Use of fenestrated-branched endovascular aneurysm repair to treat Carrel patch aneurysmal degeneration after open thoracoabdominal aortic aneurysm repair

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ABSTRACT

Two patients with a history of open type II thoracoabdominal aortic aneurysm repair presented with saccular aneurysmal degeneration of the Carrel patch. The degenerated segments measured 6.2 cm and 7.4 cm, respectively, and involved the celiac artery, superior mesenteric artery, and right renal artery. Both patients successfully underwent a custom fenestrated-branched endovascular aneurysm repair with downgoing branches to the celiac artery, superior mesenteric artery, and right renal artery and a stented fenestration to the left renal artery. Completion angiography demonstrated no endoleak and patent visceral-renal segments. Both patients were discharged home on postoperative day 2. (J Vasc Surg Cases and Innovative Techniques 2019;5:117-21.)

Keywords: Carrel patch; Fenestrated; Aneurysm

Open surgical repair of type II thoracoabdominal aortic aneurysm (TAAA) requires visceral-renal vessel revascularization.[1-6] The Carrel patch technique accomplishes this by using a full-thickness patch of aortic tissue containing several orifices of the visceral arteries. This Carrel patch most commonly includes the origins of the celiac artery (CA), superior mesenteric artery (SMA), and right renal artery (RRA) and is sutured to the aortic graft in an end-to-side fashion. Whereas this strategy is highly efficient, minimizing ischemia time and technical complexity, the segment of retained native aorta is prone to recurrent aneurysmal disease in approximately 4% to 7.5% of patients.[2,3,7-9] In fact, Carrel patch aneurysmal degeneration is one of the most common indications for reintervention after open TAAA repair.[1,7,8,10] Given that open repair for Carrel patch aneurysm is associated with a 40% mortality, alternative repair strategies with decreased morbidity and mortality represent a significant unmet need.[1,7,8]

Currently, fenestrated-branched endovascular aneurysm repair (F/B-EVAR) is used in the United States, in the context of Food and Drug Administration (FDA)-sponsored investigational device exemption (IDE) trials, to treat TAAA in patients who are at high risk for open repair.[11-15]

Whereas off-the-shelf and physician-modified designs confer certain advantages, company-manufactured, custom-made devices are well suited to endovascular repair of Carrel patch aneurysms.[11-13,16] In cases of prior open repair, in which reimplantation and patch degeneration often lead to significant distortions of the normal anatomic configuration, custom-made F/B-EVAR can be designed to be patient specific and to accommodate a variety of branch vessel anatomy. We report two cases using company-manufactured, custom-made F/B-EVAR to treat aneurysmal degeneration of Carrel patches after open TAAA repair. The patients described have consented to participation in our FDA-approved IDE clinical trial (IDE #G130210) and to the publication of this article.

CASE REPORT

Patient A is an 87-year-old woman with a history of open type II TAAA repair in 2009, with a Carrel patch involving the CA, SMA, and RRA and a separate bypass to the left renal artery (LRA). During routine computed tomography angiography (CTA) surveillance, the patient was found to have degeneration of the Carrel patch, resulting in a saccular aneurysm measuring 7.4 cm in maximum diameter (Fig 1, *A*).

Patient B is a 35-year-old man with a history of open type II TAAA repair in 2010, with a Carrel patch for the CA, SMA, and RRA and reimplantation of the LRA. His aneurysm was associated with a history of *ACTA2* autosomal dominant genetic mutation and a chronic type B aortic dissection. During routine CTA surveillance, the patient was found to have degeneration of the Carrel patch, resulting in a saccular aneurysm measuring 6.2 cm in maximum diameter (Fig 1, *B*).

