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Caudally directed in situ fenestrated endografting for emergent thoracoabdominal aortic aneurysm repair

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ABSTRACT

We previously described a transfemoral antegrade in situ laser fenestration technique (in situ fenestrated endovascular abdominal aortic aneurysm repair) for ruptured thoracoabdominal aortic aneurysms. In the present report, we have described an alternative technique of caudally directed in situ fenestrated endografts using upper extremity access for branch vessel incorporation. This technique involves partial deployment of the aortic stent graft in the thoracic aorta to achieve proximal control, followed by sequential branch incorporation using a laser probe through a steerable sheath, from the upper extremity access. The advantages of the technique include rapid proximal aortic control before branch incorporation without target vessel prestenting and separation of in situ fenestration from the target branch vessel origin, facilitating cannulation of angulated branch vessels. (J Vasc Surg Cases and Innovative Techniques 2021;7:553-7.)

Keywords: Ruptured thoracoabdominal aortic aneurysm; In situ fenestrated; Branched endovascular aortic repair

A ruptured thoracoabdominal aortic aneurysm (TAAA) is a highly lethal process, even when emergent repairs are attempted.[1] Although fenestrated/branched endovascular aortic repair (F/BEVAR) and parallel grafting are often used endovascular repair techniques for TAAAs,[2-4] the repair of ruptured TAAAs poses a unique challenge because of the high complexity and the time required to cannulate each viscerorenal vessel before the ruptured aneurysm is sealed.[5] Pioneered for preservation of the left subclavian artery during zone 2 thoracic endovascular aortic repairs,[6-8] feasibility of antegrade in situ fenestration for viscerorenal branch incorporation was first demonstrated by Le Houerou et al.[9] We have previously described a successful application of transfemoral antegrade in situ fenestration (in situ fenestrated endovascular abdominal aortic aneurysm repair

[IS-FEVAR]) technique to repair ruptured TAAAs.[10] However, we have found that application of IS-FEVAR can be difficult in cases in which the target vessels have significant caudal or cranial angulations. In the present report, we have described a novel technique of caudally directed in situ (CDIS)-FEVAR, which is well suited for emergent repair of TAAAs with angulated viscerorenal target vessels. The patient provided written informed consent for the report of his case, and the requirement for institutional review board approval was waived.

CASE REPORT AND TECHNIQUE

A 74-year-old man with severe aortic valvular stenosis and an incidentally discovered 9.5-cm Crawford extent IV TAAA had presented with shortness of breath and had undergone successful transcatheter aortic valve replacement. While recovering from this procedure, he developed acute abdominal and back pain. Computed tomography angiography (CTA) demonstrated new periaortic stranding, consistent with a contained TAAA rupture (Fig 1). He was hemodynamically stable with normal renal function. However, given the risk of impending free rupture, he was taken emergently to the operating room for total endovascular repair.

