Technical Note

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Electrosurgical In Situ Fenestration of Aortic Endograft

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Abstract

Purpose: Endovascular interventions have become the primary choice for treating complex aortic pathologies, particularly with the use of fenestrated and branched endografts. However, limitations, such as manufacturing time have restricted their applicability in urgent situations. This has led to explore alternative off-the-shelf solutions, including in situ fenestration. Within this technical note, we describe technical aspects of in situ fenestration using electrosurgical guidewire, in both antegrade and retrograde approaches, explaining advantages and limitation compared with other in situ fenestration techniques. **Technique:** The technique involves standard main body endograft deployment followed by targeted in situ fenestration using an electrified guidewire. Two illustrative cases are presented to demonstrate the technical aspects and clinical outcomes of this procedure. **Conclusion:** Electrosurgical in situ fenestration emerges as an effective technique for urgent treatment of complex aortic diseases. Further research is warranted to validate its safety and durability in larger patient cohorts.

Clinical Impact

Electrosurgical in situ fenestration allows to expand the feasibility of complex endovascular repairs in emegency settings. Electrosurgical in situ fenestration combines the benefits of thermal methods, offering broad availability and lower costs. Compared to other in situ fenestration techniques, the proposed technology allows for the creation of extremely small fenestrations with minimal and precise tissue disruption.

Keywords

in situ fenestration, complex aortic disease, aneurysm, septotomy, electrosurgical, electrosurgical in situ fenestration, in situ laser fenestration, arch, thoracoabdominal

Introduction

Endovascular repair using fenestrated and branched custom-made endograft represents the first line therapy for patients with a complex aortic aneurysm and high clinical risk. However, the applicability of these solutions has some limitations, mainly related to manufacturing time.

It has been estimated that the risk of aneurysm rupture is 6.1%±2.3% at 180 days of waiting time for custom-made devices.[1] Aneurysm diameter >70 mm is associated with an increased risk of rupture during the waiting period.[2]

In the urgent setting, off-label solutions have been proposed: parallel graft technique, physician modified endograft and in situ fenestration. The fenestration of the endograft can be obtained using mechanical and thermal methods, with different characteristics in terms of fenestration precision, availability, and costs. According to the target vessel intended to be fenestrated, antegrade or retrograde approaches can be performed. In this technical note, we describe technical aspects of the application of electrosurgical in situ fenestration for retrograde and antegrade fenestration of aortic endografts, explaining advantages and limitation compared with other in situ fenestration techniques.

Technique

We describe a new technique to perform in situ fenestration of endografts during aortic repair using an electrified guidewire.

