Antegrade in situ fenestrated endovascular repair of a ruptured thoracoabdominal aortic aneurysm

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ABSTRACT

We describe a technique for antegrade in situ laser fenestration that has several advantages in the setting of ruptured thoracoabdominal aortic aneurysms. This technique involves rapid aneurysm sealing by deployment of aortic stent graft, followed by sequential incorporation of branch vessels using a laser probe through steerable sheath. The advantages of this technique include (1) rapid seal of the ruptured aneurysm, (2) preservation of the visceral and renal branch perfusion, (3) use of an off-the-shelf device, and (4) the ability to be performed without general anesthesia. (J Vasc Surg Cases and Innovative Techniques 2020;6:416-21.)

Keywords: In situ laser fenestration; Thoracoabdominal aortic aneurysm; Fenestrated endovascular aortic repair; Thoracic endovascular aortic repair

Ruptured thoracoabdominal aortic aneurysms (TAAA) have a near 100% mortality, even when emergent repairs are attempted.[1] Although fenestrated/branched endovascular aortic repair and parallel grafting are commonly employed techniques for endovascular repair of TAAA,[2-4] repair of ruptured TAAA represents a special case where these may not be well-suited. This is because substantial amount of time is required to cannulate each critical viscerorenal vessels before the ruptured aneurysm is sealed. Off-the-shelf and physician-modified endografts, aiming to provide immediate access to branched/fenestrated endografts, do not decrease the high complexity and time required for implantation and seal of the aneurysm.[5] Therefore, their applicability in unstable ruptured TAAA remains extremely challenging. Parallel grafting technique can be used, but gutter leak and branch compression can make the outcome unpredictable and less reproducible.[3,4] Pioneered for preservation of the left subclavian artery during zone 2 thoracic endovascular aortic repairs (TEVAR), the in situ fenestration technique has been applied using a laser probe for nonemergent repairs of juxtarenal, TAAA.[6-10] We report a case of an antegrade in situ fenestration technique used to achieve endovascular repair of ruptured TAAA. This technique may be uniquely suited for ruptured TAAA, by allowing immediate aortic aneurysm seal, before incorporation of the visceral renal target vessels. The patient provided consent for publication of this case report. Institutional review board approval was waived.

CASE AND TECHNIQUE

A 72-year-old man with hypertension, chronic obstructive pulmonary disease, and history of zone 2 TEVAR with left carotid-subclavian bypass 2 years ago, presented to an outside hospital with chest and abdominal pain. Computed tomography angiography (CTA) showed a large extent 1 TAAA with mediastinal hematoma (Fig 1, *A*). There was a complete loss of distal seal from the previous TEVAR, leading to robust type Ib endoleak (Fig 1, *B*). On arrival to our center, the patient was hypotensive with a systolic blood pressure of 80 mm Hg while maintaining mentation. Based on patient age and comorbidities in the setting of marginal hemodynamics, the decision was made to perform an emergent total endovascular repair using antegrade in situ laser fenestration technique.

Under local anesthesia, a single percutaneous femoral access was obtained. While allowing permissive hypotension with an awake patient, a 7F × 55 cm TourGuide steerable sheath (Medtronic, Minneapolis, Minn) was used to rapidly deploy balloon expandable stents (VisiPro, Medtronic) in the visceral and renal arteries (Fig 2, *A-D*). Care was taken to deploy the stents entirely in the branch vessels with no protrusion into the aorta. These stents served as markers for in situ fenestration. Three-dimensional fusion imaging guidance was not used.