With the patient under general anesthesia, we performed a left brachial cut down for branch stenting and percutaneous access of the right common femoral artery for introduction of the aortic components. Through the left brachial access, a 12- × 45-cm DrySeal Flex sheath (W.L. Gore & Associates, Flagstaff, Ariz) was positioned into the descending thoracic aorta. Through the femoral access, a 36- × 32- × 209-mm Zenith Alpha thoracic endograft (Cook Medical, Bloomington, Ind) was introduced and partially deployed to the third stent row (Fig 2, A). Using a 2.3-mm laser probe (Spectranetics, Colorado Springs, Colo) introduced through an 8F × 90-cm TourGuide steerable sheath
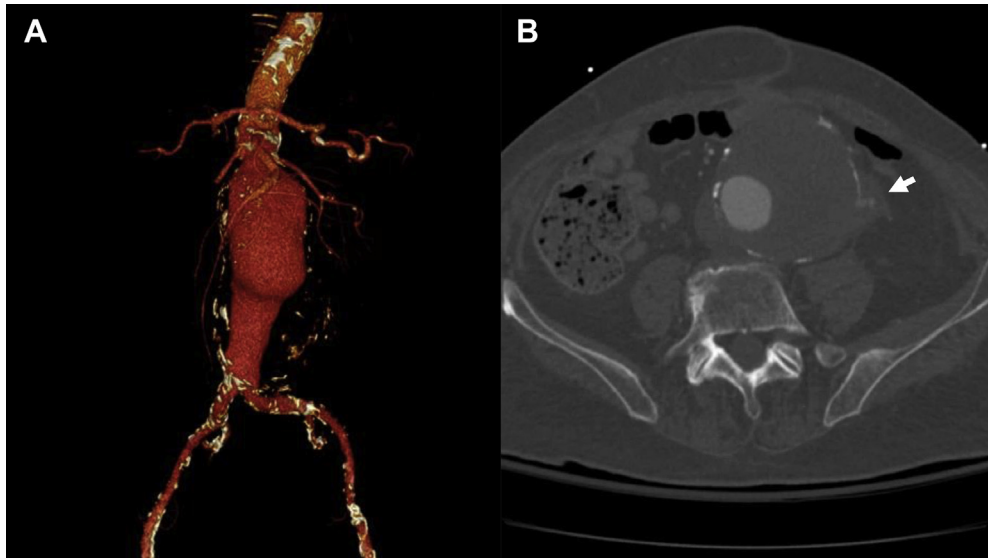
Fig 1. A, Preoperative three-dimensional computed tomography angiography (CTA) reconstruction showing thoracoabdominal aortic aneurysm (TAAA). **B,** Computed tomography scan showing contained rupture of TAAA (*arrow*).
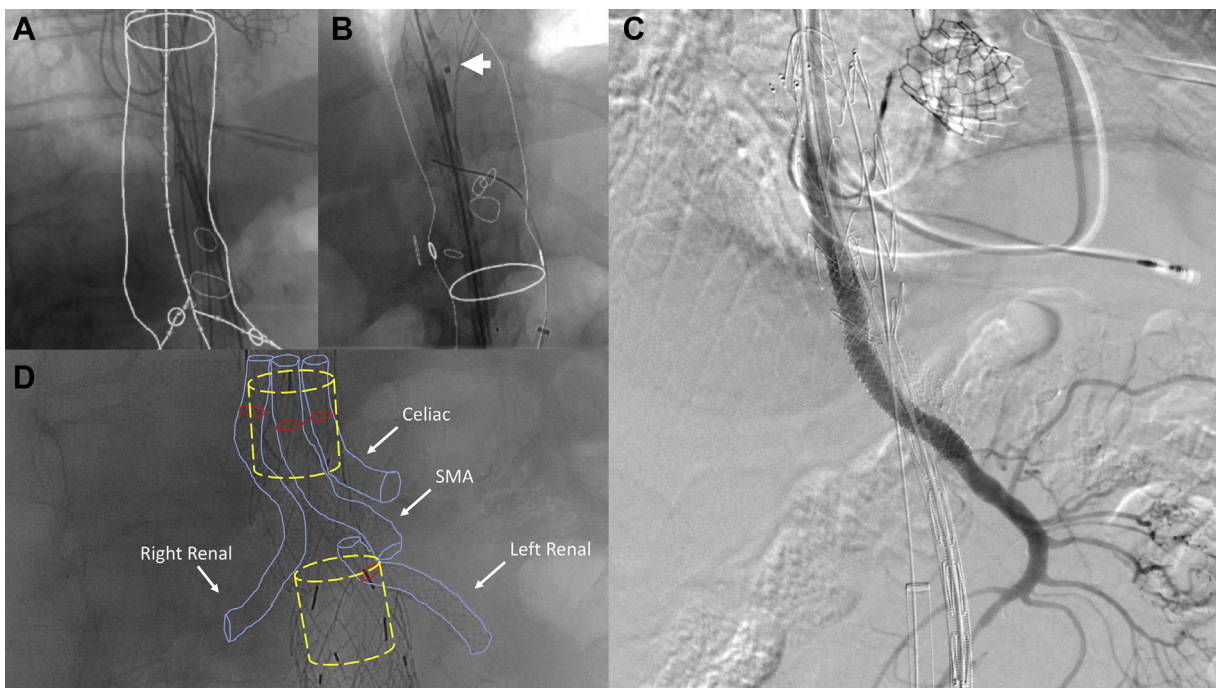

Fig 2. Steps for caudally directed in situ fenestrated endovascular abdominal aortic aneurysm repair (CDIS-FEVAR). **A,** Partial deployment of endograft. **B,** In situ fenestration creation using a laser probe (*arrow*). **C,** Sequential creation of caudally directed branch stents. **D,** Deployment of aortic cuffs (*yellow dotted lines*) to reinforce in situ fenestrations (*red circles*) and stabilize the caudally directed branch stents (*blue outlines*). *SMA,* Superior mesenteric artery.