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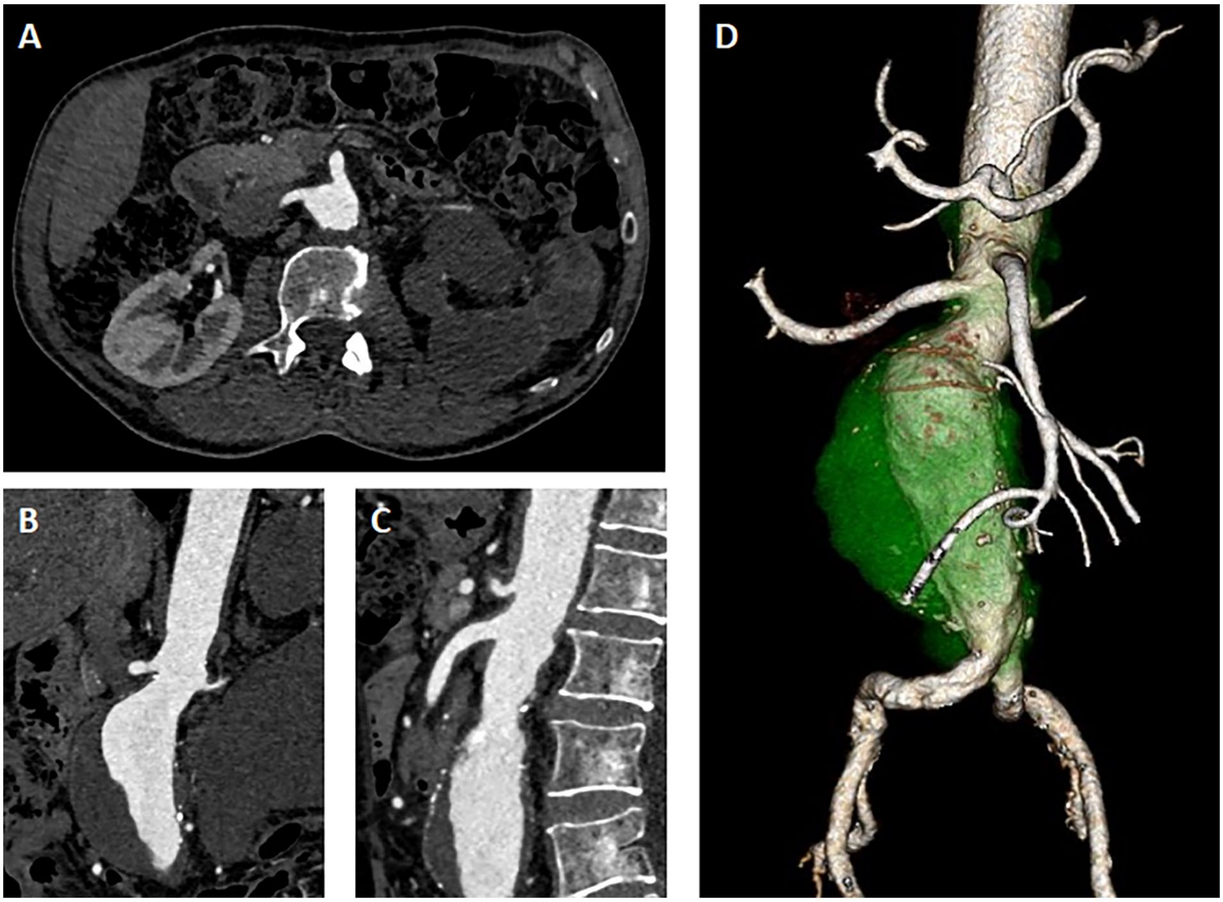

Figure 1. Preoperative CT scan. (A) Axial view of the aorta at the level of the superior mesenteric and right renal artery origin. (B) Coronal view of the juxtarenal abdominal aortic aneurysm. (C) Sagittal view of the suprarenal aortic segment. (D) 3D reconstruction.

Interventions were performed in a fully integrated hybrid room (Discovery IGS 740, GE HealthCare, USA) with onlay fusion (Vision, GE HealthCare, USA) and cone-beam computed tomography (CT) scan (Advantage Workstation, GE HealthCare) capabilities. Consent for treatment and publication was obtained before the intervention. Bilateral ultrasound guided percutaneous access was obtained and double Perclose ProStyle (Abbott Vascular, Plymouth, MN, USA) was preimplanted unilaterally or bilaterally, using the Preclose technique.[3] If an upper extremity access was required, ultrasound guided percutaneous access of the left radial artery was obtained. After endograft deployment with standard technique and target vessels coverage, stent-graft in situ fenestration was performed using an electrified guidewire. The modification of the Astato guidewire consisted in the removal of the coating for 2 cm at the distal end using a scalpel, until the metal is exposed. The modified guidewire is isolated with a catheter flushed with 5% dextrose to prevent blood coagulation.

We present 2 cases to highlight technical aspects of this procedure.

Case 1: Right Renal Artery and Superior Mesenteric Artery Electrosurgical In Situ Fenestration

A 75-year-old male patient with a past medical history of hypertension, previous myocardial infarction, severe chronic obstructive pulmonary disease (COPD) and left kidney atrophy with normal renal function (serum creatinine 0.9 mg/dL, estimated glomerular filtration rate—eGFR 83 mL/min/1.73 m^2) presented with a tender 6 cm juxtarenal abdominal aortic aneurysm. At the preoperative computed tomography angiography (CTA) scan, the right renal artery (RRA) and the superior mesenteric artery (SMA) originated at the same level, 10 mm below the take-off of the celiac trunk (CT); this aortic portion presented with a regular and constant aortic diameter of 24 mm (Figure 1). Total left kidney atrophy was confirmed by renal scintigraphy.

