Use of Fenestrated Stent-Grafts for Preservation of Spinal Artery Flow During Endovascular Repair of Thoracoabdominal Aortic Disease

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We illustrate the safety and feasibility of the application of fenestrated stent-grafts for the preservation of spinal artery flow during endovascular repair of thoracoabdominal aortic aneurysms (TAAA) in 2 patients deemed high-risk for spinal cord ischemia (SCI). In one case, an unstented fenestration was used in a 78-year-old male treated for distal stent-graft induced new entry tear. In the other case, a fenestration with a bridging stent-graft was used to revascularize a spinal artery in a 66-year-old female with Marfan disease and island patch aneurysm following open TAAA reconstruction. Both procedures were successful without any postoperative neurologic complication. The unstented fenestration led to a type III endoleak that required the relining of the aortic stent-graft 2 years later. The stented spinal fenestration was patent at a 5-year imaging follow-up.

INTRODUCTION

Although fenestrated-branched endovascular repair (F-BEVAR) has revolutionized the treatment of thoracoabdominal aortic aneurysms (TAAA),[1,2] occurrence of spinal cord ischemia (SCI) remains a devastating event.[3,4] The peril of SCI exists on a continuum, increasing as aortic coverage increases, but given the presence of an extensive collateral spinal network the number/percentage of segmental arteries covered, rather than the loss of any specific one, might be a more useful indicator of the risk for post-operative paraplegia.[5,6] We illustrate the application of F-BEVAR technology for the preservation of spinal artery flow during the endovascular repair of TAAA.

CASE REPORT(S)

Patient A was a 78-year-old man without a diagnosis of connective tissue disorders, hypertension, and hyperlipidemia. He was a previous smoker without chronic obstructive pulmonary disease or asthma and had a left atrophic kidney with stage III chronic kidney disease. At age 60, he underwent open surgical repair of postdissection Crawford type I TAAA. At age 70, he was found to have a 65-mm aneurysm of the para-visceral aorta associated with the presence of a residual entry tear a few centimeters above the diaphragm; all renal-mesenteric vessels (but the left renal artery) were patent and perfused from the true lumen. Therefore, TEVAR was performed to cover the residual entry tear. After the procedure, the patient developed transient paraparesis, and further aortic coverage was deferred. Imaging follow-up at 3 and 5 years showed a stable size of the abdominal aneurysm with complete false lumen thrombosis (Fig. 1). However, 6 years post-TEVAR, the patient was admitted to the emergency department with acute abdominal pain, and CTA showed a new entry tear in the distal infrarenal aorta

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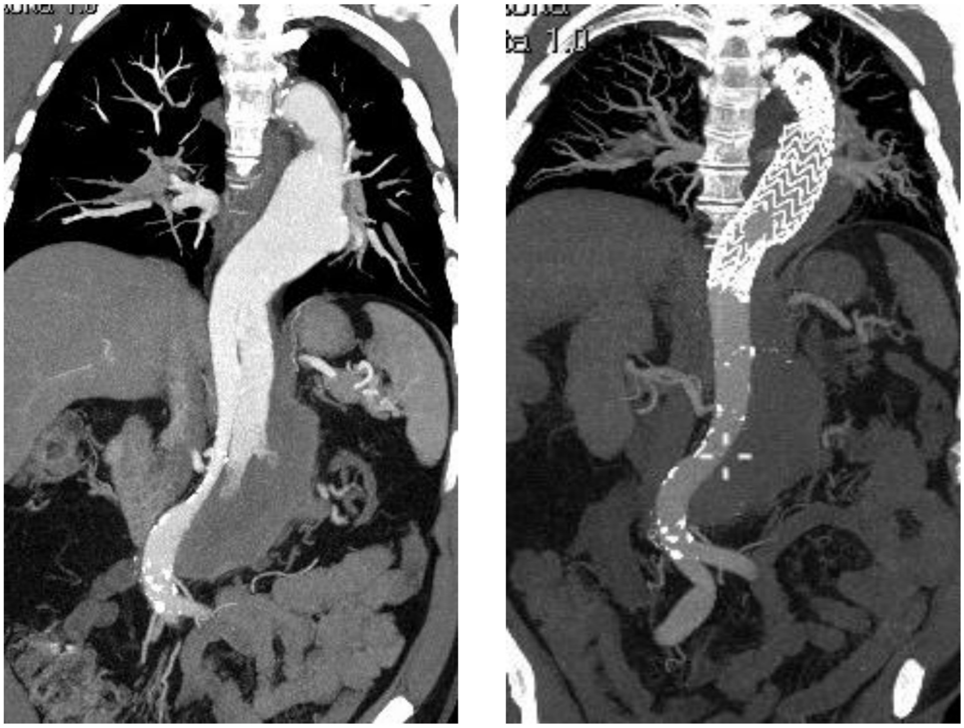

