vertebrojugular fistula; VVF = vertebrovertebral fistula; CBF = caroticobrachiocephalic fistula; CBS = carotid blowout syndrome; CAF = carotid artery fistula; VJF = vertebral artery fistula; VVF = vertebrovertebral fistula; CBF = caroticobrachiocephalic fistula; ICH = intracerebral hemorrhage; SAH = subarachnoid hemorrhage. D= days; wk = weeks; mo = months; yr = years.**

**Conventional surgical treatment**

Although standard surgical procedures on the extracranial carotid and vertebral arteries are generally straightforward, complex lesions such as those previously discussed pose unique challenges. Historically, surgical options for the treatment of extracranial pseudoaneurysms included vessel ligation, extracranial–intracranial bypass, and direct vessel repair; however, these surgeries are technically challenging. In particular, ICA pseudoaneurysms near the skull base necessitate extensive exposures to achieve proximal and distal control, which may result in significant morbidity and mortality. Direct repair of VA pseudoaneurysms is also associated with high dissections, carotid-airway fistulas, in-stent stenosis, and atherosclerosis [Table 1].
morbidity and mortality due to the anatomic depth of the vessel, extensive periarterial plexus, prevalence of collateral blood flow, and risk of vertebrobasilar ischemia.\(^{[12,24,40]}\)

Surgical treatment of AVFs is similarly difficult. Ideally, the procedure entails interruption of the fistula with arterial and venous reconstruction.\(^{[30,38]}\) However, the technical challenge and consequent morbidity related to surgical exposure are similar to those of pseudoaneurysm repair.\(^{[29]}\) Furthermore, the large caliber of the extracranial carotid and vertebral arteries produces large shunts and pressure differences. This results in rich arterial and venous collateral formation and arterialization of the thin-walled veins, which makes surgery even more delicate. If the fistula cannot be fully trapped, ligation of the affected vessel is the only other surgical option.

Surgical management of CBS involves emergent ligation of the affected common or proximal internal carotid artery; however, vessel sacrifice increases the risk of stroke.\(^{[40]}\) Additionally, these patients are generally high risk candidates for general anesthesia. Furthermore, identification of the source of bleeding can be extremely difficult due to the tumor bulk, coexisting infection or dense scarring secondary to the previous treatment. Consequently, these procedures have been associated with a 60% incidence of neurological complications and 40% overall mortality.\(^{[14,17]}\)

**Advantages of covered stents in the extracranial vessels**

Preserving vessel patency is ideal when treating vascular lesions of the extracranial cerebral circulation. Sacrificing extracranial cerebral vessels increases morbidity and mortality, especially in patients with poor collateral circulation.\(^{[23,56]}\) Indeed, iatrogenic vertebrobasilar insufficiency has been reported after deliberate sacrifice of one vertebral artery, even after an antecedent balloon test occlusion suggested its safety.\(^{[5]}\) Additionally, preservation of the complete extracranial cerebral vasculature is desirable in young patients\(^{[49,90]}\) and patients with systemic vasculatides or connective tissue disorders, where future neurovascular lesions must be anticipated.\(^{[62,91,98]}\)

Because of the risk of surgical complications, endovascular approaches are useful for extracranial cerebral vasculature. Balloon occlusion and coil embolization are commonly used endovascular techniques; however, these procedures sacrifice the parent vessel. Another technique is overlapping bare metal stents, which has been used to trigger hemodynamic changes that accelerate the thrombosis of dissecting pseudoaneurysms; however, this technique has limited utility in cases of an expanding pseudoaneurysm or active bleeding, where an immediate, blood-tight seal is required. Covered stents circumvent these limitations by immediately excluding breaches of the vessel wall while maintaining parent vessel patency.

**History of covered stents in the extracranial vessels**

The earliest covered stent used for neurovascular intervention was the Craggstent (Boston Scientific Corp., Natick, MA), later renamed the Passager endograft, which was used in two cases to treat carotid artery pseudoaneurysms.\(^{[71,77]}\) This device consisted of a self-expanding Nitinol stent covered by a polyester fabric designed and marketed for bypass grafting in the iliac and superficial femoral arteries. The primary disadvantage of this device was that the delivery catheter was too short to allow a percutaneous approach from the groin, thus necessitating direct puncture of the CCA. Early neurovascular interventions were also performed with homemade devices made of Gortex,\(^{[97]}\) PTFE\(^{[43,35]}\) or autologous-vein\(^{[69]}\) grafts sutured to balloon-expandable Palmaz stents (Johnson and Johnson, New Brunswick, NJ).

