# In situ needle fenestration for revascularization of the left subclavian artery during thoracic endovascular aortic repair

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**Abstract:**

Intentional coverage of the left subclavian artery (LSA) is frequently performed during thoracic endovascular aneurysm repair (TEVAR) to ensure an adequate length of the proximal landing zone. Revascularization of the LSA, by either open surgical or endovascular means, is recommended in such cases to minimize the risk of stroke and spinal cord ischemia. Herein we describe the successful use of the in situ needle fenestration technique in a patient undergoing TEVAR with LSA coverage for the treatment of a chronic type B aortic dissection with a descending thoracic aorta diameter of 7.5 cm. An adjustable puncture needle in conjunction with a steerable sheath was used for the creation of the fenestration which was sequentially dilated with balloons of gradually increasing diameter. A balloon-expandable covered stent was subsequently used as a side branch. Computed tomography angiography one month after the procedure revealed complete thrombosis of the dissecting aneurysm.

## INTRODUCTION

The latest ESVS guidelines on the management of descending thoracic aorta diseases recommend that, in patients with chronic aortic dissection, an aortic diameter greater than 60 mm should be considered as an indication for treatment in patients at reasonable surgical risk (Class IIa, Level of evidence C).[1] Endovascular repair should be considered in such patients, provided that the anatomy is suitable for endografting and that the centre is dedicated (Class IIa, Level of evidence C).[1] One of the most important determinants of suitability is the length of the proximal landing zone, with the application of traditional thoracic endovascular aneurysm repair (TEVAR) requiring a proximal landing zone of at least 2 cm. The problem of an inadequate proximal landing zone can be overcome by the intentional coverage of the LSA, which is associated, however, with an increased risk of stroke and spinal cord ischemia.[1,2] Therefore, preventive LSA revascularisation should be considered in elective TEVAR cases when it is planned to intentionally cover the left subclavian artery.[1,3]

Several techniques have been used for the revascularization of the LSA during TEVAR, with open surgical techniques being the most frequent. These techniques include either carotid-subclavian bypass or carotid-subclavian transposition. More recently, endovascular procedures, including the chimney technique, in situ fenestration or customized fenestrated arch devices, have been introduced and gradually gain in popularity. Herein we describe the successful use of the in situ needle fenestration technique in a patient undergoing TEVAR with LSA coverage for the treatment of a chronic type B aortic dissection with a descending thoracic aorta diameter of 7.5 cm.

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## CASE REPORT

A 65-year-old male with history of a chronic type B aortic dissection presented to the outpatient clinic of our Department. The dissection had occurred 7 years before and was being treated conservatively. A few days before his appointment, the patient had been submitted to a computed tomography angiography (CTA) which verified the presence of the type B aortic dissection with the entry tear located at the inner curvature of the aortic arch, 1 cm below the origin of the left subclavian artery (LSA) (Figure 1). The aortic arch was bovine type, with the innominate and the left common carotid artery (LCCA) sharing a common orifice. The celiac and the left renal artery originated from the true lumen whereas the right renal artery originated from the false lumen. The superior mesenteric artery (SMA) was dissected down to the origin of the middle colic artery with the middle colic artery being supplied by the false lumen and the rest of the SMA by the true lumen. The dissection ended at the bifurcation of the right common iliac artery. The maximum diameter of the upper third of the descending thoracic aorta (DTA) was 75 mm, while the diameter of the middle and the lower third was 40 mm.

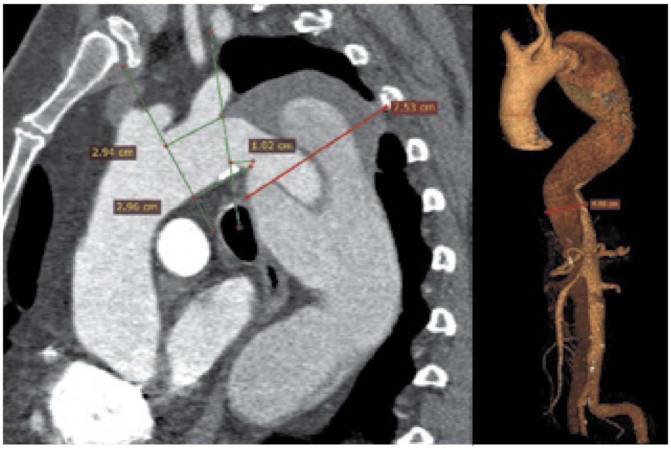

**Figure 1.** CTA showing a type B aortic dissection with the entry tear located at the inner curvature of the aortic arch, 1 cm below the origin of the left subclavian artery. The diameter of the descending thoracic aorta at the widest point was 7.5 cm, while the diameter of the middle and the lower third was 40 mm.

