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► **To cite this version:**

Mathieu Pernot, Nicolas D'ostrevy, Antonio Piperata, Olivier Busuttil, Louis Labrousse. Percutaneous Total Aortic Arch Repair With In Situ Laser Fenestration. *Annals of Thoracic Surgery*, 2022, 114 (5), pp.e389-e392. 10.1016/j.athoracsur.2022.01.052 . hal-04567796

**HAL Id: hal-04567796**

**<https://hal.science/hal-04567796>**

Submitted on 3 May 2024

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# Percutaneous Total Aortic Arch Repair With In Situ Laser Fenestration

Mathieu Pernot 1, MD, PhD, Nicolas d'Ostrevy 1-2, MD, Antonio Piperata 1, MD, Olivier Busuttill 1, MD, and Louis Labrousse 1, MD, PhD

1 UMCV, Hopital Cardiologique de Haut-Leveque, Bordeaux University Hospital, Bordeaux, France

2 Department of Cardiac Surgery, CHU Clermont-Ferrand, France

## Abstract

Prosthetic replacement of the aortic arch requires a cardiopulmonary bypass and deep hypothermic circulatory arrest. Thus, it is associated with major perioperative risks, and custom-made devices have been developed. However, the time required for this procedure precludes emergency cases, and anatomical prerequisites limit the creation of appropriate devices. Here, we present a totally endovascular approach that allowed an exclusion of the aortic arch with the usual commercial devices. We explain, step by step, the procedure and the materials carefully selected for each step.

## Introduction

Aortic arch aneurysm treatment is a high-risk procedure associated with significant perioperative morbidity [1] and mortality; moreover, some patients are unfit for surgery. The first reports of using branched stent-grafts for aortic arch pathology demonstrated low mortality rates [2], but the stroke rates remained unacceptably high [3]. It is possible to perform full endovascular aortic arch exclusion with custom-made devices [4], but the time required to create these devices precludes this approach for emergency cases. We describe a total aortic arch endoprosthetic repair procedure, performed with the usual commercial devices, with extracorporeal circulation from femoral to supraaortic vessels and in situ laser fenestration.

## TECHNIQUE

**PREOPERATIVE PLANNING AND IMAGE FUSION GUIDANCE.** All procedures were performed in a hybrid room (Azurion, Philips Healthcare, Best, The Netherlands). The first step was to make a preoperative plan with Vessel Navigator software. We defined 2 landmarks in the ascending aorta for the proximal and distal limits of the proximal landing zone. We also placed 2 landmarks for supraaortic stenting: 1 at the bifurcation of the brachiocephalic arterial trunk and the other at the bifurcation of the left vertebral artery. We defined the diameters of the stents, as follows: for both the aorta and supraaortic trunks, in chronic aneurysmal pathology, the stents should be oversized by at least 25%; in aortic dissections, we recommend stents that are only 10% oversized. An unenhanced intraoperative cone-beam computed tomography (CT) should be acquired, and the surgeon should register both the preoperative CT and cone-beam CT images with landmarks. As the first option for landmarks, we suggest using vascular calcifications. As an alternative, the tracheal bifurcation can be used as a landmark. Then, the images are fused and used as a reference during the surgical procedure.

**EXTRACORPOREAL CEREBRAL SELECTIVE CIRCULATION.** Both common carotid arteries, the left subclavian artery, a femoral artery, and a femoral vein were dissected with a minimally invasive approach (ie, cuts of 2-3 cm). Intravenous heparin was administered, and the activated clotting time was monitored; it was over 300 seconds during the entire procedure. We cannulated the femoral vein with a 17F straight venous cannula (Medtronic Vascular, Santa Rosa, CA) and a 6F sheath for the implantation of a temporary pacing lead to stabilize the delivery of the prosthesis.