Fig. 1. Patient A. Left box: computed tomography angiography (CTA) before thoracic endovascular aortic repair (TEVAR) showing false lumen perfusion in the descending thoracic aorta (DTA) and aneurysmal degeneration of the para-visceral aorta. *Right box*: CTA 5 years after TEVAR showing complete false lumen thrombosis in the DTA and stable diameter at the para-visceral aortic segment.

associated with rapid aneurysm expansion (>70-mm). Therefore, a tubular stent-graft was placed in the distal infrarenal aorta to cover the entry tear (Fig. 2). One-year imaging control showed a new asymptomatic entry tear in the para-visceral aorta, and a custom-made endovascular solution was deemed the best option. Given the planned extensive aortic coverage and history of SCI, a large spinal artery taking off from the aneurysm was preserved with a custom-made fenestrated-branched device (Fig. 3) featuring 5 fenestrations (spinal artery, celiac trunk, superior mesenteric artery, right renal artery, right accessory renal artery). The procedure was technically successful; the 6x6-mm spinal fenestration was left unstented, due to the small size of the spinal artery (3-mm) and the absence of any clear endoleak at completion aortography. During the post-operative period, the patient developed transient neurological symptoms related to cerebellar infarct diagnosed with magnetic resonance imaging (the procedure required upper arm access for cannulation and stenting of the mesenteric vessels). Imaging follow-up 2 years after the operation showed good stent-graft position with widely patent target vessels (Fig. 4); however, at this time, there was a type I endoleak from the previously unstented spinal fenestration that had resulted in a 1-cm increase in size at the para-visceral abdominal segment. Therefore, the aortic stent-graft was relined to cover the spinal fenestration. The patient did not develop any further complication, and a 2-year CTA follow-up showed table aneurysm sac with complete resolution of the previous endoleak.

Patient B was a 66-year-old woman with Marfan's syndrome, treated hypertension and hyperlipidemia, mild congestive heart failure, and moderate aortic insufficiency. She was a previous smoker without chronic obstructive pulmonary disease or asthma and had a left atrophic kidney with stage III chronic kidney disease. At age 50, she underwent open surgical repair of Crawford type II TAAA with separate patch reimplantation of renal-mesenteric arteries and intercostal arteries. At age 63, she was found to have 55-mm aneurysm in the intercostal patch, which eventually enlarged to 63-mm. Due to the prior extensive aortic replacement, the patient was considered high-risk for SCI, and a custom-made stent-graft with 2 branches (superior mesenteric artery, right renal artery) and 2 fenestrations (one for the celiac trunk, as well as a separate 6