The patient had history of hypertension, dyslipidemia and heterozygous beta thalassemia. He did not report any thoracic or abdominal pain over the past 7 years.

Due to the lack of a landing zone with an adequate length below the LSA, endovascular repair with coverage of the LSA and revascularization through an in situ fenestration was decided. The procedure was performed in the operating room with the use of an OEC Elite CFD mobile C-arm (GE healthcare, Chicago, IL, USA). Under general anesthesia, the left common femoral artery (CFA) and the left brachial artery (BA) were exposed. Unfractionated heparin was administered by an intravenous bolus injection of 5,000 IU. A Lunderquist Extra-Stiff Wire (Cook Medical, Bloomington, IL, USA) was advanced through the left CFA to the ascending aorta and an 8F, 55 cm steerable Fustar sheath (Lifetech Scientific Inc, Shenzhen, China) was positioned to the aortic arch through the left BA. An 20 cm in length Ankura (Lifetech Scientific Inc, Shenzhen, China) tapered thoracic endograft with a proximal diameter of 40 mm and distal diameter of 36 mm was advanced over the Lunderquist wire. Systolic blood pressure was reduced to 80 mmHg, digital subtraction angiography was performed through the Fustar sheath and the endograft was deployed just after the common origin of the innominate and the LCCA, covering the orifice of the LSA. The Fustar sheath was withdrawn into the proximal LSA and the puncture needle was inserted and stabilized at the origin of the LSA by inflating the balloon which is incorporated at the tip of the needle sheath. The needle was deployed piercing the fabric of the endograft (Figure 2) and a 0.014” wire was inserted into the endograft through the needle. The hole on the fabric was dilated with a 3 mm in diameter balloon and then the 0.014” wire was exchanged with a 0.035” standard wire. Sequential dilatations with a 5 mm and an 8 mm in diameter balloon were subsequently performed, followed by the placement of a 59 mm in length and 12 mm in diameter covered stent (BeGraft, Bentley InnoMed GmbH, Hechingen, Germany). Completion angiography confirmed the patency of the LSA and the vertebral artery as well as the absence of endoleaks.

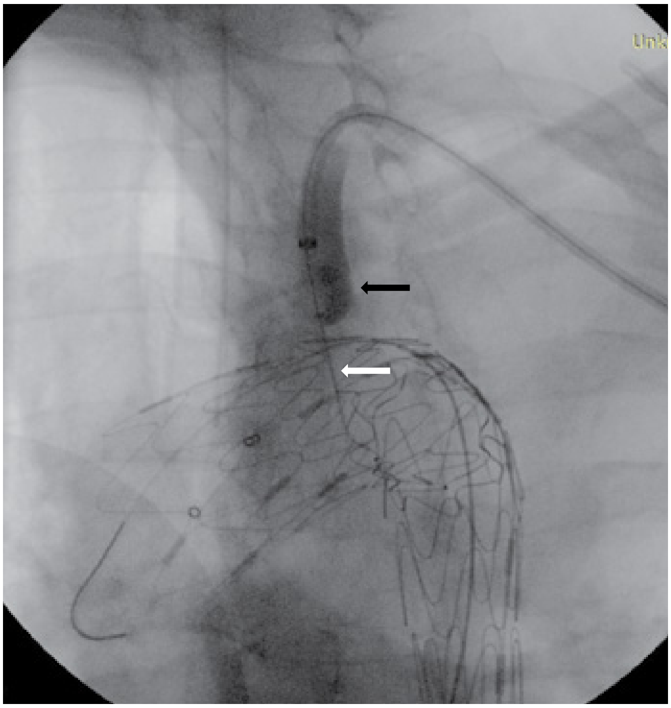

**Figure 2.** The thoracic endograft was been deployed in the aortic arch, the needle sheath has been stabilized at the origin of the LSA by inflating the balloon (black arrow) and the needle has been pushed through the endograft fabric (white arrow).