The 2 carotid arteries and the left subclavian artery were then cannulated with, respectively, angled and straight canulae. All the canulae were connected to the extracorporeal life support circuit, and cerebral selective perfusion was started. The 2 carotid arteries were clamped upstream of the cannulation sites and punctured upstream of the cross-clamping site for sheath implantation. The extracorporeal life support blood flow was adjusted, based on near infrared spectroscopy data (INVOS Somanetics, Troy, MI). The aortic stent graft was brought into position through the femoral arterial access, and released under rapid ventricular pacing. We recommend using 1 long module (at least 200 mm) to avoid a double Dacron (INVISTA, Wichita, KS) layer laser fenestration; we prefer to use a RelayPro (Terumo Aortic, Somerset, NJ), due to the thinness of the Dacron. After implantation, we exchanged the RelayPro loader with a dry-seal sheath (W.L. Gore and Associates, Flagstaff, AZ). The flush port catheter was used for monitoring both the visceral perfusion and the perfusion of the distal lower limb. Depending on the neck length, the Helix-FX EndoAnchor System (Medtronic Vascular) can be used to secure the endoprosthesis. IN SITU LASER FENESTRATION. Laser fenestration of the 3 supraaortic arch vessels was conducted retrogradely, through the femoral sheath. We performed a left carotid revascularization first, because performing a brachiocephalic arterial trunk stent first might introduce interference. For this step, we initially used the TourGuide Steerable Sheath (7F diameter, Medtronic Vascular, Santa Rosa, CA), with a long introducer. However, its stability was sometimes limited; thus, we currently prefer to use a Launcher internal mammary catheter (Medtronic Vascular). In our experience, the image obtained with the preoperative CT was sufficiently clear to obviate a new iodine injection (Figures 1A, 1B). However, when necessary, an iodine injection can be performed through the introducer, after placing it into the target vessel; this procedure might optimize the step. Next, a 0.9-mm laser catheter (Turbo Elite, Philips Healthcare), coupled to the CVX300 system (Spectranetics, Colorado Springs, CO), was positioned in the internal mammary launcher catheter. Then, antegrade fenestrations were performed by activating the laser probe for 2 to 3 seconds (wavelength: 810 nm, 14-18 W). After creating the laser perforation, a 0.014-inch, 360-cm Sion-Blue guide (Asahi Intecc USA, Inc, Santa Ana, CA) was used to catheterize the target vessels (Figures 2A, 2B). The Sion-Blue was retrieved with a lasso (EN-Snare, Merit Medical System, South Jordan, UT) through the target artery sheath. The guidewire was externalized through the introducer, and it was used as a cableway to insert a 2.5 to 3-mm peripheral cutting balloon (Boston Scientific, Marlborough, MA). After the balloon crossed the endoprosthesis, it was inflated. Through the target vessel sheath, on the Asahi Sion guidewire, a 0.035 Trailblazer support catheter (Medtronic Vascular) was pulled across the endoprosthesis fenestration to reach the launcher guide catheter. The Sion guidewire was replaced with a 0.35 Terumo radiofocus hydrophilic guidewire (Terumo Medical Corporation). On it, a standard percutaneous transluminal angioplasty balloon (Cordis, Santa Clara, California, US) was inflated to enlarge the fenestrated orifice, and a Bentley stent (Bentley InnoMed, Hechingen, Germany) was then delivered. Next, stent flaring was ensured with a proximal Cordis balloon inflation. After the complete revascularization of all target vessels, we removed the sheaths. The vessels upstream and downstream of the puncture site were carefully purged to avoid stroke. The puncture site for the sheath was repaired. After unclamping the vessel, the cardiopulmonary bypass was stopped in the corresponding cannula. The cannula was removed under near-infrared spectroscopy control, again purging the vessel and, when necessary, repairing it during a short carotid clamp. The operation was repeated on all target vessels. Final angiographic control was performed to check for any endoleaks confirmed by the postoperative CT (Figure 3).