After branch vessel prestenting, the femoral access was upsized to 18F (DrySeal Flex, W. L. Gore & Associates, Flagstaff, Ariz) and tapered 46-40 mm × 218 mm and 37-31 mm × 207 mm Medtronic Valient Navion thoracic stent grafts (Medtronic), landing proximally into the prior thoracic stent graft, covering the zone of rupture, as well

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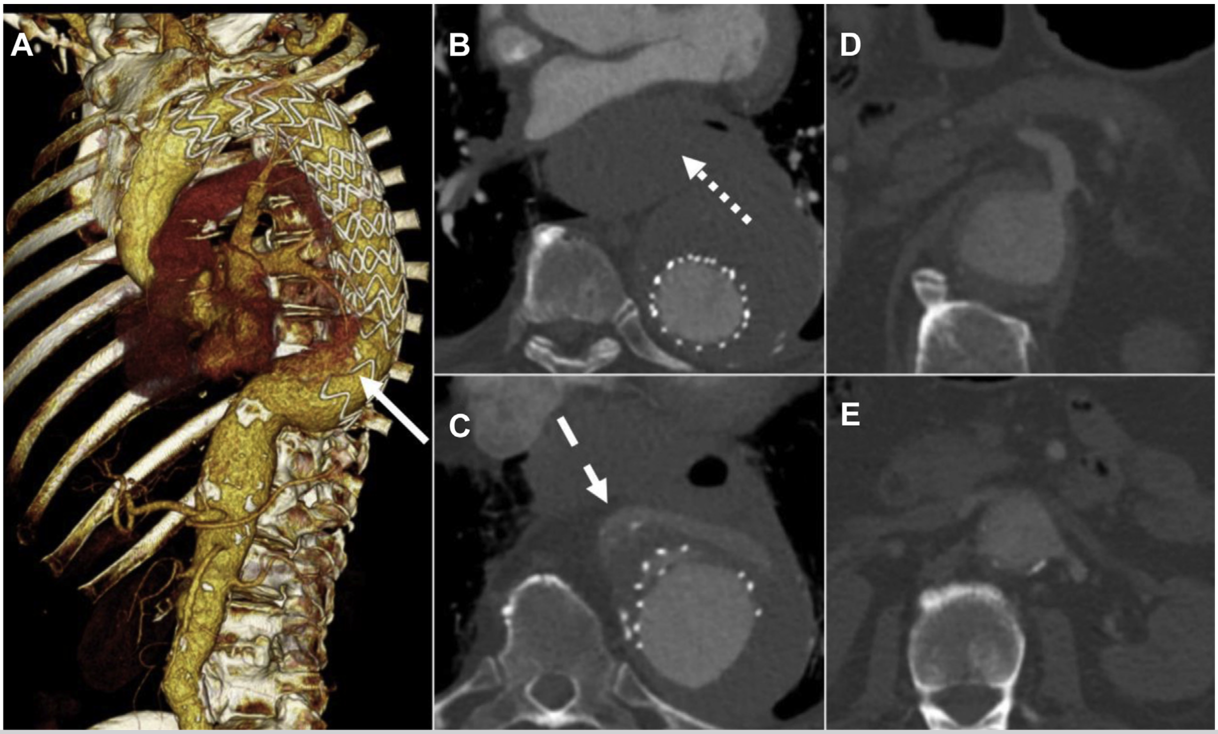

Fig 1. Computed tomography angiography with three-dimensional reconstruction demonstrating an 8-cm extent 1 thoracoabdominal aortic aneurysm (TAAA) after previous thoracic endovascular aortic repair (TEVAR). **A,** There is a robust type IB endoleak (*solid arrow*) **(C)** distal to the previous thoracic stent graft (*long dashed arrow*). **B,** The mediastinal hematoma created a mass effect on the heart and pulmonary artery (*short dashed arrow*). The visceral **(D)** and pararenal **(E)** aorta were aneurysmal.