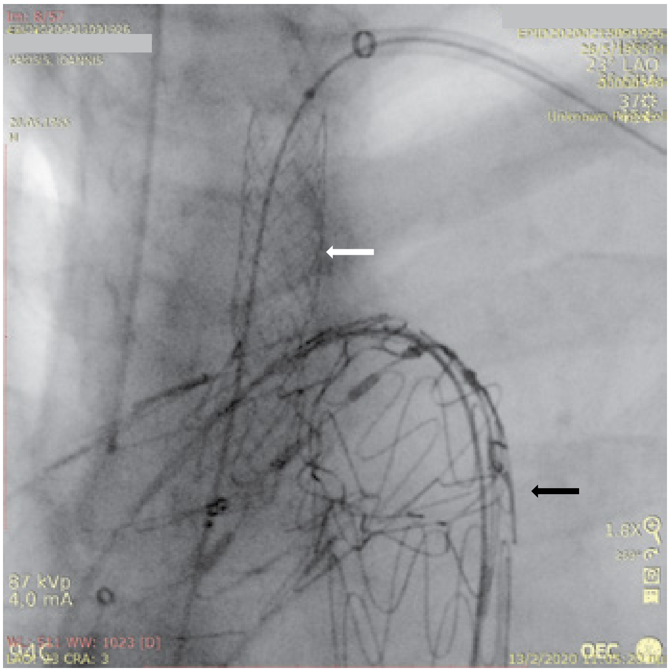

**Figure 3.** The thoracic endograft was been deployed in the aortic arch (black arrow) and a covered stent has been deployed through the fenestration (white arrow).

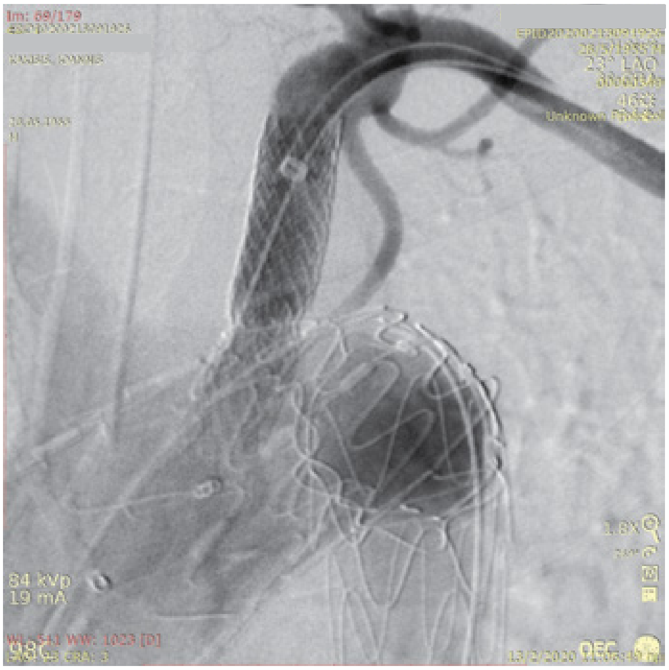

**Figure 4.** Completion angiography verifying the patency of the LSA and its branches as well as the absence of endoleaks.

The patient was discharged on the second postoperative day. CTA at 1 month showed no endoleaks and complete thrombosis of the false lumen down to the level of the 11th thoracic vertebra (Figure 5). The false lumen at the level of the abdominal aorta remained patent, permitting perfusion of the right kidney, since the right renal artery originated from the false lumen. The diameter of the abdominal aorta at the level of the diaphragm was 4 cm whereas the diameter of the infrarenal aorta was 3.1 cm. Therefore, no further invasive treatment was deemed necessary and the patient was placed under surveillance.

**Figure 5.** CTA 1 month post-TEVAR showing no endoleaks and complete thrombosis of the false lumen down to the level of the 11th thoracic vertebra.

## DISCUSSION

Endovascular techniques for the revascularization of the LSA during TEVAR represent minimally invasive alternatives to the traditional carotid-subclavian bypass or transposition. Initially described for the rescue of an inadvertently covered LSA, the chimney technique is limited by the possibility of gutter-related type Ia endoleak, the incidence of which was 19% in the most recently published series,[4] whereas chimney stent occlusion occurs much less frequently.[4,5] In an effort to cope with these problems, the method of in situ fenestration was introduced, initially for the emergency treatment of acute traumatic thoracic transection[6] and gradually for the endovascular treatment of practically all thoracic aortic pathologies, including aneurysms, dissections, penetrating aortic ulcers, intramural hematomas and coarctations.[7]