## COMMENT

The first 6 patients to undergo implantations in our institution were treated in the last part of 2020 and the early part of 2021. All procedures were successful, and all patients recovered without neurologic, cardiac, or bleeding complications. The large number of operative steps explained the long duration of the operation. However, this technique makes it possible to simplify the postoperative course, compared with the reference surgery through a sternotomy, which requires complete cardiopulmonary bypass and hypothermia. In our opinion, the keys to preventing strokes were the control of cerebral embolic risk, by clamping and purging the vessels at the end of the procedure, and the use of 3-axis cerebral perfusion.

FIGURES

Figure 1

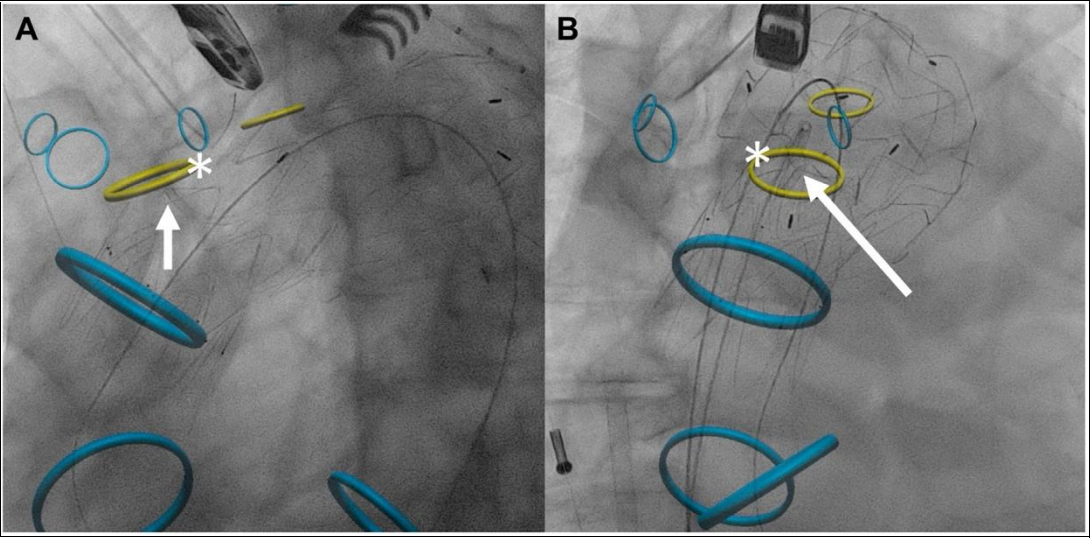


Figure 2

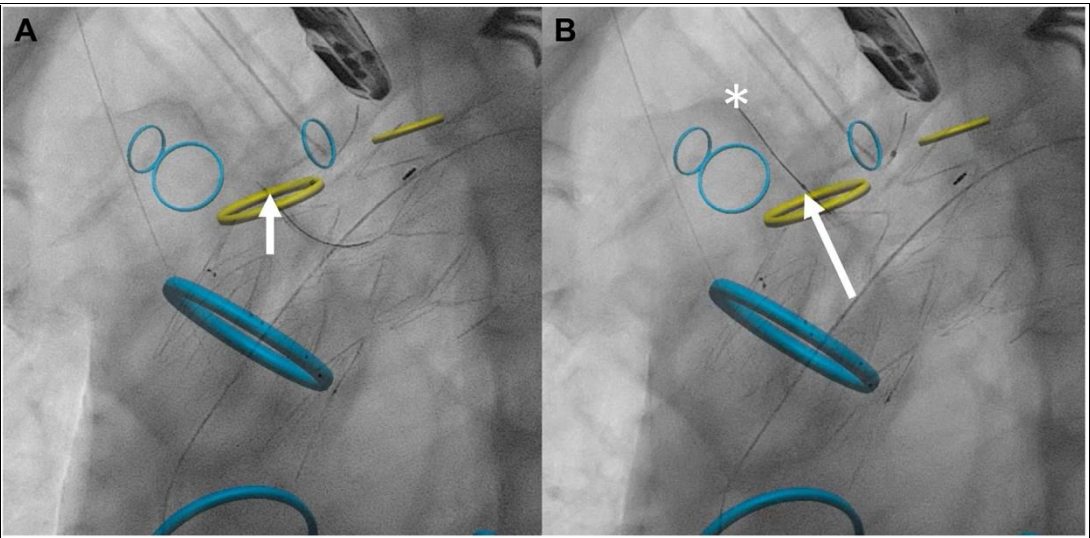