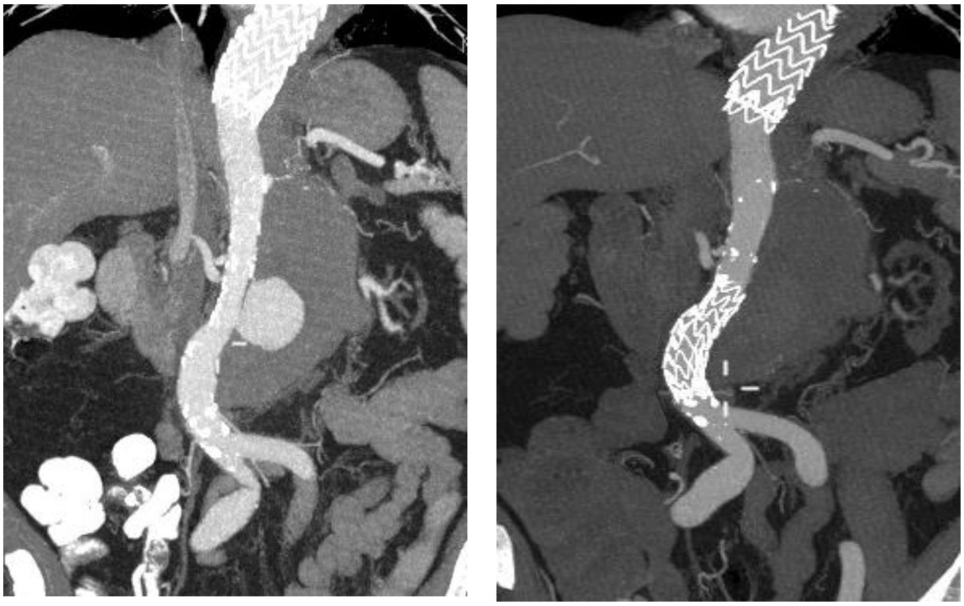

Fig. 2. Patient A. Left box: computed tomography angiography (CTA) 6 years after thoracic endovascular aortic repair (TEVAR) showing new entry tear at the infrarenal aortic segment associated with rapid aneurysm expansion that required urgent treatment with straight endograft. Right box: post-operative CTA 30 days after straight endograft placement showing the correct position of the new endograft and absence of residual false lumen perfusion.

× 6-mm fenestration for the largest patent intercostal artery) was planned. The procedure was technically successful, and the spinal fenestration was stented with a combination of bridging stent-grafts, balloon-expandable (6 × 27-mm Atrium V12) proximally and self-expandable (5 × 25-mm Viabahn) distally. The postoperative course was free from major adverse events. Five-year imaging follow-up showed good stent-graft position with patent target vessels, including the stented spinal artery (Fig. 5); there was a type II endoleak from a small intercostal artery in the patch aneurysm, the size of which had decreased to 48-mm (Fig. 6). The patient did not undergo any further reintervention.

DISCUSSION

This series illustrates the successful application of F-BEVAR technology for endovascular incorporation of spinal arteries in TAAA repair. Both patients were treated because of large or rapidly expanding aneurysms and given their history were deemed to be at high-risk for SCI. In one case, the technique was facilitated by the large diameter of the spinal artery, which allowed the use of conventional stent-grafts to bridge the target vessel. Although in the case where the fenestration was left unstented, this resulted in the loss of contact between the aortic wall and the device with endoleak requiring relining of the main endograft body. No neurologic complications were noted likely due to collateral flow development.

From a technical standpoint, we believe 4-mm to be the lowest diameter threshold for successful and durable incorporation of spinal arteries into a fenestrated repair. Although no definitive conclusions can be drawn from the present report, current F-BEVAR literature defines renal artery (RA) suitability for incorporation into fenestrations as diameter ≥4.0-mm.[7] Indeed, several technical challenges must be addressed if the stenting of smaller target vessels is planned, the main problem being that the smallest bridging stent-graft (BSG) that can be used is 5-mm in diameter while 6-mm is the smallest diameter that can be manufactured for fenestrations. Therefore, there may be a concern that the use of a ≤5-mm BSG could result in insufficient flaring, thereby predisposing to a type IIIC endoleak, while excessive inflation within a small artery may cause rupture or dissection. Accordingly, a recent study investigated outcomes of small-sized (i.e. <4.0 mm) versus good-sized (i.e. ≥4.0 mm) RA targets and found that incorporation of small RA was associated with lower technical success,