as all viscerorenal branches. This achieved a seal across the ruptured aorta with 1-mm oversizing within the previous endograft proximally, and 30% oversizing distally in the infrarenal aorta. This initiated viscerorenal warm-ischemia time (Fig 3, *A*). A 2.3-mm laser probe (Spectranetics, Colorado Springs, Colo) was then delivered through a 7F × 55-cm TourGuide sheath to perform antegrade in situ fenestration. For each branch vessel, we obtained a down-the-barrel as well as a profile view of the target branch stents (Fig 3, *B* and *C*). This strategy allowed precise positioning of the laser probe. With gentle forward pressure, a brief moment of energy delivery was performed, resulting in a pop-through of the probe into the target branch stent. Successful luminal access was confirmed with angiography through the laser probe (Fig 3, *D*). A 0.35" guidewire (Terumo, Sumerset, NJ) was advanced through the laser probe then exchanged to a support wire (Rosen, Cook Medical, Bloomington, Ind). Over the support wire, the newly created laser fenestration was sequentially dilated using 4-mm and 6-mm balloons (EverCross, Medronic), which allowed delivery and deployment of the bridging covered stent across the fenestration (iCast, Atrium, Hudson, NH). Each bridging stent was flared with partial inflation of a10-mm noncutting angioplasty balloon, to secure seal across the in situ fenestration. The superior mesenteric artery (SMA) was revascularized first, followed by renals, and celiac (Fig 4, *A-D*).

Completion angiogram demonstrated successful aneurysm exclusion, and patent viscerorenal stents (Fig 4, *E*). Total procedure time was 2 hours and 38 minutes. SMA warm ischemia time, determined by the interval from the aortic stent graft to bridging stent deployments (not including balloon flare), was 15 minutes, right renal 24 minutes, left renal 1 hour 15 minutes, and celiac 1 hour 35 minutes. Estimated blood loss was 50 mL. Fluoroscopy time was 66 minutes, total radiation 895 mGr, and total contrast used was 90 mL. The patient remained awake throughout the procedure, and hemodynamics stabilized upon deployment of the thoracic stent graft.

Postoperative CTA demonstrated complete aneurysm seal without endoleaks. Postoperatively, his serum creatinine peaked at 1.3 mg/dL (1.06 mg/dL preoperatively), and decreased to 1.0 on the day of discharge. There was no other metabolic abnormalities, and patient was discharged home on postoperative day 6 on home oxygen. The 3-month CTA demonstrated decreased aneurysm sac from 74 mm to 61 mm, patent branch stents, and no endoleak (Fig 5).