An endovascular procedure was planned, with a standard bifurcated main body to be deployed just below the CT with

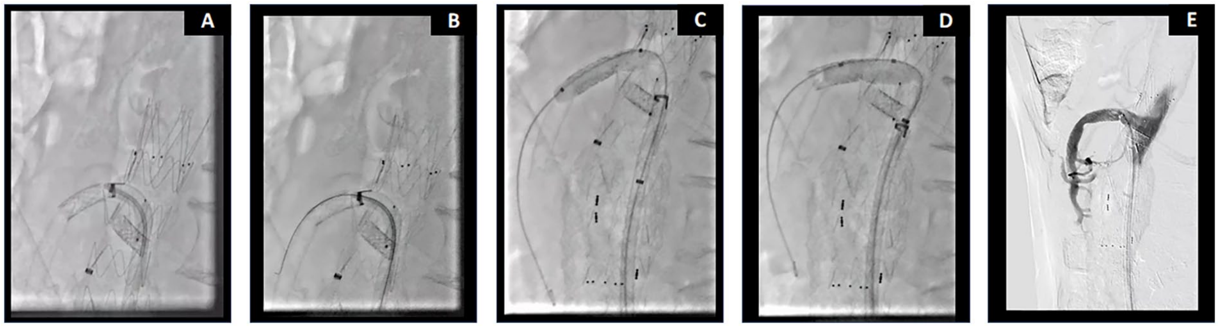

Figure 2. Intraoperative details. (A) Steerable sheath precisely oriented facing the origin of the SMA, based on the previous stent. (B) The modified guidewire is advanced into the superior mesenteric artery, after obtaining in situ fenestration of the main body. (C) Deployment of the bridging stent. (D) Flaring of the bridging stent. (E) Selective superior mesenteric artery angiography after bridging stent deployment.

SMA and RRA overstenting. Diameter of the graft was chosen considering a 20% oversizing, to obtain full graft apposition at the level of the visceral aorta and reduce the target vessel instability during the follow-up due to aortic wall-graft gap.

Revascularization of 2 target vessels was planned to be performed with in situ fenestration technique using an electrified guidewire.

After bilateral percutaneous femoral access was obtained, pre-stenting of the RRA and SMA was performed with BeGraft peripheral stents (Bentley InnoMed GmbH, Hechingen, Germany), to have a marker during the subsequent in situ fenestration. Left renal artery was plugged to prevent type II endoleak.

The bifurcated main body (Treo, Terumo Aortic, Inchinnan, UK) was deployed from the right femoral access in a cross-leg fashion just below the origin of the CT under onlay fusion guidance. The reason for the use of the Treo graft is that it has the longest main body (up to 90 mm above the bifurcation).

A 16 Fr 22 mm curvature Heli-FX steerable sheath (Medtronic, Santa Rosa, CA, USA) was oriented orthogonally facing the origin of the SMA, guided by the previous stent and onlay fusion. A modified Astato XS 20 0.014-inch 300 cm wire (Asahi Intecc USA, Santa Ana, CA) and a multi-purpose (MP) catheter were introduced.

After ensuring that the wire was fully isolated, the cautery was connected to the modified distal end of the wire, and the passage of current was switched on, by applying a 40 Watts power energy. The wire was advanced to achieve in situ fenestration of the main body, successfully entering the SMA. A 0.014-inch CXI Support Catheter (Cook Medical, Bloomington, Indiana, USA) was pushed over the Astato guidewire into the target vessel. At this point, MP catheter was pushed through the created fenestration over the 0.014 CXI to exchange the guidewire with a 0.035-inch Rosen (Cook Medical, Bloomington, Indiana, USA). The procedure was completed by performing the dilatation of the fenestration with a 6 mm diameter and 20 mm length balloon, the target vessel stenting with BeGraft peripheral stent and bridging stent flaring (Figure 2). The same technique was utilized to perform in situ fenestration for the RRA. The procedure was completed by adding the 2 iliac limbs.

Ischemia time was 10 minutes for the SMA and 25 minutes for the RRA.

Completion angiography demonstrated regular patency of the endograft and target vessels, in the absence of any endoleak. A non-contrast cone-beam CT scan was performed at the end of the procedure, and it displayed regular expansion of the bridging stent, with no evidence of kinking.