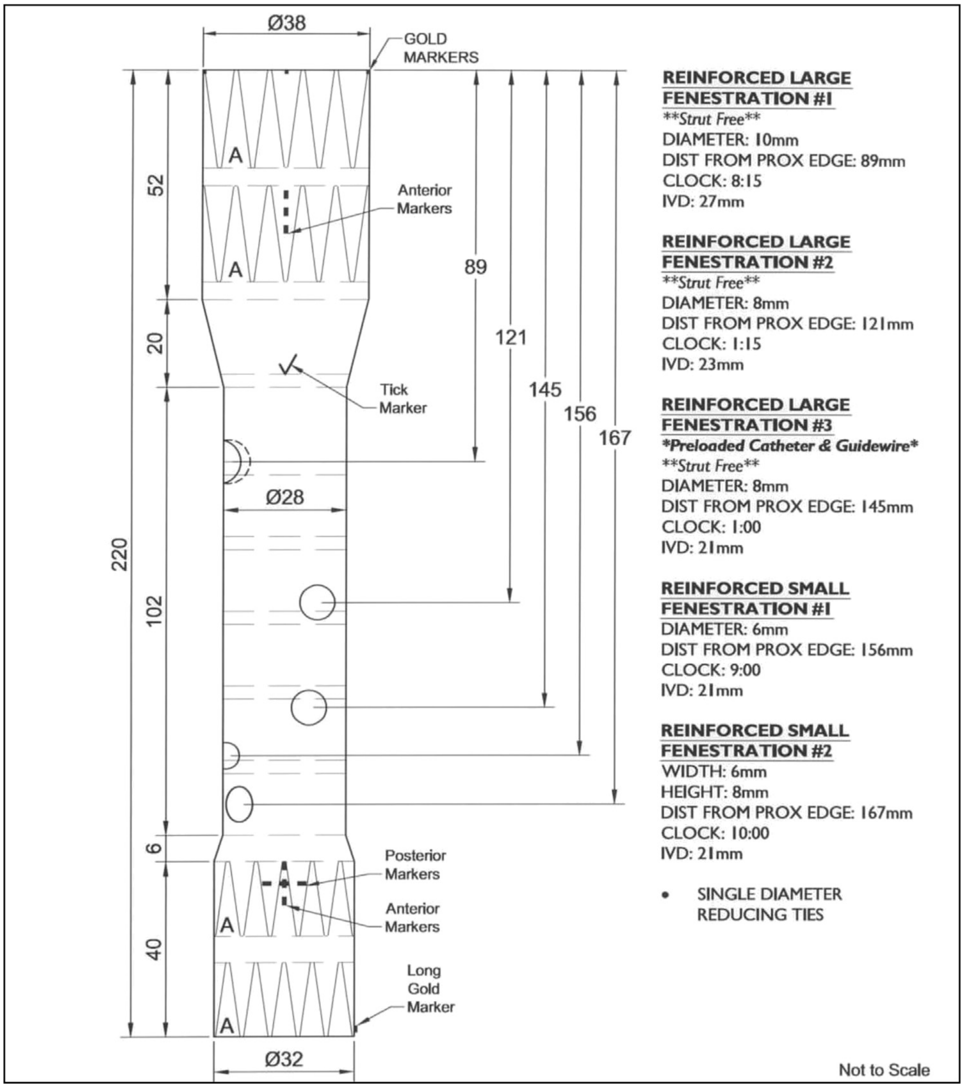

Fig. 3. Patient A. Technical drawing of the custom-made endograft with 5 fenestrations. The highest 10-mm large fenestration was left unstented for perfusion of the spinal artery.

higher risk of arterial disruption, a higher rate of target vessel instability, and lower patency rates.[8] Therefore, although the incorporation of small target arteries could be feasible, caution should be exercised, given the potential for increased complications and lower durability. Furthermore, as described in one of the presented cases, preservation of a small spinal artery in an area where the stent-graft is adjacent to the inner aortic wall might be achieved with the use of an unsupported fenestration, offering the possibility to cover the fenestration should this result in a type IC endoleak later on during follow-up.

