Experimental Evaluation of Complete Endovascular Arch Reconstruction by In Situ Retrograde Fenestration

Ludovic Canaud, MD, PhD, Elsa Madeleine Faure, MD, Pascal Branchereau, MD, Baris Ata Ozdemir, BS, MRCS, Charles Marty-Ané, MD, PhD, and Pierre Alric, MD, PhD

Department of Thoracic and Vascular Surgery, Arnaud de Villeneuve Hospital, Montpellier; and INSERM U 1046, Montpellier, France

Background. **The aim of this experimental study was to assess the feasibility of complete endovascular arch reconstruction by in situ retrograde fenestration and to investigate the impact of stent-graft material on stent-graft fenestrations.**

Methods. **The experiments were performed using 8 cadaveric human thoracic aortas (aortic arch) using 2 different stent-graft types: woven polyester (Valiant Captivia; Medtronic Vascular, Santa Rosa, CA) and expanded polytetrafluoroethylene (conformable [C]-TAG; W.L. Gore & Associates, Flagstaff, AZ). A benchtop aortic pulsatile flow model was used. Stent-grafts were deployed into the aortic arch, covering the ostia of the supraaortic trunks. A 5-mm 30-degree angioscope was introduced into the ascending aorta to monitor the procedure. Retrograde fenestration and deployment of the balloon expandable stent-graft was performed sequentially for each supraaortic trunk. Subsequent to stent-graft explantation, macroscopic evaluation of each fenestration was performed.**

Results. **All attempts to fenestrate the C-TAG and Valiant stent-grafts and implant the covered stent through the supraaortic trunks were successful. In all cases, branch stents were patent and no endoleak was evident. The Valiant stent-graft was easier to puncture because of the higher radial force of the stent-graft providing better counterpressure; however, stent-graft material had no impact on the quality of fenestrations.**

Conclusions. **Total endovascular repair of the aortic arch through in situ retrograde fenestration of stent-grafts is feasible. The behavior of the 2 types of stent-graft was significantly different while the fenestrations were fashioned, but stent-graft material had no impact on the quality of fenestrations.**

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Deep hypothermic circulatory arrest is required for cerebral protection during surgical repair of the aortic arch with replacement [1]. Mortality and morbidity associated with transverse aortic arch replacement in the standard-risk population has decreased over the past few decades with the implementation of various modifications of surgical technique. Despite these recent advances, aortic arch reconstruction remains challenging, particularly in elderly patients, those requiring emergency repair, and those with major preexisting comorbidities. Many patients are deemed unsuitable for open repair.

More recently a combined endovascular and open approach has been adopted as a valuable alternative, consisting of supraaortic debranching and revascularization followed by stent-graft deployment [2]. Debranching is performed to provide an appropriate landing zone for the stent-graft while preserving perfusion to the supraaortic trunks. Although this approach provides an attractive alternative for the treatment of pathologic conditions of the aortic arch, the majority of these adjunctive procedures remain major operations and are associated with significant perioperative mortality. Branched stent-grafts that permit completely percutaneous aortic arch repair have been proposed [3]. The disadvantages of this modular approach include the time required time to manufacture and deliver custom-made stent-grafts for urgent cases and the high costs associated these sorts of modular devices. Most notably, there is a high rate of embolism associated with this approach, which is probably related to the complexity of multibranched unibody stent-graft deployment.

The concept of retrograde in situ fenestration combines intentional stent-graft coverage of the supraaortic trunks with subsequent reestablishment of blood flow by retrograde puncture of the device. This approach is an attractive alternative that eliminates the need for preoperative custom tailoring (allowing repair of emergent cases) and the inherent risk of cerebral embolism associated with catheterization of difficulties side branches.

The aim of this experimental study was to assess the feasibility of complete endovascular arch reconstruction by in situ retrograde fenestration and to investigate whether the quality of stent-graft fenestrations varied with stent-graft material.

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Address correspondence to Dr Canaud, Service de Chirurgie Vasculaire et Thoracique, Hôpital A de Villeneuve, 191 av Doyen Gaston Giraud 34090, Montpellier, France; e-mail: ludoviccanaud@hotmail.com.