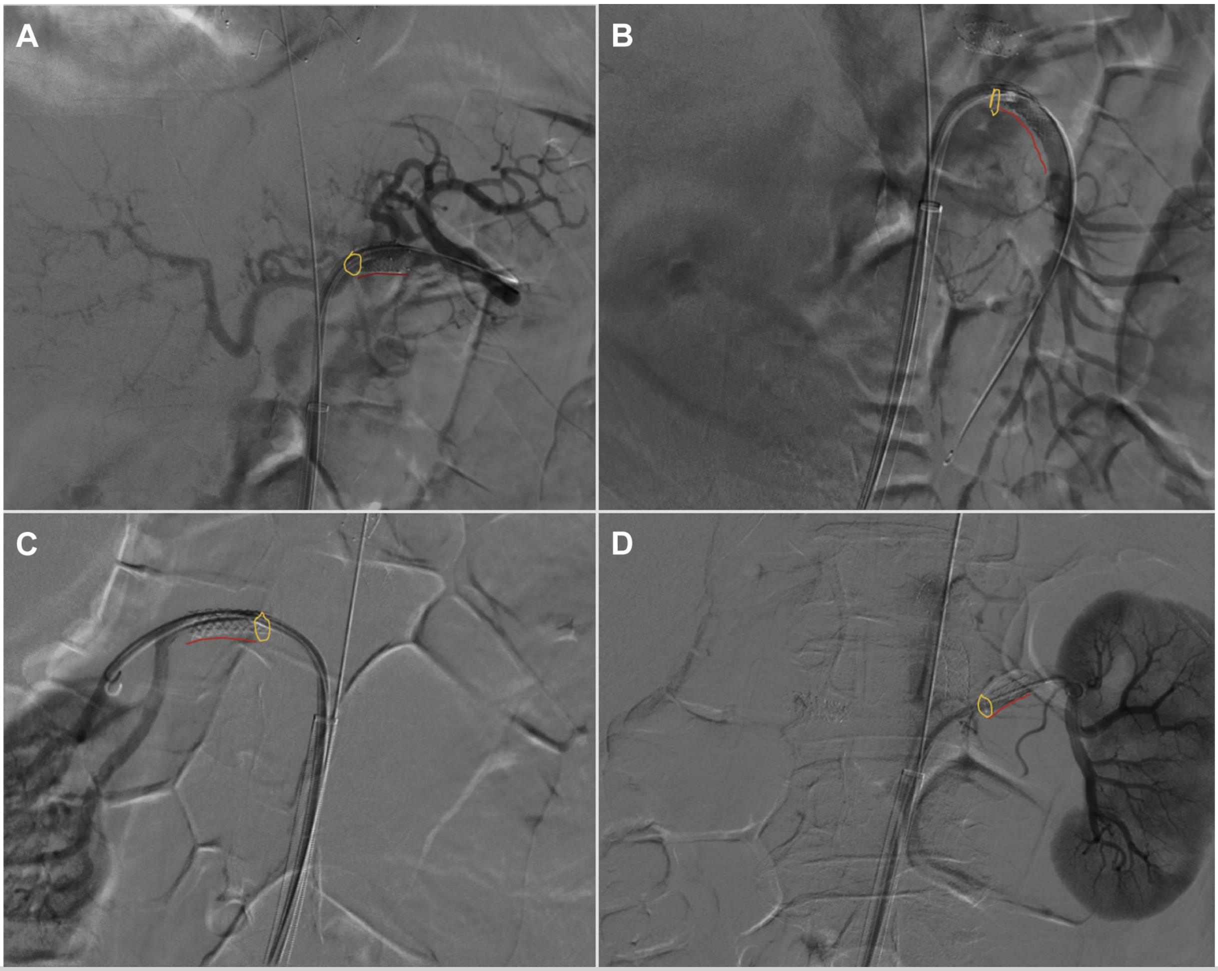

Fig 2. Balloon-expandable stenting is performed for all visceral and renal arteries. The celiac **(A)**, super mesenteric artery (SMA) **(B)**, and bilateral renal arteries **(C)** and **(D)** are done in sequential order as depicted. Celiac, SMA, right renal, and left renal arteries took 7, 5, 6, and 10 minutes for cannulation and stent placement, respectively. *Yellow rings* and *red lines* were added to highlight the origin and contour of the target vessels, respectively.

DISCUSSION

In patients with ruptured TAAA, manufacturing and shipping time of custom fenestrated/branched endografts is prohibitive. Although off-the-shelf devices, designed to accommodate most anatomy, eliminate the custom manufacturing process, implantation of these devices remains highly complex, requiring substantial time before an aneurysm seal is achieved. It remains uncertain if outcomes of patients with ruptured TAAA, particularly with unstable hemodynamics, can be improved even if these devices are readily available. In a series by Hongku et al,[5] 11 consecutive patients were treated with an off-the-shelf device for urgent and emergent endovascular TAAA repairs. There was one intraoperative death, and the 30-day mortality was 27%, but notably, only two patients were hemodynamically unstable.

There are several technical considerations that make application of fenestrated/branched endografts in ruptured TAAA patients challenging. First, the use of an aortic occlusion balloon, which can be life saving in ruptured infrarenal AAA, is not feasible in ruptured TAAA because inflation of an aortic occlusion balloon in the proximal to mid descending thoracic aorta, whereas performing multiple viscerorenal cannulations as well as bifurcated endograft results in prolonged ischemia time. Second, most off-the-shelf devices for TAAA are designed to be implanted using both femoral and upper extremity access.[2] This often requires a large sheath introduction in the upper extremity access,