One-month follow-up CTA scan confirmed aneurysm exclusion, with target vessels patency and no type I/III endoleak or target vessel instability (Figure 3). No complications were observed at the 6-month follow-up assessment.

Case 2: Left Subclavian Artery Electrosurgical In Situ Fenestration

A 51-year-old male patient, with silent past medical history, was referred to our hospital for a type B acute dissection with recurrent pain and right lower limb malperfusion. At the CTA scan images, the dissection started from the left subclavian artery (LSA) and extended to the right external iliac artery, with collapsed aortic true lumen and right external iliac artery occlusion (Figure 4).

An endovascular procedure was planned utilizing the stabilize technique. Due to the absence of an adequate proximal landing zone distally to the LSA, the team opted for LSA retrograde electrosurgical in situ fenestration.

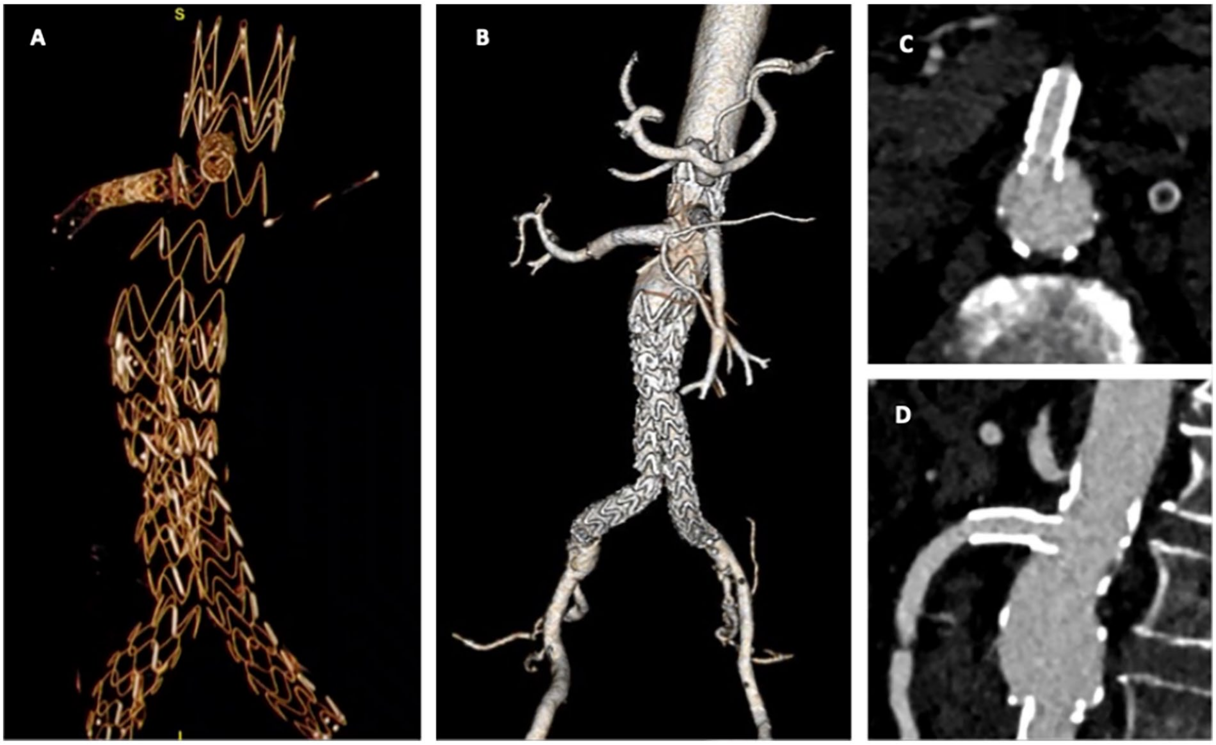

Figure 3. Post-operative CT scan. (A) 3D reconstruction of the cone-beam CT scan at the end of the procedure. (B) 3D reconstruction of 1-month post-operative CT scan. (C) Axial view of the superior mesenteric artery at 1-month postoperative CT scan. (D) Sagittal view of the superior mesenteric artery at 1-month postoperative CT scan.