The Wallgraft (Boston Scientific, Natick, MA), which consists of a PET (Dacron; E.I. duPont de Nemours and Co., Wilmington, DE) covered self-expanding cobalt super alloy stent, is more widely used. The longitudinal flexibility of this device allows for better conformability to the tortuous arterial walls than the homemade devices;\(^{[45]}\) however, the Wallgraft has several important disadvantages. First, PET is highly immunogenic,\(^{[26,49,55]}\) which animal studies suggest, increases the rate of vessel thrombosis.\(^{[64]}\) Second, the Wallgraft delivery system requires a 9-French arterial sheath in the carotid and vertebral arteries, which may increase the risk of pseudoaneurysms or groin hematomas at the femoral puncture site. Finally, the PET covering is initially porous until a clot forms to seal the fabric. In acute bleeding situations, such as CBS, the fabric does not seal rapidly enough to prevent exsanguination.\(^{[99]}\)

Newer self-expanding devices include the Fluency and Viabahn, which were FDA approved for the treatment of tracheobronchial strictures in 2003 and 2005, respectively. Both are composed of a Nitinol stent covered with PTFE. These devices are more flexible, conform more easily to the vessel walls, and the PTFE covering is less thrombogenic. In recent times, these devices have become available in long delivery sheaths necessary for placement in the extracranial cerebral circulation; however, large delivery sheaths are still required. Other self-expanding devices have been used including the Symbiot,\(^{[52,62]}\) which is only available in Europe, and the Corvita Endoluminal Stent-Graft,\(^{[109]}\) which did not come into the market. The primary advantage of self-expanding stents is that they re-expand after external compression. Therefore, self-expanding stents are preferred for the carotid artery\(^{[81]}\) and at the carotid bifurcation, to accommodate the difference in diameters between the common and internal carotid arteries.\(^{[11]}\) In all our cases, four Fluency stents were used, which were all self-
expanding and configured appropriately to match the size of the CCA, ICA, and VA, with immediate angiographic reconstruction of the parent vessel and isolation of the pseudoaneurysm / fistula connection.

Commercially available balloon-expandable covered stents are also available [Table 2]. The most common of these devices is the Jostent Coronary Stent Graft (Abbott, Redwood City, CA), which was FDA approved in 2001. This device consists of a PTFE graft sandwiched between two stainless steel stents. Also available is the iCAST (Atrium Medical Corporation, Hudson, NH), a PTFE-covered, single stainless steel stent, which was FDA approved in 2005, for the treatment of tracheobronchial strictures. An advantage of a balloon-expandable deployment system in treating AVFs is the ability to over-dilate the vessel. This firmly fixes the stent, thus avoiding an endoleak between the graft and vessel wall. However, the several drawbacks to these devices are that they are expensive, lack flexibility, are susceptible to mechanical distortion, and require high deployment pressure. The latter is particularly important when treating fragile vessels.

**Technical success**

Table 3 summarizes the outcomes of previously reported cases. In our literature review, three technical failures were reported, resulting in a technical success rate of 98.2%. Kwok et al. reported carotid artery rupture during deployment of a balloon-expandable covered stent for the treatment of CBS. The authors postulated that the cause of the rupture was due to the high pressure required to inflate the stent in an artery already torn by normal blood pressure. In another patient treated for CBS, Lesley et al. reported a vein-covered Palmaz stent that failed to deploy. Finally, surgeons treating a patient with Ehlers-Danlos Syndrome type IV were unable to treat an ICA aneurysm just below the skull base, because the Symbiot covered stent would not negotiate the vessel tortuosity.

**Complications associated with covered stents**

Immediate complications occurred in 15 of 164 procedures (9.1%). Embolic complications during covered stent placement are due to dissection or rupture and embolization of the atheromatous plaque. Two patients described by May et al. and Chang et al. suffered embolic strokes, the former during treatment of a pseudoaneurysm post carotid endarterectomy, and the latter for CBS. Six additional patients experienced post-procedural transient ischemic attacks.

Dissections were encountered in three cases (1.8%). Duane et al. reported an ICA dissection during covered stent placement for the treatment of a traumatic pseudoaneurysm. The patient was maintained on anticoagulation therapy, because endovascular treatment was delayed in order to allow healing of the operative site; however, at follow-up the stent was thrombosed. Priestley et al. reported a VA dissection during treatment for an AVF that resolved spontaneously by six months. Hoppe et al. reported a dissection of the CCA in a patient being treated for CBS. The dissection was treated with two bare self-expanding Nitinol stents and a follow-up angiography demonstrated normal luminal integrity.

Additional immediate complications were reported by Chang et al. who described two cases (1.8%) of acute, asymptomatic thrombosis of the CCA after covered stent deployment for the treatment of CBS. In one case the thrombosis was successfully lysed by intravenous glycoprotein IIb / IIIa inhibitor infusion. Also, Lim et al. reported an ICA dissection during treatment of an AVG that resolved spontaneously by six months. Hoppe et al. reported a dissection of the CCA in a patient being treated for CBS. The dissection was treated with two bare self-expanding Nitinol stents and a follow-up angiography demonstrated normal luminal integrity.