Patients A and B were referred to the UMass Memorial Center for Complex Aortic Disease for evaluation for minimally invasive repair. Both patients successfully underwent F/B-EVAR with a custom-made, company-manufactured device with downgoing branches to the CA, SMA, and RRA and a stented small fenestration to the LRA. All repairs were planned on the basis of measurements obtained from high-resolution CTA images on a three-dimensional
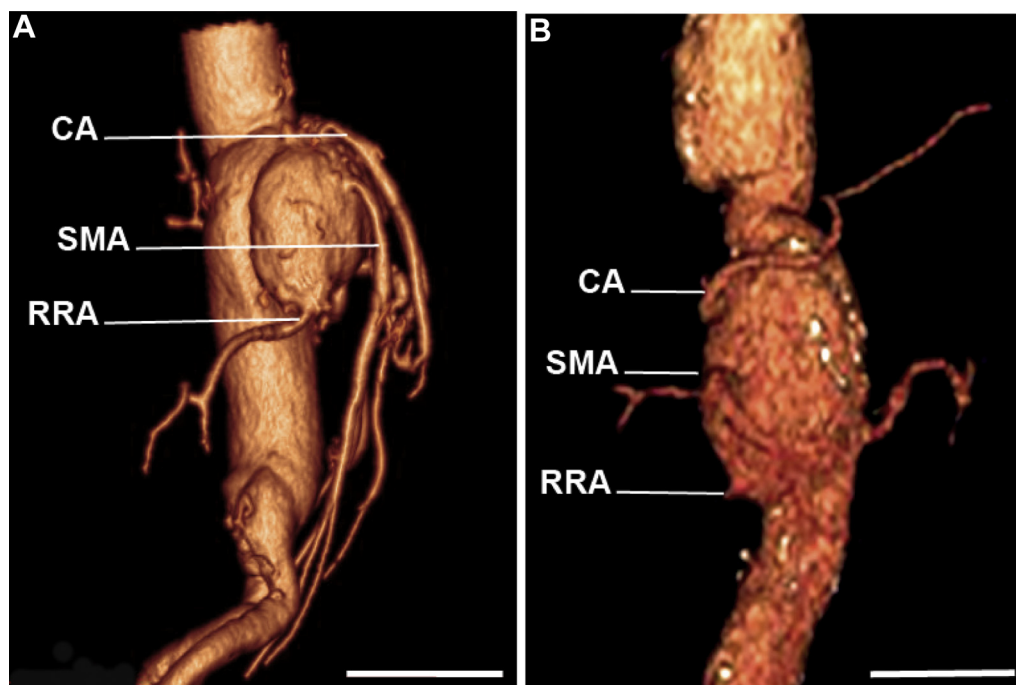
Fig 1. Preoperative three-dimensional model of aneurysmal degeneration of the Carrel patch in patient A **(A)**, resulting in a saccular aneurysm measuring 7.4 cm in maximum diameter, and patient B **(B)**, resulting in a saccular aneurysm measuring 6.2 cm in maximum diameter. The *scale bar* is 50 mm. *CA,* Celiac artery; *RRA,* right renal artery; *SMA,* superior mesenteric artery.

workstation using standard centerline flow orthogonal techniques (TeraRecon, Foster City, Calif). Custom-made F/B-EVAR grafts were manufactured using the Cook endograft platform (Cook Medical, Bloomington, Ind). Both repairs were performed using a single surgically exposed femoral artery access site and a single surgically exposed axillary artery access site (through an infraclavicular incision). The main body F/B-EVAR graft was designed with a modified preloaded delivery system using a preloaded cannulation catheter for the left renal fenestration. This preloading design enabled cannulation and bridging stent graft placement through the delivery system from the ipsilateral groin access site (Fig 2). The CA, SMA, and RRA were cannulated from the open right axillary artery exposure. The advantage of accessing the right axillary artery is an ergonomic one because the C-arm is positioned to the left of the patient, and all other aspects of the operation are performed with the surgeon at the patient's right side. Because no clinical consequences of this approach have been identified, these advantages justify its use. No strokes occurred during the 30-day follow-up period. Balloon-expandable stent grafts (iCast; Atrium, Hudson, NH) were used as bridging stents for all target arteries. It is our practice not to reline iCast balloon-expandable stent grafts with self-expanding stents, given the relative baseline stiffness and radial force of an iCast stent graft. Conversely, Viabahn stent grafts (W. L. Gore & Associates, Flagstaff, Ariz) are highly flexible with less radial force. As a result, most centers that use Viabahn stent grafts choose to reline Viabahn branches. In our opinion, this is perfectly reasonable, but it does increase cost, number of components used, and technical complexity. The literature

supports the use of either strategy for branches, with neither being established as superior to the other.