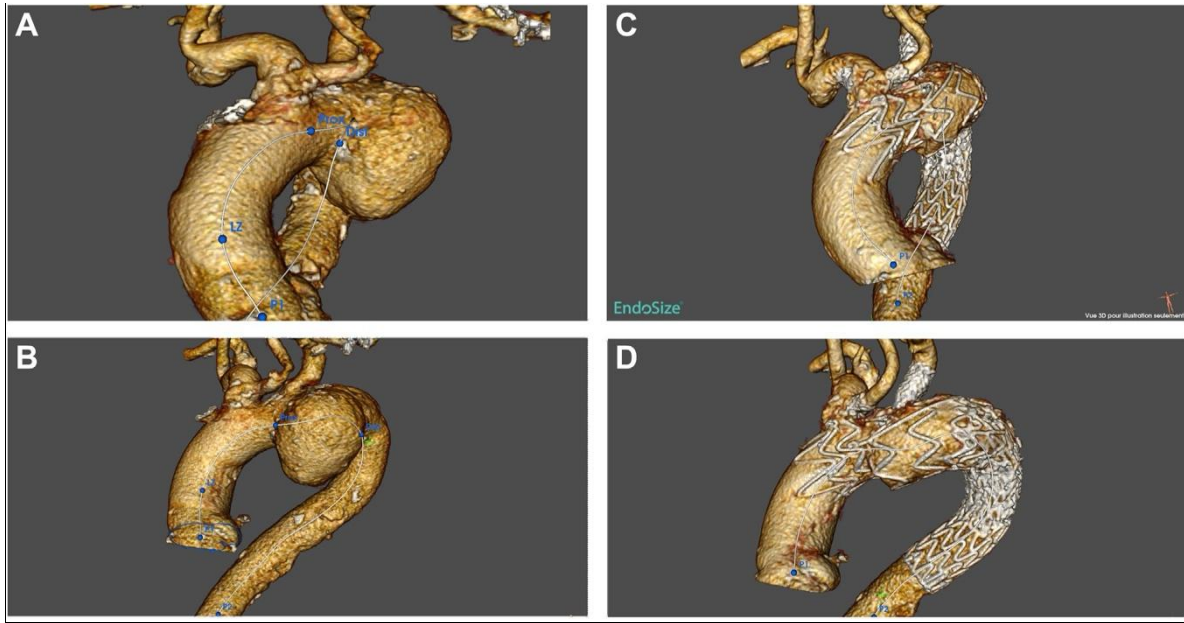


Figure 3



### Figure Legends :

FIGURE 1 Fusion of fluoroscopy and computed tomography images shows the tip of the internal mammary catheter (ar- row), positioned to face the future fenestration site (\*) on the left common carotid artery. (A) Front view; (B) side view.

FIGURE 2 Fusion of fluoroscopy and computed tomography images before (A) and after (B) fenestration. The internal mammary catheter carries the laser probe (arrow) and the Sion Blue (Asahi Intecc USA, Inc, Santa Ana, CA) guidewire through the fenestration (\*).

FIGURE 3 Three-dimensional volume rendering of preoperative and postoperative computed tomography. (A, B) Preoperative view of distal horizontal aortic aneurysm. (C, D) Postoperative views with identical angulations.

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