Table 2: Balloon-expandable covered stents used in extracranial neurovasculature

| Device                  | Manufacturer                        | Construction                                           | Comments                                      |
|-------------------------|-------------------------------------|--------------------------------------------------------|-----------------------------------------------|
| Jostent coronary stent  | Abbott (Redwood City, CA)           | PTFE graft sandwiched between two stainless steel stents|                                               |
| iCAST                   | Atrium Medical Corporation (Hudson, NH) | PTFE covered single stainless steel stent             |                                               |
| Symbiot                 | Boston Scientific (Natick, MA)       | Nitinol stent covered with PTFE                        | Only available in Europe                      |
| Corvita endoluminal stent-graft | Corvita corp. (Miami, FL) | Braided, metallic mesh tube covered with layers of polycarbonate urethane fibers | Did not come to market |

Table 3: Self-expanding covered stents used in extracranial neurovasculature

| Device            | Manufacturer                        | Construction                      | Comments                     |
|-------------------|-------------------------------------|----------------------------------|------------------------------|
| Craggstent        | Boston Scientific Corp. (Natick, MA) | Nitinol stent covered with polyester fabric | Also known as Passager endograft |
| Wallgraft          | Boston Scientific Corp. (Natick, MA) | Cobalt super alloy stent covered with PET |                              |
| Fluency           | Bard (Tempe, AZ)                    | Nitinol stent covered with PTFE   |                              |
| Viabahn / Hemobahn | Gore and Associates (Flagstaff, AZ) | Nitinol stent covered with PTFE   |                              |

PTFE = polytetrafluoroethylene
undiagnosed ruptured abdominal aortic aneurysm. Such remote vascular complications have been reported during neurointerventional procedures in these patients,\(^{47,105}\) however, the authors did not encounter any difficulties traversing the abdominal aorta. Finally, Kwok et al.\(^{59}\) reported rupture of the target vessel during covered stent deployment as discussed a little earlier in the text.

Seven of the 25 patients (28\%) treated for CBS suffered re-hemorrhage after initial hemostasis was achieved with covered stent implantation.\(^{15,45\}\) Four patients suffered re-hemorrhage secondary to disease progression,\(^{46,54}\) between 19 days and two months after the initial treatment. One patient suffered a fatal re-bleed two days after treatment, possibly from inadequate covered stent placement due to the patient’s critical clinical status. Another patient suffered a re-bleed nine days after covered stent placement, due to a residual flow around the device. Attempted balloon angioplasty expansion of the stent caused it to rupture, resulting in massive extravasation. The re-bleed in one patient was attributed to disseminated intravascular coagulation, as there were no complications associated with the placement of a covered stent. Other reported delayed complications included one patient who developed multiple brain abscesses secondary to septic thrombosis of the carotid artery,\(^{40}\) and one patient treated with a PTFE covered Palmaz stent, who developed a small type-I endoleak, three days after the procedure.\(^{39}\)

Subacute thrombosis and intimal hyperplasia leading to in-stent stenosis or vessel occlusion are the primary complications associated with covered stents. The graft material may delay endothelialization\(^{25\}\) resulting in thrombotic occlusion of the stented vessel.\(^{45\}\) Additionally, traumatized vessels are hypercoagulable. Placement of a covered stent further retards the flow, which may compound the risk of occlusion.\(^{18\}\) Other factors contributing to stent occlusion include graft material,\(^{26,45,55}\) small vessel size, dissection, and under-dilation of the stent.\(^{34\}\) In contrast, the synthetic layers of the covered stents theoretically act as mechanical barriers that allow only minimal intimal hyperplasia. However, end-stent stenosis is more common with covered stents compared to conventional stents,\(^{16\}\) and it has been suggested that stenosis primarily occurs adjacent to a bend or kink.\(^{111}\) There is no evidence to suggest an appropriate time to stop dual anti-platelet therapy. There is no consensus in the reviewed published literature regarding the type and duration of anti-platelets and / or anti-coagulation therapy. In some of the published data, patients were treated with aspirin alone; other reports indicate treatment with aspirin and plavix, others with aspirin and warfarin. The duration of anti-coagulation and / or anti-platelets vary from one month to lifetime treatment. Keeping in mind the large area of synthetic graft material exposure to the circulation, and based on the best evidence from conventional carotid artery stenting literature for atherosclerotic carotid artery disease, all our patients were maintained on dual anti-platelet therapy for six months, and thereafter continued on aspirin alone.

The long-term patency of covered stents in extracranial cerebral circulation is unknown. Nine of the 109 patients who underwent angiographic follow-up developed total occlusion of the stented vessel,\(^{15,28,45,49,71,72,79}\) which gave an overall occlusion rate of 8.3\%. These cases included four ICA pseudoaneurysms, one VA pseudoaneurysm, and four patients with CBS. Occlusion was asymptomatic in all nine patients. Follow-up in the patients with pseudoaneurysms ranged from two to twenty-three months. Duane et al.,\(^{28\}\) cited persistent narrowing at the end of the stent due to an intimal flap as the possible cause of the occlusion. Huttl et al.,\(^{49\}\) described total occlusion of a Jostent in the VA at two months, which was attributed to mechanical distortion caused by external mechanical compression. Four cases of subacute carotid thrombosis were reported in patients treated for CBS;\(^{15,45\}\) nevertheless, the use of covered stents for immediate hemostatic control in CBS is a reasonable alternative to surgical ligation or permanent balloon occlusion.