Completion angiography showed excellent stent graft architecture with no kinks or component separations, no evidence of endoleak, and patent visceral branches (Fig 3). Total operative time was 4 hours and 6 minutes for patient A and 4 hours and 19 minutes for patient B. Postoperative courses were uneventful for both patients, with discharge to home on postoperative day 2. On 1-month surveillance imaging, both repairs were found to be intact with complete aneurysm exclusion and all target arteries patent (Fig 4). Patient B's 1-month CTA surveillance demonstrated a type II endoleak that is likely to be due to reimplanted intercostal arteries during the initial open repair and two lumbar branches that are distal to the original open surgical repair. We plan to observe and to monitor the type II endoleak with serial CTA imaging. If the endoleak persists and the aneurysm sac expands over time, we will then treat the endoleak with translumbar coil embolization.

DISCUSSION

Open TAAA repair requires revascularization of visceral and renal vessels, which is commonly accomplished using the Carrel patch technique.[17] This surgical technique reduces the number of anastomoses and allows expeditious repair.[1-6,18] However, the retained native aortic tissue may continue to degenerate over time, resulting in a Carrel patch aneurysm. In one report, the mean time from TAAA repair to visceral patch aneurysm
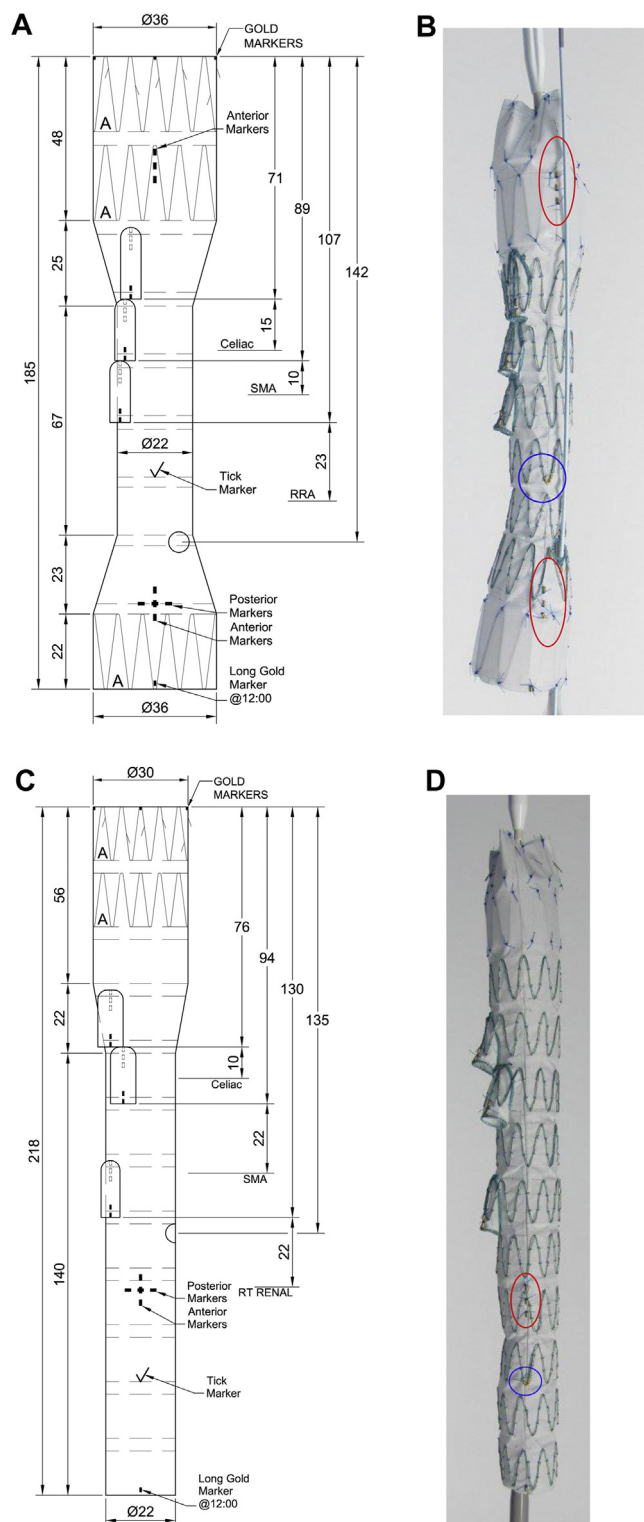
Fig 2. Custom-made fenestrated-branched endovascular aneurysm repair (F/B-EVAR) design and corresponding graft. **A,** Patient A custom-made F/B-EVAR design. **B,** Patient A F/B-EVAR graft. **C,** Patient B preoperative custom-made F/B-EVAR design. **D,** Patient B F/B-EVAR graft. *RRA,* Right renal artery; *RT,* right; *SMA,* superior mesenteric artery. The *red ellipse* indicates anterior marker, and the *blue ellipse* indicates tick marker; *Ø* is diameter in millimeters. All numbers are in millimeters.