There are three main techniques for the in situ creation of a fenestration: laser, radiofrequency and needle puncture. They all share the same advantages of rapid use in off-the shelf endografts, without the risk of gutter-related endoleaks and stent compression. Technical success rate exceeds 93% and the risk of type II endoleak from the LSA is only 2%.[7-9] Of major concern, however, is the damage caused by these fenestrations to the endograft fabric. Based on studies of material properties, Crawford et al have reported that an energy-based fenestration technique (radiofrequency or laser) is preferable to needle-based techniques as it is associated with less fabric fraying.[8] On the contrary, Jayet et al have shown that needle-based fenestrations cause less mechanical resistance loss and lower leak rates through the stent-fenestration interface.[10]

Medical literature is also inconclusive regarding the best endograft to be used for the fenestration. Both polytetrafluoroethylene and Dacron endografts have been successfully fenestrated. Canaud et al have reported that the stent-graft material has no impact on the quality of fenestrations.[11] On the other hand, Eadie et al found that the Zenith fabric (Cook Medical LLC, Bloomington, IN, USA) had the greatest strength after fenestration, but was limited by the inability to fully dilate the fenestration with the conventional balloons.[12] The Talent and Endurant grafts (Medtronic CardioVascular, Santa Rosa, CA, USA) could be dilated with balloons, but the orifices were markedly elliptical not circular. After accelerated fatigue testing, there was an increase in the size of fenestrations of the Talent fabric, whereas there was no increase in fenestration size for the Endurant fabric, Zenith fabric, or the ePTFE fabric (Endofit, LeMaitre Vascular Inc., Burlington, MA, USA). Similarly, Lin et al showed that the fenestrations caused various degrees of tearing in all endografts, but this was more pronounced in the monofilament twill weave of the Talent graft, compared to the multifilament weave of the Zenith, Anaconda (Terumo Aortic, Vascutek Ltd, Scotland, UK) and Endurant endografts.[13] Another risk highlighted by these authors was that the low-energy laser fenestrations created apertures with fraying yarns and some poorly attached round debris which could lead to potential embolization of branch vessels. In any case and regardless of the graft material, the puncture/dilation angle makes a significant impact on the shape and quality of fenestrations, with the best fenestration quality achieved with 90° puncture/dilation angles.[14]

The selection of the appropriate stent for the side branch poses another dilemma. Interestingly, almost all stents have been used including both covered and bare metal stents: the balloon-expandable covered stents Jostent (Abbott, Vascular Instruments, Rangendingen, Germany), Advanta V12 (Maquet Cardiovascular, Hudson, NH, USA), BeGraft (Bentley InnoMed GmbH, Hechingen, Germany), and Lifestream (Bard Peripheral Vascular, Inc, Tempe, AZ, USA), the self-expanding covered stents FLUENCY (Bard Peripheral Vascular, NJ, USA) and Viabahn (W.L. Gore Associates, Inc, Flagstaff, AZ, USA), as well as bare metal balloon-expandable stents such as the Visi-Pro (Medtronic CardioVascular, Santa Rosa, CA, USA) or the Express LD (Boston Scientific Corporation, Marlborough, MA, USA). No direct or indirect comparison has been made among these stents when they are used as a side branch after an in situ fenestration.

It is also interesting that there are several types of needles that can be used for piercing an endograft and creating an in situ fenestration. Liver biopsy needles, percutaneous transhepatic cholangiography needles, aspiration biopsy needles, tracheal biopsy needles and even trimmed guidewires, the distal stiff end of which has been handmade into sharp needle shape preoperatively, have all been successfully used. The use of the Outback (Cordis, Bridgewater, NJ) as well as the Pioneer Plus (Volcano Corporation, San Diego, CA, USA) reentry catheter has also been described in single case reports.[15,16] Undoubtedly, the most sophisticated system, and the only dedicated so far, is the one described in our report, consisting of an adjustable puncture needle and a steerable sheath.[17]

Although the technique of in situ fenestration is relatively new, there have already been published a few studies reporting on the mid-term results in patients with aortic arch pathologies.[18,19] The main concern is the creation of a nonreinforced fenestration with a possibly increased risk for type III endoleak due to fabric damage and tearing. In a registry of 50 in situ fenestrations created in 25 patients, there were 2 early type III endoleaks and 2 additional after a mean follow-up of 32 months. All of them were treated by endolining and flaring of the connecting stent graft.[18] In conclusion, the technique appears to be a valuable alternative for LSA revascularization during TEVAR, but long-term results are needed before definitive conclusions are reached.

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