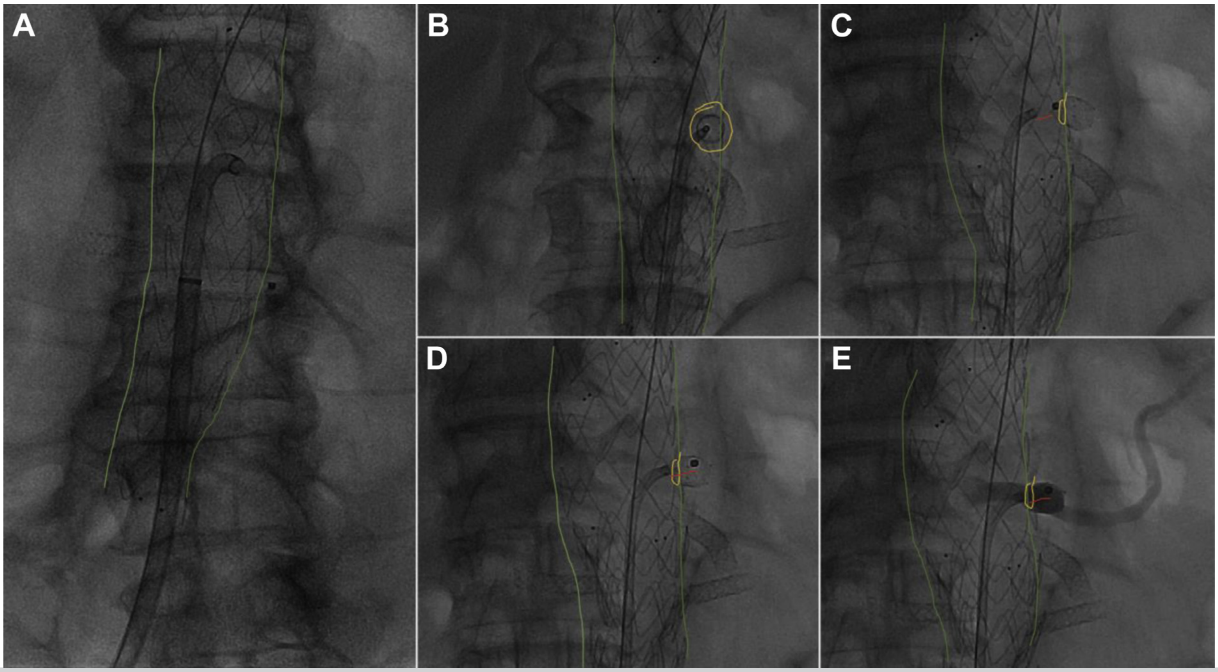

Fig 3. Antegrade laser in situ fenestration is created after aortic seal. **A,** The thoracic stent graft is deployed to achieve seal of the ruptured aorta. The laser probe is brought to a down-the-barrel view **(B)**, followed by a profile view **(C)** for precise positioning. Gentle forward pressure is used with brief energy delivery to visualize a pop-through of the probe **(D)**. Successful luminal access is angiographically confirmed **(E)**. *Yellow rings* and *red lines* were added to highlight the origin and contour of the target vessels, respectively.

Fig 4. Bridge stenting is performed with balloon-expandable covered stents. The superior mesenteric artery (SMA) is revascularized first **(A)**, followed by the renal arteries **(B** and **C)**, and then finally the celiac artery **(D)**, limiting visceral ischemia time. **E,** Completion angiography. The previous type IB endoleak is no longer seen. There are no endoleaks and/or component separations. All visceral stent grafts are patent without type II endoleaks or stenosis. *Yellow rings* and *red lines* were added to highlight the origin and contour of the target vessels, respectively.