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Material and Methods

The study was approved by our institutional review committee. Consent was obtained from the relatives of each cadaveric aorta donor.

Harvesting and Preparation of Aortas

In accordance with French regulation, 9 fresh non-aneurysmal human aortas were harvested at autopsy from men and women who had died up to 4 days previously.

The aortas were harvested from 2 cm above the level of the aortic valve proximally to the iliac bifurcation distally. The brachiocephalic trunk, the left common carotid artery, and the left subclavian artery were harvested to maximal length. Each aorta was immediately packed in ice and maintained at 4°C. Experiments were performed within 2 hours of harvest. Aortic sections were sent to the Department of Pathology for microscopic evaluation (staining with hematoxylin and eosin) to confirm the presence of 3 layers of aortic wall comparable to fresh specimens.

Bench Test Model

A previously described benchtop closed-system pulsatile flow model was used to mimic aortic flow and pressure as close to normal physiologic conditions as possible [4].

Experimental Setup

PREPARATION OF AORTA. After harvest of the entire aorta, an 8-mm knitted polyester graft was anastomosed to the distal part of each supraaortic trunk. The distal end of the graft was then connected to a closed circuit to simulate antegrade flow into the aortic branch vessels during the experiment. Abdominal aortic branches were ligated 1 cm distal to their origin, and intercostal and lumbar arteries were oversewn. Each aorta was then coupled to the closed-system pulsatile flow model. Once each aorta was incorporated into the circulatory circuit, the pump was activated, leading to pulsatile flow: 60 pulses/min and pressure of 150/80 mm Hg.

MONITORING THE PROCEDURE. To monitor the procedure, a 5-mm 30-degree angioscope (Richard Wolf, Vernon Hills, IL,) connected to a video camera was introduced into the ascending aorta through a simple 3-0 purse-string Vicryl suture (Ethicon, Somerville, NJ) (Fig 1).

STENT-GRAFTS. Two types of commercial stent-grafts of 100-mm length (Fig 2) were used: the Valiant Captivia stent-graft (Medtronic Vascular, Santa Rosa, CA) and the conformable TAG (C-TAG) stent-graft (WL Gore & Associates, Flagstaff, AZ).

The Valiant is composed of a nitinol stent framework between layers of polyester graft. Individual stents are sutured to the outside of the polyester graft material. The proximal end features an open bare stent segment.

The C-TAG is composed of a symmetrically expanded polytetrafluoroethylene tube reinforced externally with a layer of expanded polytetrafluoroethylene. An exoskeleton consisting of nitinol stents is attached to cover the length of the graft.

Fig 1. Benchtop closed-system pulsatile flow model. A graft is anastomosed to the distal segments of the aortic arch side branches. To monitor the procedure, a 5-mm angioscope connected to a camera was introduced into the ascending aorta.

STENT-GRAFT PLACEMENT. Stent-grafts were deployed into the aortic arch, covering the ostia of the supraaortic trunks. Delivery of the covered stent was performed in a retrograde fashion.

RETROGRADE FENESTRATION. Retrograde fenestration and deployment of the balloon expandable stent-graft was performed sequentially for each of the supraaortic trunks (brachiocephalic trunk, left common carotid artery, and subclavian artery) using the same technique. The puncture of the stent-graft was performed using a 20-gauge needle, and a 0.035-inch guide wire was advanced through the aperture into the descending aorta. The graft puncture site was subsequently dilated by advancing a 5F introducer sheath with its dilator tip over the 0.035-inch guide wire. This was followed by dilation of the fenestration with a standard 4-mm angioplasty balloon (Wanda; Boston Scientific, Natick, MA). Thereafter, a balloon-expandable covered stent (Atrium Medical Corp, Hudson, NH) that was 22-mm in length (the diameter of which was selected by referencing the diameter of the supraaortic vessel treated; systematic oversizing of 1 mm), was passed and positioned across the fenestration. The balloon-expandable stent-graft was then deployed 5 mm into the aorta. Proximal flaring of the covered stent was initially performed using a non-compliant balloon (Coda; Cook Medical, Bloomington, IL) introduced through the supraaortic vessel. Final flaring of the covered stent was then performed using the same noncompliant balloon introduced through the abdominal aorta.

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