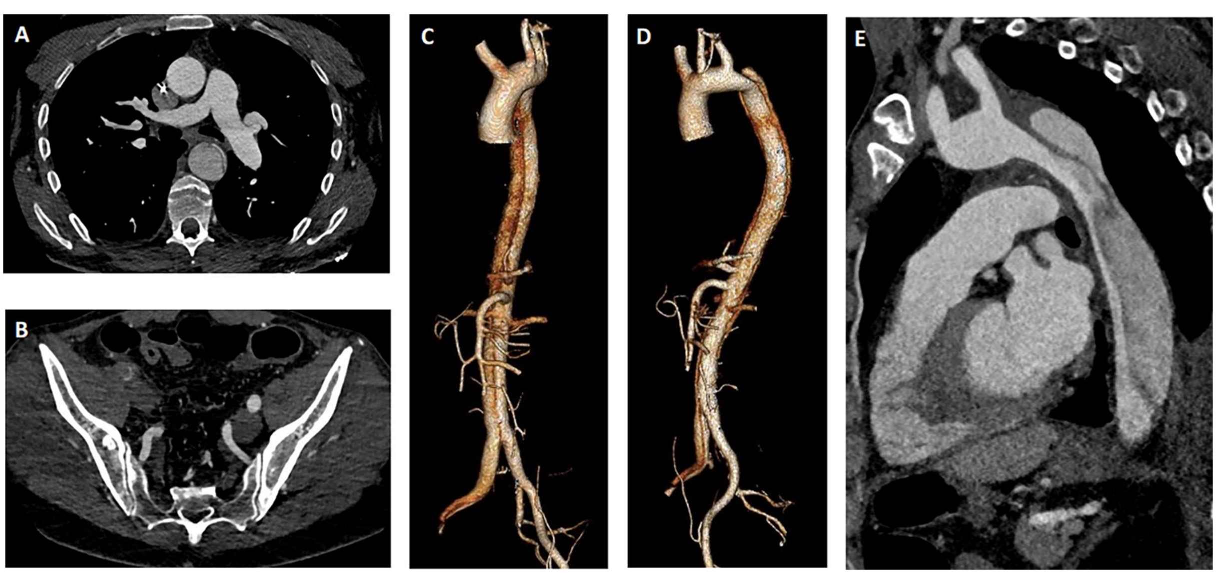

Figure 4. Preoperative CT scan. (A) Axial view of the thoracic aorta showing true lumen collapse. (B) Axial view of the iliac arteries showing complete thrombosis of the right external iliac artery. (C, D) 3D reconstruction. (E) Sagittal view of the thoracic aorta.