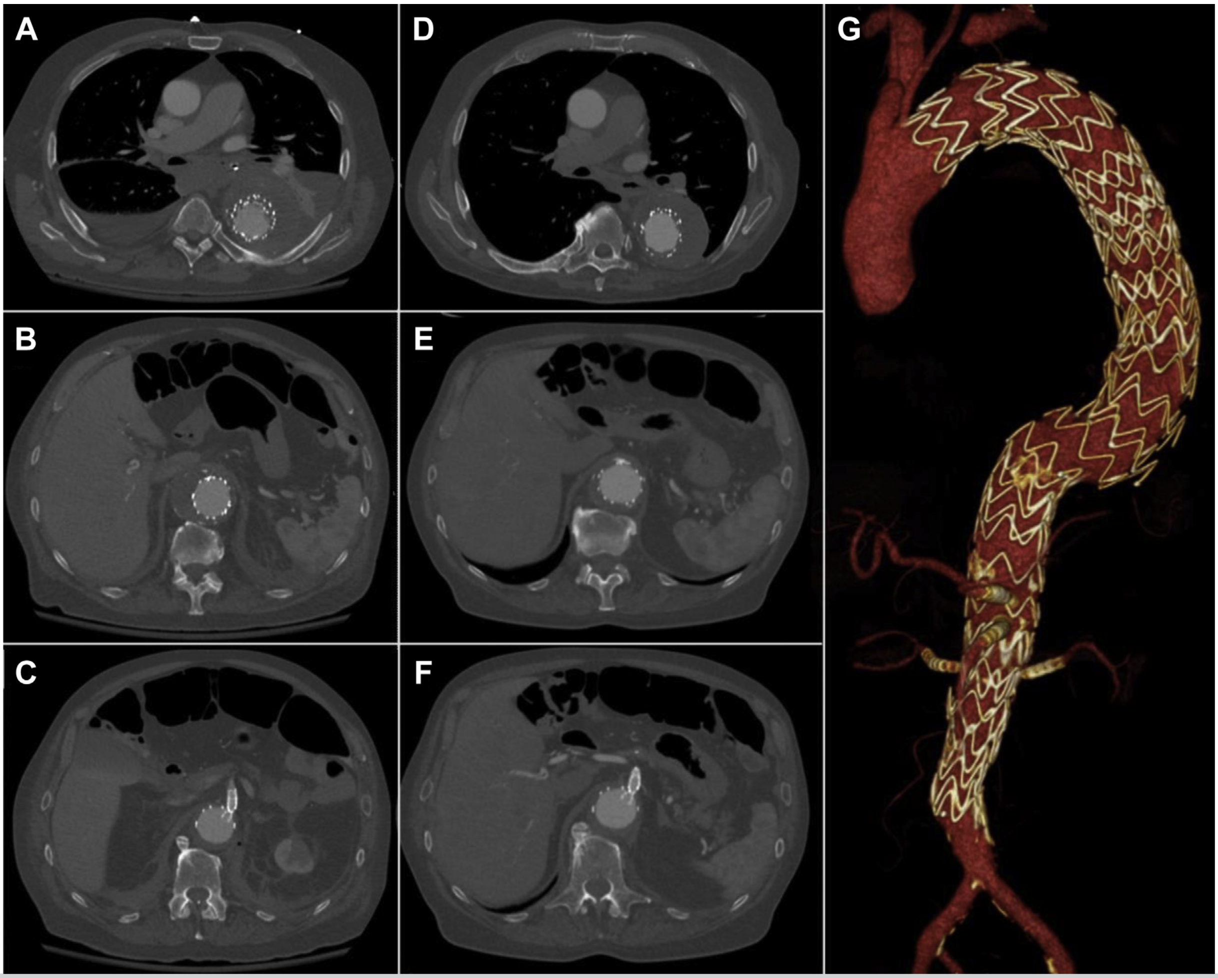

Fig 5. Postoperative computed tomography angiography (CTA) on day 5 **(A-C)** and at 3 months **(D-G)** show patent branch stents without stenosis, complete aneurysm exclusion without endoleak, and aneurysm sac regression.

which is poorly tolerated without general anesthesia. General anesthesia induction without aneurysm seal, however, can trigger loss of compensatory vasoconstriction in patients with a rupture, leading to circulatory collapse. Third, general procedural steps of fenestrated/branched endografts may be fundamentally unsuitable for ruptured unstable TAAA. The aneurysm is not sealed until the last of the numerous components is deployed. In other words, the requisite time associated with target vessels cannulation and bridging stents before aneurysm is sealed can be prohibitively long in unstable ruptured TAAA.