detection was 6.5 years.[7-9] Patients with known connective tissue disorders have an 18% incidence of Carrel patch aneurysm, whereas a 5.6% incidence of Carrel patch aneurysm is reported in patients with degenerative aneurysms without connective tissue disorder.[6-8,10] The natural history of Carrel patch aneurysms, including growth rate and risk of rupture, is unknown. However, because of the saccular morphology of Carrel patch aneurysms, they are considered to have a higher risk of rupture than fusiform aneurysms, and ruptures have been reported to occur at a diameter >6 cm.[4,5,7-9,19]

Open repair of Carrel patch aneurysm is associated with a 40% mortality rate due to factors including the technical difficulty of redo surgical dissection and inflammation around the previous repair.[1,7,8] These repairs often require cardiopulmonary bypass and are associated with long operative times, significant blood loss, and prolonged lengths of stay in the intensive care unit.[7-9]

Endovascular exclusion techniques have been described as a successful treatment option for recurrent aneurysmal degeneration after open TAAA repair. Intercostal patch and thoracic aorta graft anastomosis aneurysmal degeneration after open TAAA repair have been excluded by using aortic endografts.[10,20] Although minimally invasive, this approach resulted in the sacrifice of all patent intercostals in that segment; however, no spinal cord ischemia complications occurred. Unlike intercostal patch aneurysms, Carrel patch aneurysms cannot be treated with standard endografts that exclude the visceral and renal aorta because this will result in end-organ ischemia. Two previous case reports from other countries have described the use of F/B-EVAR for pseudoaneurysms in the visceral segment after TAAA repair.[21,22] One report described a four-fenestration design, employed to treat pseudoaneurysm at the CA origin.[21] Performed in 2012, the procedure time was 5 hours, and the hospital stay was 8 days; 18-month imaging revealed an intact repair with regression of the aneurysm sac. The other report described a three-branch design (the LRA was chronically occluded) to treat a recurrent Carrel patch aneurysmal degeneration after a redo open TAAA repair done previously for initial patch aneurysmal degeneration.[22] Performed in 2006, the procedure time was 12 hours, and the hospital stay was 13 days; 12-month imaging revealed an intact repair. These reports, along with ours, demonstrate that custom-made company-manufactured F/B-EVAR is a safe and effective minimally invasive treatment option for Carrel patch aneurysmal degeneration.