(Medtronic, Minneapolis, Minn) within the 12F DrySeal Flex sheath (W. L. Gore & Associates) from the brachial approach, the fabric of the endograft was penetrated above the first target vessel (Fig 2, *B*). After creation of the in situ fenestration with the laser probe, a short (22-mm) iCast (Atrium, Hudson, NH) was deployed. This created an antegrade in situ branch portal through which the steerable sheath facilitated target vessel catheterization. Next, longer bridging balloon expandable
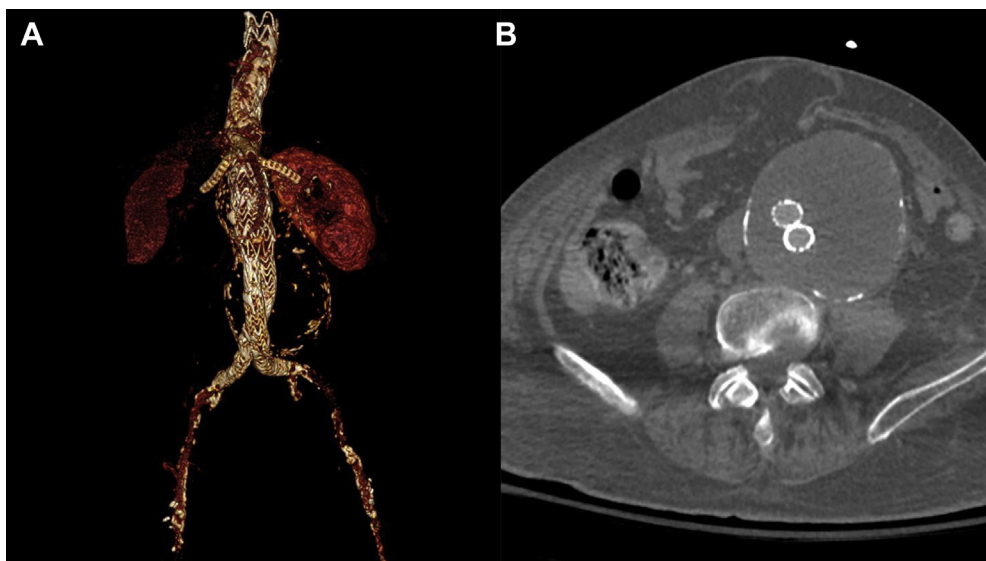
Fig 3. A, Postoperative three-dimensional computed tomography angiography reconstruction showing patent branch stents. **B,** Computed tomography scan showing successful exclusion of aneurysm sac.
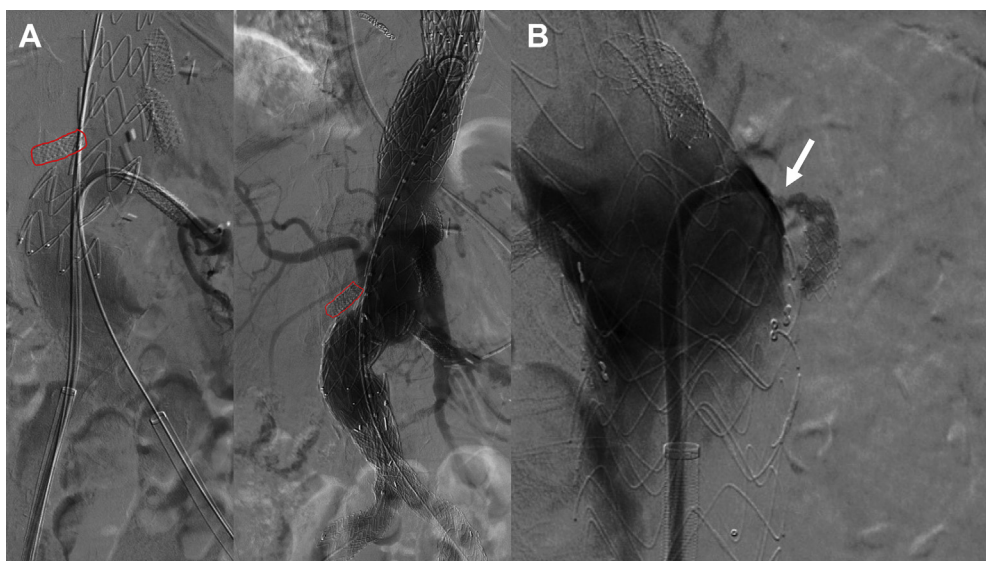

Fig 4. A, Failed renal artery incorporation during transfemoral in situ fenestrated endovascular abdominal aortic aneurysm repair (IS-FEVAR) due to angulated right renal artery (*red outlines*), preventing "down-the-barrel" view. **B,** Retroperitoneal perforation (*arrow*) caused by laser probe misalignment with the left renal artery.

covered stents (Viabahn VBX; W. L. Gore & Associates) were deployed into the target vessel, creating caudally directed branch stents (Fig 2, *C*). The celiac artery, superior mesenteric artery, and bilateral renal arteries were sequentially incorporated in this manner through individual branch portals.

Aortic extension cuffs were deployed across the in situ fenestrations to provide additional branch stability and protection against type III endoleaks (Fig 2, *D*). Finally, a bifurcated endograft (35- × 14-mm Excluder; W. L. Gore & Associates) and iliac limbs were placed, achieving a distal seal in the bilateral common iliac arteries and preserving both internal iliac arteries.