Reimplantation of intercostal arteries as an ''island'' patch is often used during open surgical repair of TAAA to reduce the risk of SCI. However, the native aorta around the reimplanted vessels is at risk of later aneurysmal degeneration, with an estimated prevalence of 1−8%.[9] Past endovascular repairs in this setting have included the simple exclusion of the involved patch, debranching followed by stent-graft coverage, and use of physician-modified endografts or parallel-graft techniques.[10−12]

Accurate pre-operative knowledge of the arterial supply to the spinal cord is mandatory to plan the

Fig. 4. Patient A. Computed tomography angiography 2 years after placement of the custom-made fenestrated endograft showing sustained patency of the unstented spinal artery.

Fig. 5. Patient B. Computed tomography angiography 2 years after placement of the custom-made fenestrated-branched endograft showing sustained patency of the stented spinal artery.

incorporation of spinal arteries in the repair. The ability to discriminate between arterial and venous structures, as well as the absence of interference due to neighbor skeletal structures or the patient's body mass, might represent theoretical advantages of magnetic resonance angiography over CTA.[13] However, millimeter-sized arteries are nowadays well within the detection capabilities of thin-slice CTA[14]; this is even more true if only clinically relevant (i.e. of adequate size for technically successful incorporation) vessels are considered. Furthermore, since CTA is the imaging modality of choice prior to scheduled complex endovascular aortic procedures, the information required for detailed analysis of

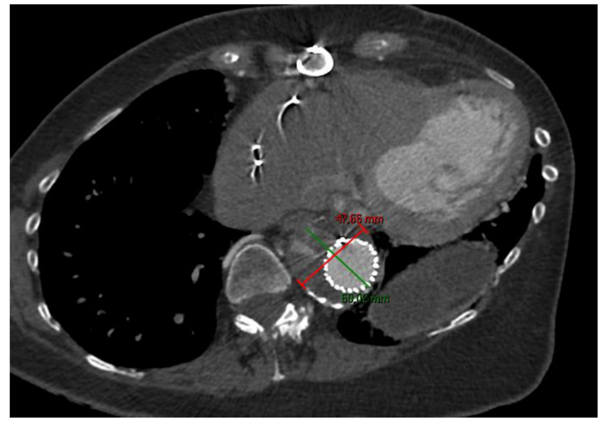

Fig. 6. Patient B. Computed tomography angiography 2 years after placement of the custom-made fenestrated-branched endograft. There is a small type II endoleak in the sac, the size of which was reduced to a maximal oblique diameter of 48 mm.

spinal cord vascular anatomy is already available in everyday clinical practice. For these reasons, we do not routinely perform magnetic resonance angiography for the evaluation of spinal cord vasculature prior to F-BEVAR procedures.

This experience also shows the importance of lifelong surveillance after open or endovascular TAAA repair, especially in patients with dissection and in those with connective tissue disorders. Indeed, TEVAR for dissection carries a risk for stent-graft induced new entry tears, which, in turn, may warrant further re-intervention,[15,16] and regular lifelong imaging controls are, therefore, warranted.

CONCLUSIONS

Application of custom-made fenestrated stent-grafts is safe and feasible for the incorporation of spinal arteries during secondary endovascular repair of TAAA in selected cases. This technique might expand the endovascular armamentarium for the treatment of thoracoabdominal aortic disease.

COMPLIANCE WITH ETHICAL STANDARDS

- Consent for publication was obtained by the relevant local ethical committee.
- Ethical approval by the relevant local ethical committee was not required for this type of study.
- Informed consent was obtained from study participants for publications of anonymized clinical details.

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