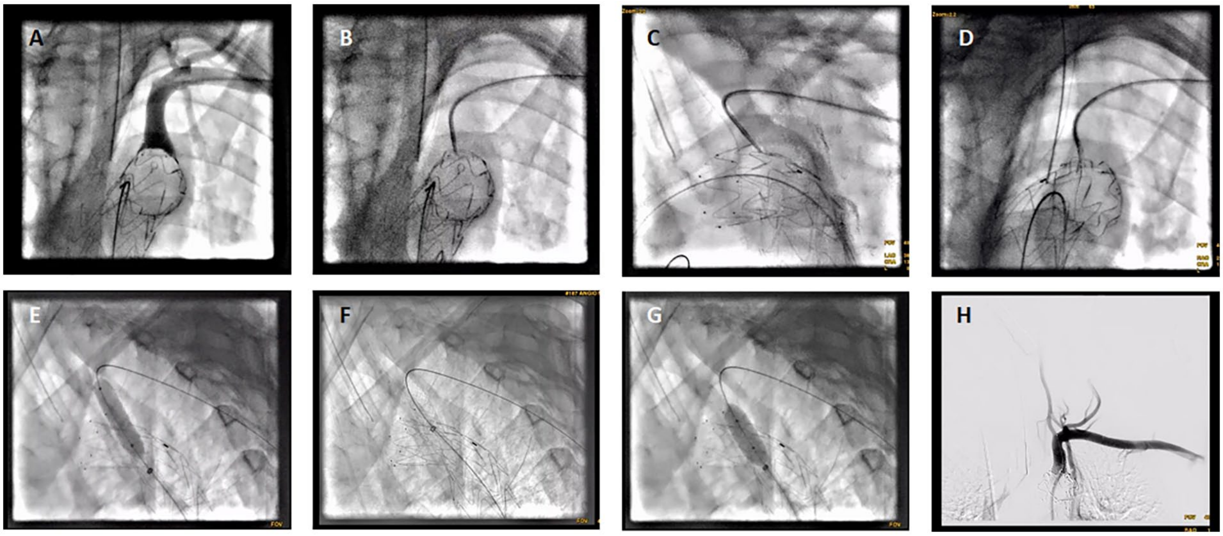

Figure 5. Intraoperative details. (A) Selective angiography of the left subclavian artery. (B, C) Guiding catheter positioned perpendicularly to the graft, confirmed in 2 projections. (D) The modified guidewire is advanced into the descending thoracic aorta, after obtaining in situ fenestration of the main body. (E, F) Deployment of the bridging stent. (G) Flaring of the bridging stent. (H) Selective left subclavian artery angiography after bridging stent deployment.

After bilateral percutaneous femoral access and left percutaneous radial access was obtained, a thoracic endograft (Relay Pro, Terumo Aortic, Inchinnan, UK) was deployed distally to the left common carotid artery, with LSA overstenting. In this case, a 10% oversizing was chosen due to the underlying aortic disease. A dissection stent (Zenith Dissection Endovascular Stent, Cook Medical, Bloomington, Indiana, USA) was deployed at the level of the visceral vessels. Ballooning of both the thoracic endograft and dissection stent was performed according to the stabilize technique, to improve true lumen expansion and false lumen remodeling.[4]

According to the orientation of the LSA, a 6F JR 4.0 guiding catheter was advanced from the left radial artery into the LSA, until contact with the endograft was obtained. As previously described, a modified Astato XS 20 0.014-inch 300 cm wire connected to the cautery was used to perform the electrocautery in situ fenestration for the LSA. After obtaining the fenestration, the modified guidewire was snared from the right femoral artery, obtaining a through-and-trough wire. A 6 Fr × 90 cm sheath was advanced from the right femoral artery over the through-and-through guidewire. Dilation of the fenestration was performed with 6 mm × 20 mm balloon and a VIABAHN VBX Balloon Expandable stent (W.L. Gore & Associates, Flagstaff, Arizona, USA) was placed as bridging stent in the LSA. Flaring was performed with standard technique (Figure 5).

The procedure was completed with stenting of the right iliac artery to address right lower limb malperfusion, using a covered balloon-expandable stent at the common iliac artery and an uncovered self-expandable stent in the external iliac artery.

Completion angiography demonstrated regular patency of the endograft, as well as the supra-aortic vessels and visceral vessels, and the iliac axis bilaterally, with no evidence of endoleaks. Non-contrast cone-beam CT scan confirmed regular expansion of the LSA bridging stent.

The postoperative course was uneventful, with complete resolution of the right lower limb malperfusion. Three-month follow-up CTA scan confirmed normal patency of the aortic endograft and LSA bridging stent, complete thrombosis of the false lumen, in absence of radiological signs of malperfusion (Figure 6). At the 6-month clinical evaluation, no complications were detected.

Discussion

In this technical note, we presented the adoption of electrosurgical wire for in situ fenestration of aortic endografts to allow target vessels revascularization during complex endovascular aortic procedure. In situ fenestration is performed by carefully aligning the wire orthogonally to the target vessel and advancing it through the endograft while activating the cautery to create the fenestration.