In-stent stenosis due to intimal hyperplasia was described in an additional three cases of traumatic ICA pseudoaneurysms,\(^{14,73,79\}\) as also one case of a VA pseudoaneurysm with multiple AVFs.\(^{92\}5\) McNeil et al.,\(^{73\}\) and Flood et al.,\(^{34\}\) each reported 50\% ICA in-stent stenosis following placement of a Wallgraft and Jostent at 10 months and one year, respectively. Parodi et al.,\(^{79\}\) reported 90\% ICA in-stent stenosis following placement of a vein-covered Palmaz stent, which progressed to complete occlusion 39 months after initial covered stent placement. Sancak et al.,\(^{82\}\) reported 50\% VA re-stenosis at 18 months successfully treated by balloon angioplasty.

**Additional neurovascular applications**

With newer generations of covered stents, intracranial applications might be expanded. Wang et al.,\(^{110\}\) recently reported 10 patients with direct carotid cavernous fistulas treated with covered stent implantation. Technical failure occurred in one patient due to the rigidity of the covered stent and tortuosity of the ICA. A second patient had recurrence of symptoms the morning after the procedure necessitating ipsilateral ICA occlusion with detachable coils. Of the remaining eight patients, follow-up angiography ranging from five to forty-eight months showed complete exclusion of all direct carotid cavernous fistulas and stent patency without in-stent stenosis.

**CONCLUSION**

Covered stents are useful for extracranial neuroendovascular interventions in selected patients,
for the treatment of a variety of lesions, especially pseudoaneurysms, AVFs, and CBS. However, larger studies are required to determine the true incidence of periprocedural complications. The three cases described in this article, and a review of the present literature, suggest that embolic events and dissections are the most frequent immediate complications. Studies evaluating the long-term safety, stent patency, and permanency of hemostasis are also needed. The widespread use of covered stents requires the development of more flexible devices with longer delivery systems, specifically designed for neuroendovascular intervention.