As experience with complex endovascular aneurysm repair has grown, its application to Carrel patch aneurysm has been proposed to mitigate some of the morbidity and mortality of open repair and the limitations of conventional endovascular repair. Our approach, using custom-made, company-manufactured F/B-EVAR,
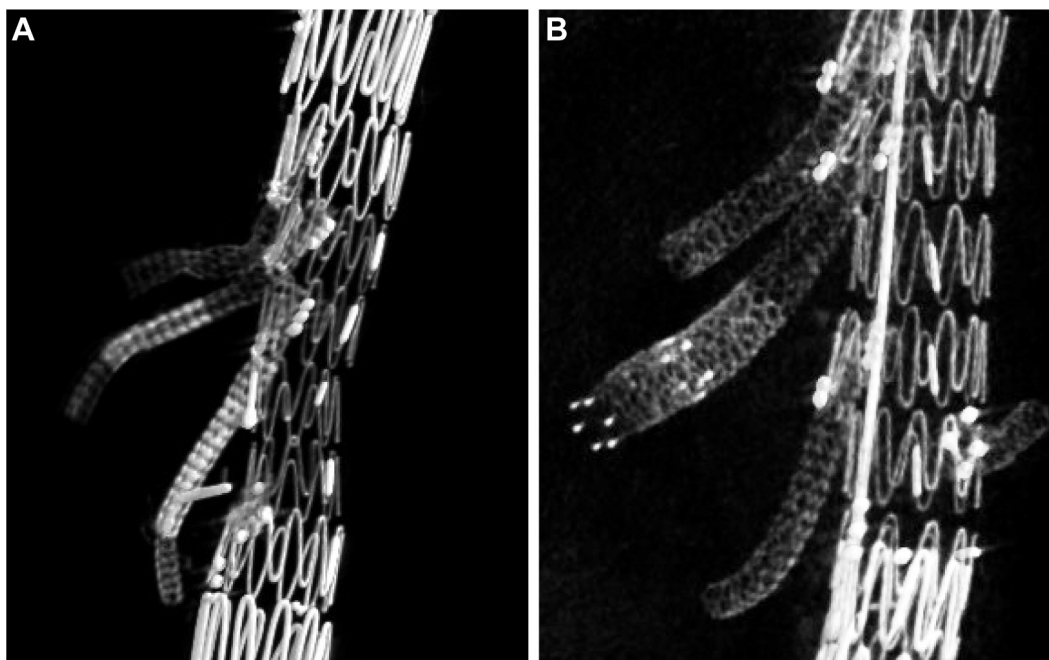
Fig 3. Intraoperative three-dimensional reconstruction of fenestrated-branched endovascular aneurysm repair (F/B-EVAR) after stent graft deployment in patient A **(A)** and patient B **(B)**.
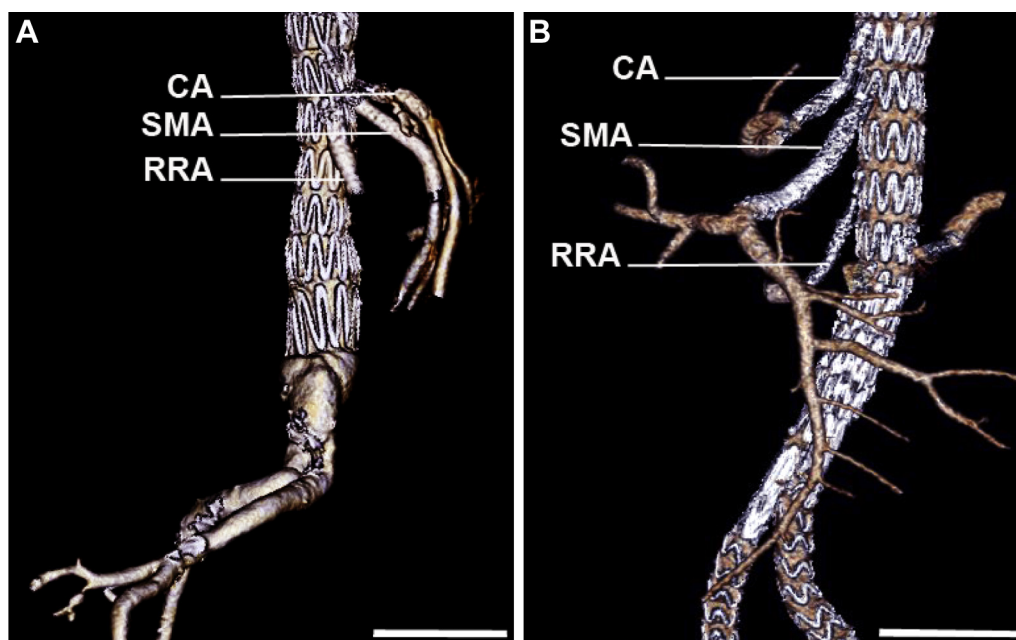

Fig 4. The 1-month three-dimensional reconstruction of fenestrated-branched endovascular aneurysm repair (F/B-EVAR) graft in patient A **(A)** and patient B **(B)**. The *scale bar* is 50 mm. *CA*, Celiac artery; *RRA*, right renal artery; *SMA*, superior mesenteric artery.

addressed these challenges, with good technical success and short-term outcomes. However, the midterm and long-term durability of this treatment strategy must be evaluated; per our protocol, these patients are evaluated at 6 and 12 months postoperatively and annually thereafter with CTA. This is especially true for young patients with connective tissue disorders, such as patient B, who have many years of life ahead of them in which long-term durability is critical if we are to deem this strategy successful. Based on our experience, within the context of an FDA-approved IDE clinical trial at a high-volume center with rigorous follow-up, the role of F/B-EVAR can safely be extended to include patients with Carrel patch aneurysm.

CONCLUSIONS

Aneurysmal degeneration of Carrel patches in patients with previous open TAAA repair can be successfully treated with F/B-EVAR. Custom-made, company-manufactured endografts offer the widest diversity of device configurations to address anatomy that can be extremely variable in patients with Carrel patch aneurysms.

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