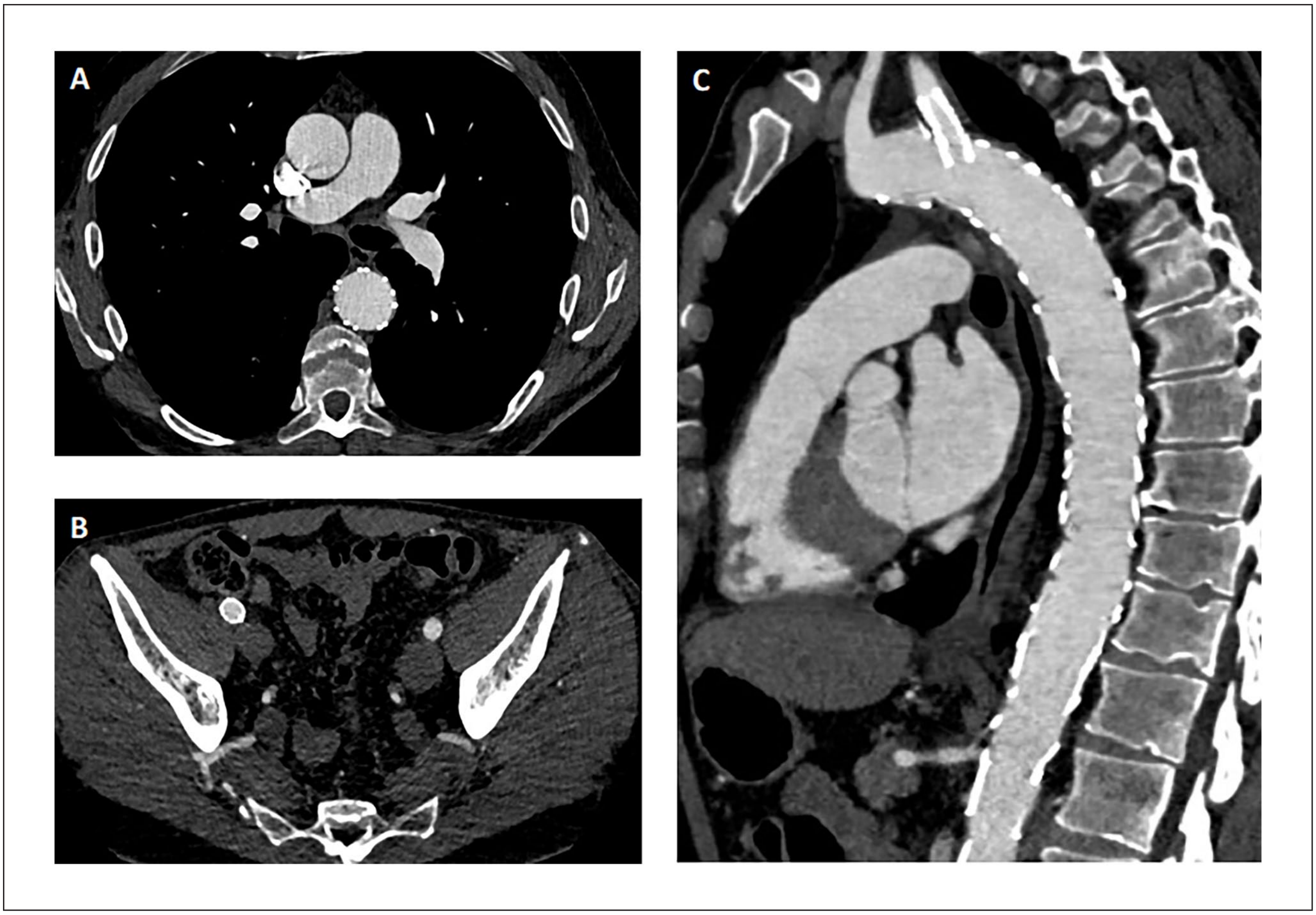

Figure 6. Three-month postoperative CT scan. (A) Axial view of the thoracic aorta showing true lumen expansion. (B) Axial view of the iliac arteries showing patency of the right external iliac stent. (C) Sagittal view of the thoracic aorta.

Different endovascular solutions are available to treat aortic arch and thoracoabdominal aorta. Custom-made fenestrated and branched devices have well-documented high technical success and durable outcomes both for treating aortic arch and thoracoabdominal aorta diseases, as well as juxta/pararenal aortic aneurysms.[5,6] However, time for graft manufacturing is the main limitation for applicability of these technology, which basically cannot be used in the urgent setting.