REFERENCES

1. Ahn JY, Chung YS, Lee BH, Choi SW, Kim OJ. Stent-graft placement in a traumatic internal carotid-internal jugular vein fistula and pseudoaneurysm. J Clin Neurosci 2004;11:1636-9.
2. Akiyama Y, Nakahara I, Tanaka M, Iwamura Y, Hayashi J, Harada K, et al. Urgent endovascular suture-graft placement for a ruptured traumatic pseudoaneurysm of the extracranial carotid artery. J Trauma 2005;58:624-7.
3. Amar AP, Levy ML, Giannotta SL. Iatrogenic vertebrobasilar insufficiency after surgery of the subclavian or brachial artery: Review of three cases. Neurosurgery 1998;43:1450-7.
4. Amar AP, Teitelbaum GP, Giannotta SL, Larsen DW. Covered suture-graft repair of the brachiocephalic arteries: technical note. Neurosurgery 2002;51:249-52.
5. Assadian A, Senekowitsch C, Rotter R, Zolits C, Strassegger J, Hgmuller GW. Long-term results of covered stent repair of internal carotid artery dissections. J Vasc Surg 2004;40:484-7.
6. Baldus S, Koster R, Reimers J, Hamm CW. Membrane-covered stents for the treatment of aorticoronal vein graft disease. Catheter Cardiovasc Interv 2000;50:83-8.
7. Baril DT, Ellozy SH, Carroccio A, Patel AB, Lookein RA, Marin ML. Endovascular repair of an infected carotid artery pseudoaneurysm. J Vasc Surg 2004;40:1024-7.
8. Barkhordarian S. Stent graft repair of traumatic vertebral pseudoaneurysm with arteriovenous fistula. Vasc Endovascular Surg 2007;19:E254-7.
9. Beale PJ. Late development of a false aneurysm of the common carotid artery. Br J Surg 1971;58:76-8.
10. Beaujeux RL, Reizine DC, Cassasco A, Aymard A, Rufenchat D, Khayata MH, et al. Endovascular treatment of vertebral arteriovenous fistula. Radiology 1992;183:361-7.
11. Bellotta R, Sesana M, Baglioni R, Luzzani L, Talarico M, Sarcina A. Endovascular treatment of a symptomatic carotid artery aneurysm with a stent graft. Vasc Endovascular Surg 2008;42:276-8.
12. Blickenstein KL, Weaver FA, Yellin AE, Stain SC, Finck E. Trends in the management of traumatic vertebral artery injuries. Am J Surg Pathol 1989;13:101-5.
13. Briguori C, Svelvetta L, Baldassarre MP. Endovascular repair of a carotid pseudoaneurysm with Fluency Plus stent graft implantation. J Invasive Cardiol 2007;19:E245-7.
14. Chalopuka JC, Putnam CM, Citardi MJ, Ross DA, Sasaki CT. Endovascular therapy for the carotid blowout syndrome in head and neck surgical patients: Diagnostic and managerial considerations. AJNR Am J Neuroradiol 1996;17:843-52.
15. Chang FC, Linnig JF, Luo CS, Guo WY, Teng MM, Tai SK, et al. Carotid blowout syndrome in patients with head-and-neck cancers: Reconstractive management by self-expandable stent-grafts. AJNR Am J Neuroradiol 2007;28:181-8.
16. Cill BE, Akpinar E, Peyrinicroul B, Celskige S. Utility of covered stents for extracranial internal carotid artery stenosis. AJNR Am J Neuroradiol 2004;25:1168-71.
17. Citardi MJ, Chalopuka JC, Son YH, Arian S, Sasaki CT. Management of carotid artery rupture by monitored endovascular therapeutic occlusion (1988-1994). Laryngoscope 1995;105:1086-92.
18. Cottoiren CC, Moore EE, Ray CE Jr, Ciesla DJ, Johnson JL, Moore JB, et al. Carotid artery stents for blunt cerebrovascular injury: risks exceed benefits.
19. Cox MW, Wittkaker DR, Martinez C, Fox CJ, Feuerstein IM, Gillespie DL. Traumatic pseudoaneurysms of the head and neck: Early endovascular intervention. J Vasc Surg 2007;46:1227-33.
20. De Filippo CM, Modugno P, Nasso G, Canosa C, Spatuzza P, Testa N, et al. Pseudoaneurysm after patch-free carotid bifurcation endarterectomy: A case report. Vasc Endovascular Surg 2007;41:448-51.
21. de los Reyes RA, Moser FG, Sachs DP, Boehm FH. Direct repair of an extracranial vertebral artery pseudoaneurysm: Case report and review of the literature. Neurosurgery 1990;26:328-33.
22. DeFatta RJ, Verret DJ, Bauer P. Extracranial internal carotid artery pseudoaneurysm. Int J Pediatr Otorhinolaryngol 2005;69:1135-9.
23. Demetrias D, Theodorou D, Asensio J, Golshani S, Belberg H, Yellin A, et al. Management options in vertebral artery injuries. Br J Surg 1996;83:836-40.
24. Detwiler K, Godersky J, Gentry L. Pseudoaneurysm of the extracranial vertebral artery. Case report. J Neurosurg 1987;67:935-9.
25. Dieter RS, Ikram S, Satler LF, Babrowicz JC, Reddy B, Laird JR. Perforation complicating carotid artery stenting: the use of a covered stent. Catheter Cardiovasc Interv 2006;67:972-5.
26. Dolmatch BL, Tio FO, Li XD, Dong YH. Patency and tissue response related to two types of polytetrafluoroethylene-covered stents in the dog. J Vasc Interv Radiol 1996;7:641-9.
27. du Toit DF, Leith JG, Strauss DC, Blaszczak M, Odendaal Jde V, Warren BL. Endovascular management of traumatic cervicocephalic arteriovenous fistula. Br J Surg 2003;90:1516-21.
28. Duane TM, Parker F, Stokes GK, Parent FN, Britt LD. Endovascular carotid stent placement after trauma. J Trauma 2002;52:149-53.
29. Duncan IC, Fourie PA. Percutaneous management of concomitant post-traumatic high vertebrovertebral and caroticojugular fistulas with balloons, coils, and a covered stent. J Endovasc Ther 2003;10:882-6.
30. Ellis PK, Kennedy PT, Barros D’sa AA. Successful exclusion of a high internal carotid pseudoaneurysm using the Wallgraft endoprosthesis. Cardiovasc Intervent Radiol 2002;25:68-9.
31. Felber S, Henkes H, Weber W, Miloslawski E, Brew S, Kuhne D. Treatment of extracranial and intracranial aneurysms and arteriovenous fistulae using stent grafts. Neurosurgery 2004;55:631-8.
32. Feugier PV, Vulliez A, Bina N, Foccard B, Alauochiche B. Urgent endovascular covered-stent treatment of internal carotid artery injury caused by a gunshot. Eur J Vasc Endovasc Surg 2007;34:663-5.
33. Fleischer AS, Guthkelch AN. Management of high-cervical-intracranial internal carotid artery traumatic aneurysms. J Trauma 1987;27:330-2.
34. Flood J, Bussiere M, Teepf P, Gulka IL, Loewine S, Pelz D. In-stent stenosis following covered-stent placement. Can J Neurol Sci 2009;36:248-51.
35. Fusonie GE, Edwards JD, Redd AB. Covered stent exclusion of blunt traumatic carotid artery pseudoaneurysm: Case report and review of the literature. Ann Vasc Surg 2004;18:376-9.
36. Gerken U, Larnsky AJ, Burekoidi L, Desai K, Baderledin M, Mueller R, et al. Results of the Jostent coronary stent graft implantation in various clinical settings: Procedural and follow-up results. Catheter Cardiovasc Interv 2002;56:353-60.
37. Gonzalez A, Mayol A, Gil-Peralta A, Gonzalez-Marcos JF. Endovascular stent-graft treatment of an intracranial vertebral arteriovenous fistula. Neuroradiology 2001;43:782-4.
38. Hagspiel KD, Komorowski DJ, Shih MC, Peeler BB, Jensen ME. Treatment of carotid arteriovenous fistula with balloon-expandable tracheobronchial covered stent. J Vasc Interv Radiol 2006;17:585-6.
39. Halbach VV, Higshidt RT, Heshima GB. Treatment of vertebral arteriovenous fistulae. AJR Am J Roentgenol 1988;150:405-12.
40. Hanakita J, Suwa H, Nishihara K, Ishara K, Sakaida H. Giant pseudoaneurysm of the extracranial vertebral artery successfully treated using intraoperative balloon catheters. Neurosurgery 1991;28:738-41.
41. Hertz JA, Minion DJ, Quick RC, Moore EM, Schwartz TH, Endean ED. Endovascular exclusion of a postendarterectomy carotid pseudoaneurysm. Ann Vasc Surg 2003;17:558-61.
42. Heye S, Maleux G, Vandenberge R, Wilms G. Symptomatic internal carotid artery dissection: Endovascular treatment by stent-graft. Cardiovasc Intervent Radiol 2005;28:499-501.
43. Hilfiker PR, Razavi MK, Kee ST, Sze DY, Semba CP, Dake MD. Stent-graft therapy for subclavian artery aneurysms and fistulas: Single-center mid-term results.