The end result achieved total endovascular exclusion of the ruptured TAAA with caudally directed branches to each viscerorenal artery. The total operative time was 270 minutes, with 60 minutes of fluoroscopy time, 125 mL of contrast, and an estimated external blood loss of 300 mL.

The postoperative day 1 CTA demonstrated successful exclusion of the aneurysm sac with patent viscerorenal artery bridging stents. The patient had an uneventful postoperative course without a significant decrease in renal function or the development of spinal cord ischemia and was discharged home on postoperative day 5. He remained well 5 months after

repair with surveillance CTA continuing to demonstrate patent branch stents, no evidence of endoleak, and a stable aneurysm sac (Fig 3; Supplementary Video).

DISCUSSION

For patients with a ruptured or symptomatic TAAA, the manufacturing and shipping time of custom fenestrated/branched endografts is prohibitive. In these circumstances, the options include off-the-shelf devices designed to accommodate most anatomy or physician-modified endografts[11] to allow immediate access to fenestrated/branched devices. However, implantation of these devices requires substantial time, and the aneurysm seal will not be achieved until the last component has been implanted. This limitation is reflected by the results from a series by Hongku et al,[5] in which 11 consecutive patients were treated with an off-the-shelf multibranched endograft (t-Branch; Cook Medical) for urgent and emergent TAAA repair. Of the 11 patients, 1 died intraoperatively death. The 30-day mortality was 27%; however, only two patients were hemodynamically unstable.[5]

Attempting to overcome the inherent limitations of conventional F/BEVAR, we have reported our technique of transfemoral antegrade in situ FEVAR for treatment of unstable ruptured TAAAs[10] and have performed IS-FEVAR in five cases. Through this experience, we have found that one significant limitation of IS-FEVAR is the incorporation of angulated target vessels, especially renal arteries where the "down-the-barrel" view of the target vessels can be difficult to achieve. In two cases, we were unable to incorporate a renal artery with a highly angulated origin (Fig 4, A). We also had an additional case of misalignment of the laser probe, resulting in a retroperitoneal perforation, which was sealed with an additional aortic stent graft (Fig 4, B). The conceptual design of CDIS-FEVAR was aimed at overcoming this limitation by creating in situ fenestrations across the partially deployed aortic endograft several centimeters above each target vessel to preserve a range of working spaces to cannulate each target vessel more efficiently. In addition, in situ fenestration is safer in the caudal direction across the partially deployed endograft, with a lower risk of aortic wall perforation (Fig 2, B). Although precise rotational alignment is not required for the location of in situ fenestrations to the respective target vessels, we would recommend avoiding branch stents crossing each other, which can result in compression and dislocation of the bridging stents with complete aortic endograft deployment. Using this technique, prestenting of each viscerorenal target vessel is not necessary. This principle of wide anatomic suitability is similar to the design of off-the-shelf multibranched endografts.[12] It is our preference to reinforce the newly created fenestrations across the endograft with an aortic cuff, thereby creating an internal sandwich to protect against type III endoleaks and maintain the stability of the bridging stents.

In unstable patients, partial deployment in the descending thoracic aorta through a percutaneous femoral access can function as a proximal aortic control and rapidly limit ongoing hemorrhage. At this point, liberal resuscitation and induction of general anesthesia can begin. During this time, it is important to apply constant forward support on the partially deployed endograft to avoid "windsocking" and caudal migration during creation of the in situ fenestrations. In patients who do not require aortic occlusion, a "buddy" sheath can be introduced from the contralateral femoral approach to induce a gutter leak alongside the partially deployed aortic endograft, which can eliminate the ischemia time to the target vessels and reduce "windsocking."

An important limitation of this technique is the unknown long-term durability. Although we are not aware of reported data on type III endoleaks from material fatigue of in situ fenestrated endografts, the device integrity around the unreinforced fenestration created by the laser probe is a completely reasonable concern in the long term. Such failures will likely require open conversion with partial or entire endograft explantation or endovascular relining with F/BEVAR within the fenestrated endograft.[13] Notwithstanding these durability concerns, for unstable patients and patients with contained rupture with a significant risk of impending free rupture, the goal of therapy is prevention of acute exsanguination and death. In such circumstances, the use of CDIS-FEVAR can be life-saving. Therefore, the choice to use any IS-FEVAR should be made carefully for select patients.

CONCLUSIONS

CDIS-FEVAR can be useful for emergent repair of TAAA with angulated target vessels. The advantages of this technique include (1) rapid proximal aortic control of the ruptured TAAAs before viscerorenal artery incorporation; (2) no need to prestent the target vessels; (3) separation of the location of in situ endograft fenestration from the target branch vessel origin, thereby facilitating cannulation of the angulated branch vessels; and (4) the use of readily available off-the-shelf standard endovascular components. Long-term follow-up and prospective studies are required to further assess the safety, efficacy, and durability of the presented technique.

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