Many off-the-shelf solutions have been proposed to treat urgent patients deemed unfit for open surgery: off-the-shelf branch endograft, parallel graft, physician-modified endograft, and in situ fenestration. The main limitation of off-the-shelf branched solution for thoracoabdominal aorta are the instruction for use (IFU) and the extensive aortic coverage that exposes patients to a higher risk of spinal cord ischemia. Off-the-shelf solutions for the aortic arch are currently limited to single-branch endograft, which necessitate extra-anatomical bypass when a proximal landing in zone 1 or above is required. In addition, the applicability is constrained by IFU in this case as well. Parallel graft technique is associated with gutters, which limits the durability of the endovascular repair and is suggested for the treatment of maximum 2 target vessels.[7] Physician modified endograft requires accurate planning, otherwise misalignment can occur, and the manufacturing time is an important limitation for its applicability for the treatment of hemodynamically unstable patients.

In situ endograft fenestration has been reported to be a safe and effective therapeutic option for treating aortic arch disease with high technical success and low complication rates. The vast majority of the fenestrations are retrograde fenestrations performed to preserve LSA during zone 2 aortic arch disease endovascular treatment.[8,9] These procedures require reinterventions in 3% to 5% of patients and the reported overall mortality during follow-up ranges from 7% to 15%.[10,11]

More recently, in situ fenestration technique for emergency repair of complex abdominal aortic aneurysm has been demonstrated to be feasible and safe with satisfactory early and mid-term results. Technical success of this techniques, which requires antegrade fenestration of usually prestented visceral vessels, has been reported in 97% of the cases.[12]

Endograft fenestration can be obtained using either mechanical or thermal methods. The mechanical fenestration technique utilizes penetrating tools, making it the easiest technology. These include guidewires, different types of needles (ie, trans-septal, biopsy, and endoscopic ultrasound) and re-entry catheters. Although not excessively expensive, considerable force may be required to drive perforation tools through the graft material. Controlling this force is challenging, as it can lead to unexpected tool movements, potentially damaging or puncturing the vessel wall. Thermal methods consist in diathermy needle, radiofrequency probe, and a laser system, which represent the most used tool in the reported literature. Main limitation of this technology is represented by availability and elevated cost.

Transcatheter electrosurgery comes from cardiological experience, with applications in traversing occlusions, traversing tissue planes, and leaflet laceration.[13]

More recently, this technology has been applied in vascular surgery for aortic septotomy during endovascular repair of chronic post-dissection aortic aneurysm, and the results are promising.[14–16]

Electrosurgical in situ fenestration has the advantage of thermal methods, with wide availability and lower costs. Compared with others in situ fenestration technique, the proposed technology enables the creation of very small fenestration with minimal and precise fabric tears.[17]

There are 2 potential methods for fenestrating a stent-graft: the retrograde approach, which involves percutaneous access to the downstream vessel and modification of the fabric from the external surface of the graft, and the antegrade approach, where holes are created from the inside to the outside on the surface of the stent-graft at the intended target site. In this technical note, we presented and demonstrated the feasibility of both approaches.

One key advantage of graft electrosurgical in situ fenestration is the ready availability of the technology, which facilitates timely intervention. In addition, the low profile of the devices allows for easier manipulation of supporting catheters, enhancing procedural efficiency.

However, there are also some limitations to consider. One issue is the potential difficulty in advancing the catheter through the fenestration, which may necessitate pre-dilatation with a low-profile balloon or the need for multiple fenestrations. Furthermore, the behavior of the prosthesis and the unsupported fenestration over time poses a risk of fabric damage and subsequent target vessel instability.[17]

The angulation of the target vessel represents another significant technical challenge of this procedure. Correct orientation must be confirmed in 2 projections, and it is crucial to position the steerable/guiding catheter perpendicular to the graft to ensure optimal results.

Conclusion

Electrosurgical in situ fenestration can be considered an effective technique to perform fenestration of aortic endograft for urgent treatment of arch and visceral aorta disease. In this technical note, we detailed the step-by-step procedure for both antegrade and retrograde in situ fenestration using an electrified guidewire. Standardizing the technique and using appropriate device combinations for each step are crucial for ensuring procedural success. The safety and durability of the technique should be validated in future studies with larger sample sizes, particularly in relation to the behavior of endograft fenestrations during follow-up.

Declaration of Conflicting Interests

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