http://www.surgicalneurologyint.com/content/2/1/67
Maran AG, Amin M, Wilson JA. Radical neck dissection: A 19-year experience.

Hussain FM, Kopchok G, Heilbron M, Daskalakis T, Donayre C, White RA. Wallgraft endoprosthesis: Initial canine evaluation. Am J Surg 1998;64:1002-6.

Hult K, Sebestyen M, Entz L, Molnar AA, Nemes B, Berzsi V. Covered stent placement in a traumatic intracranially ventralized artery. J Vasc Interv Radiol 2004;15:201-2.

Jayaraman MV, Do HM, Marks MP. Treatment of traumatic cervical arteriovenous fistulas with N-butyl-2-cyanoacrylate. AJNR Am J Neuroradiol 2007;28:352-4.

Joo JT, Ahn JF, Chung YS, Chung SS, Kim SH, Yoon PH, et al. Therapeutic endovascular treatments for traumatic carotid injuries. J Trauma 2005;58:1599-66.

Katsaridis V, Papagiannaki C, Violias C. Treatment of an iatrogenic vertebral artery laceration with the Symbiot self expandable covered stent. Clin Neurol Neurosurg 2007;109:152-5.

Kessel D, Robertson I, Scott J, Phipp L. Surgical repair of a gunshot injury to the left carotid artery: Case report and review of literature. Vasc Endovascular Surg 2008;42:180-3.

Kubaska SM 3rd, Greenberg RK, Clair D, Barber G, Srivastava SD, Green RM, et al. Internal carotid artery pseudoaneurysms: treatment with the Wallgraft endoprosthesis. J Endovasc Ther 2003;10:182-9.

Kudelko PE 2nd, Alfaro-Franco C, Dietrich EB, Krajcer Z, Successful endoluminal repair of a popliteal artery aneurysm using the Wallgraft endoprosthesis. J Endovasc Surg 1998;5:373-7.

Kwok PC, Cheung YJ, Tang KW, Wong WK. Re: Endovascular treatment of acute carotid blow-out syndrome. J Vasc Interv Radiol 2001;12:195-6.

Layton KA, Kim YW, Hsie JH. Use of covered stent grafts in the extracranial carotid artery: Report of three patients with follow-up between 8 and 42 months. AJNR Am J Neuroradiol 2004;25:1760-3.

Lesley WS, Chaloupka JC, Weigle JB, Mangla S, Dogar MA. Preliminary experience with endovascular reconstruction for the management of carotid blowout syndrome. AJNR Am J Neuroradiol 2003;24:975-81.

Lim SP, Duddy MJ. Endovascular treatment of a carotid dissecting pseudoaneurysm in a patient with Ehlers-Danlos syndrome type IV with fatal outcome. Cardiovasc Interv Radiol 2008;31:201-4.

Lin PH, Bush RL, Lumsden AB. Successful stent-graft exclusion of a bovine patch-related carotid artery pseudoaneurysm. J Vasc Surg 2003;38:396.

Link J, Feyerabend B, Grabner M, Linstedt U, Brossmann J, Thomsen H, et al. Dacron-covered stent-grafts for the percutaneous treatment of carotid aneurysms: Effectiveness and biocompatibility--experimental study in swine. Radiology 1996;200:397-401

Lupattelli T, Garaci FG, Hopkins CE, Simonetti G. Covered stent deployment and follow-up of a case of internal carotid artery pseudoaneurysm. Cerebrovasc Dis 2003;16:98-101.