We selected the antegrade in situ laser fenestration technique for our patient, because this technique allows for a rapid aneurysm seal before target branch incorporation under local anesthesia. Once an aneurysm seal is achieved, liberal resuscitation is initiated. At this point, general anesthesia can be induced if needed. There is no need for fenestration or branch cuff alignment, which makes the deployment of aortic components and sealing of the rupture rapid. Creation of in situ fenestration is immediately followed by target branch stenting. Therefore, the aneurysm seal is not disrupted as each viscerorenal branch is sequentially incorporated.

Several aspects of this technique should be noted. First, the ischemia time to the target vessels is additive. Although the sequence of in situ fenestration that we chose was SMA, renals, followed by celiac, it would be reasonable to create renal fenestrations first, followed by visceral arteries. This approach would decrease warm ischemia time to the renals. Even though our patient had 24 and 75 minutes of ischemia time to the left and right renal arteries, respectively, our patient remarkably did not have significant postoperative renal dysfunction. Second, rapid aneurysm seal by deployment of a single thoracic stent graft was possible in this case owing to an extent 1 TAAA with suitable distal seal zone in the infrarenal aortic segment. In other types of TAAA, implantation of bifurcated endograft would be required before the aortic seal is achieved. Although this maneuver was not necessary in our case, conduct of the operation would be similar to infrarenal aortic rupture in implanting a bifurcated stent graft in addition to the thoracic stent graft. This process could add to warm ischemia time significantly. Third, angulated target artery take-off can make a down-the-barrel view difficult to achieve, therefore increasing difficulty in creation of in situ fenestration. This was the case for the left renal artery in our patient, resulting in significantly longer procedural time. As such, target vessel anatomy should be considered in choosing this technique.

Although three-dimensional fusion imaging is a valuable adjunct during fenestrated/branched endovascular aortic repair, we elected not to use this technology for this case for two reasons. First, the time it takes to register the fusion imaging adds to the total operative time. Second, patient movements under local anesthesia can cause misalignment of fusion imaging. Prestenting the branch vessels provided a more reliable visualization of the target for fenestrations in an awake patient.

Antegrade in situ fenestration has been described in a report by Le Houérou et al[10] that included 16 consecutive patients, 3 of whom were symptomatic and none with unstable rupture. We have modified this technique. Le Houérou et al used a 16F steerable sheath and a 0.9 mm laser probe, whereas we prefer a 7F steerable sheath and 2.3 mm laser probe. This strategy allows for continuous use of a 0.035 platform, thereby limiting wire exchanges and facilitating expeditious procedure. From our previous experience with in situ fenestrated zone 2 TEVAR, Medtronic thoracic stent graft was chosen as the aortic component. We feel that widely spaced stents and thin Dacron fabric facilitated the creation of the in situ fenestration. The Atrium iCast covered stents were used as the bridging stents, as they have been used in previous reports of in situ fenestrations.[6,7,10] Although this technique can be life saving for ruptured TAAA in the short term, it should be noted that our patient's follow-up is currently limited to 3 months. Long-term durability of this construct remains to be determined, particularly with respect to the lack of reinforcement around the in situ fenestration (Video).

CONCLUSIONS

Antegrade in situ laser fenestration technique is feasible for repair of ruptured TAAA. This technique allows for rapid control of bleeding with acceptable viscerorenal ischemia. Long-term follow-up, as well as prospective studies, are needed to further assess safety and efficacy of this technique.

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