Macdonald S, Gnan J, McKay AJ, Edwards RD. Endovascular treatment of acute carotid blow-out syndrome. J Vasc Interv Radiol 2000;11:184-8.

Maran AG, Amin M, Wilson JA. Radical neck dissection: A 19-year experience. J Laryngol Otol 1989;103:760-4.

Marotta TR, Buller C, Taylor D, Morris C, Zwimpfer T. Autologous vein-covered stent repair of a cervical internal carotid artery pseudoaneurysm: Technical case report. Neurosurgery 1999;42:408-12.

Martin JB, Bednarikiewicz M, Christenson JT, Rufenacht DA. Endovascular repair using vein-covered stents in the carotid artery bifurcation. Cardiovasc Surg 2002;8:499-502.

May J, White GH, Waugh R, Brennan J. Endoluminal repair of internal carotid artery aneurysms: A feasible but hazardous procedure. J Vasc Surg 1997;26:1053-60.

Mccusky RA, Divellis JL, Bryant MA, Denardo AJ, Scott JA. Endoluminal repair of carotid artery pseudoaneurysms: A word of caution. J Vasc Surg 2004;40:1020-3.

McNeil JD, Chiou AC, Gunlock MG, Grayson DE, Soares G, Hagan RT. Successful endovascular therapy of a penetrating zone III internal carotid artery injury. J Vasc Surg 2002;36:187-90.

Mokri B, Piepras DG, Sundt TM Jr, Pearson BW. Extracranial internal carotid artery aneurysms. Mayo Clin Proc 1982;57:310-21.

Moussa A, Bernheim J, Lyon R, Dayal R, Hollenbeck S, Henderson P, et al. Postcarotid endarterectomy carotid pseudoaneurysm treated with combined stent graft and coil embolization--a case report. Vasc Endovascular Surg 2005;39:191-4.

Mukherjee D, Rolfi M, Yadav JS. Endovascular treatment of carotid artery aneurysms with stent grafts. J Invasive Cardiol 2002;14:269-72.

Nicholson A, Cook AM, Dyet JF, Galloway JM. Case report: Treatment of a carotid artery pseudoaneurysm with a polyester covered nitinol stent. Clin Radiol 1995;50:872-3.

Oruckaptan HH, Ozcan OE. Giant extracranial internal carotid artery aneurysm: A rare presentation with an oropharyngeal mass. Otolarngol Head Neck Surg 2001;125:571-3.

Parodi JC, Schoinholz C, Ferreira LM, Bergan J. Endovascular stent-graft treatment of traumatic arterial lesions. Ann Vasc Surg 1999;13:121-9.

Patel JV, Rossbach MM, Cleveland Tj, Gaines PA, Beard JD. Endovascular stent-graft repair of traumatic carotid artery pseudoaneurysm. Clin Radiol 2002;57:308-11.

Phatoouros CC, Higashida RT, Malek AM, Meyers PM, Lempert TE, Dowd CF, et al. Carotid artery stent placement for atherosclerotic disease: Rationale, technique, and current status. Radiology 2002;217:26-41.

Powell RJ, Ruzuildo EM, Schermerhorn ML. Stent-graft treatment of a large internal carotid artery vein graft aneurysm. J Vasc Surg 37:1310-3.

Priestley R, Bray P, Bray A, Hunter J. Iatrogenic vertebral arteriovenous fistula treated with a hemobahn stent graft. J Endovasc Ther 2003;10:657-63.

Redekop G, Marotta T, Weill A. Treatment of traumatic aneurysms and arteriovenous fistulas of the skull base by using endovascular stents. J Neurosurg 2001;94:412-9.

Reiter BR, Marin ML, Teodorescu V, Mitty HA. Endoluminal repair of an internal carotid artery pseudoaneurysm by using endovascular stents. J Vasc Interv Radiol 1998;9:245-8.

Rich NM, Baugh JH, Hughes CW. Popliteal artery injuries in Vietnam. Am J Surg 1969;118:531-4.

Riesenman PJ, Mendes RR, Mauro MA, Farber MA. Endovascular exclusion of an external carotid artery pseudoaneurysm using a covered stent. Cardiovasc Intervent Radiol 2007;30:1025-8.

Robbs JV, Carrim AA, Kadwa AM, Mars M. Traumatic arteriovenous fistula: experience with 202 patients. Br J Surg 1994;81:1296-9.

Ruckert RI, Rutsch W, Filimonow S, Lehmann R. Successful stent-graft repair of a penetrating zone III internal carotid artery aneurysm: A rare presentation with an oropharyngeal mass. Otolaryngol Head Neck Surg 2001;125:571-3.

Sanders EM, Davis KR, Whelan CS, Deckers PJ. Threatened carotid artery rupture: A complication of radical neck surgery. J Surg Oncol 1986;33:190-3.
94. Scavee V, De Wispelaere JF, Mormont E, Coulier B, Trigaux JP, Schoevaerds JC. Pseudoaneurysm of the internal carotid artery: Treatment with a covered stent. Cardiovasc Intervent Radiol 2001;24:283-5.

95. Self ML, Mangram A, Jefferson H, Slonim S, Dunn E, Kollmeyer K. Percutaneous stent-graft repair of a traumatic common carotid-internal jugular fistula and pseudoaneurysm in a patient with cervical spine fractures. J Trauma 2004;57:1331-4.

96. Simionato F, Righi C, Scotti G. Post-traumatic dissecting aneurysm of extracranial internal carotid artery: Endovascular treatment with stenting. Neuroradiology 1999;41:543-7.

97. Singer RJ, Dake MD, Norbash A, Abe T, Marcellus ML, Marks MP. Covered stent placement for neurovascular disease. AJNR Am J Neuroradiol 1997;18:507-9.

98. Smith BL, Munschauer CE, Diamond N, Rivera F. Ruptured internal carotid aneurysm resulting from neurofibromatosis: Treatment with intraluminal stent graft. J Vasc Surg 2000;32:824-8.

99. Smith TP, Alexander MJ, Enterline DS. Delayed stenosis following placement of a polyethylene terephthalate endograft in the cervical carotid artery. Report of three cases. J Neurosurg 2003;98:421-5.

100. Surber R, Werner GS, Cohnert TU, Wahlers T, Figulla HR. Recurrent vertebral arteriovenous fistula after surgical repair: Treatment with a self-expanding stent-graft. J Endovasc Ther 2003;10:49-53.

101. Szopinski P, Ciosek P, Kielar M, Myrcha P, Pleban E, Noszczyk W. A series of 15 patients with extracranial carotid artery aneurysms: Surgical and endovascular treatment. Eur J Vasc Endovasc Surg 2005;29:256-61.

102. Thalhammer C, Kirchherr AS, Ullich F, Waigand J, Gross CM. Postcatheterization pseudoaneurysms and arteriovenous fistulas: Repair with percutaneous implantation of endovascular covered stents. Radiology 2000;214:127-31.

103. Tseng A, Ramaiah V, Rodriguez-J Lopez JA, Perkowshi PE, Del Santo PB, Gowda RG, et al. Emergent endovascular treatment of a spontaneous internal carotid artery dissection with pseudoaneurysm. J Endovasc Ther 2003;10:643-6.

104. ul Haq T, Taqoob J, Munir K, Usman MU. Endovascular-covered stent treatment of posttraumatic cervical carotid artery pseudoaneurysms. Australas Radiol 2004;48:220-3.

105. Usinskie I, Mazighi M, Bisdorff A, Houdart E. Fatal peritoneal bleeding following embolization of a carotid-cavernous fistula in Ehlers-Danlos syndrome type IV. Cardiovasc Intervent Radiol 2006;29:1104-6.

106. Van Nieuwenhove Y, Van den Brande P, Van Tussenbroek F, Debing E, Von Kemp K. Iatrogenic carotid artery pseudoaneurysm treated by an autologous vein-covered stent. Eur J Vasc Endovasc Surg 1998;16:262-5.

107. Vachon M, Laurian C, George B, D’Arrigo G, Rezine D, Aymard A, et al. Vertebral arteriovenous fistulas: A study of 49 cases and review of the literature. Cardiovasc Surg 1994;2:359-69.

108. Waigand J, Ullich F, Gross CM, Thalhammer C, Dietz R. Percutaneous treatment of pseudoaneurysms and arteriovenous fistulas after invasive vascular procedures. Catheter Cardiovasc Interv 1999;47:157-64.

109. Waldman DL, Barquist E, Poynton FG, Numaguchi Y. Stent graft of a traumatic vertebral artery injury: Case report. J Trauma 1998;44:1094-7.

110. Wang C, Xie Y, You C, Zhang C, Cheng M, He M, Sun H, Mao B. Placement of covered stents for the treatment of direct carotid cavernous fistulas. AJNR Am J Neuroradiol 2009;30:1342-6.

111. Willfort-Ehringer A, Ahmadi R, Gschwandtner ME, Haumer M, Lang W, Minar E. Single-center experience with carotid stent restenosis. J Endovasc Ther 2002;9:299-307.

112. Witz M, Gepstein R, Paran H, Shnaker A, Lehmann J, Gryton I, et al. Endovascular treatment of an open cervical fracture with carotid artery tear. Eur Spine J 2006;15 Suppl 5:650-2.

113. Yi AC, Palmer E, Luh GY, Jacobson JP, Smith DC. Endovascular treatment of carotid and vertebral pseudoaneurysms with covered stents. AJNR Am J Neuroradiol 2008;29:983-7.

114. Zingler VC, Scrupp M, Brandt T, Herrmann K, Mayer TE. Stent grafting resolved brachial plexus neuropathy due to cervical arteriovenous fistula. Eur Neurol 2004;52:250-1.