

Arch Disease: Pathology and Treatment Strategies

A review of the Gelweave™ Siena vascular graft, Thoraflex™ Hybrid device, Relay®Plus and Relay®Branch stent grafts used to treat total and distal arch pathology.

BY ROBIN H. HEIJMEN, MD, PhD, AND HECTOR W.L. DE BEAUFORT, MD, PhD

Open surgical repair of aortic arch pathology remains a challenge due to the anatomy with limited exposure of the distal region through median sternotomy, as well as the need for temporary cardiac, cerebral, and systemic circulatory arrest. Additionally, the left recurrent nerve encircles the distal arch and its injury may lead to troublesome hoarseness. Therefore, preoperative planning as well as surgical expertise are of utmost importance to achieve good surgical outcomes.

Hypothermia is routinely used to reduce the detrimental effects of ischemia during arrest but has its own associated risks. Deep hypothermic circulatory arrest ($\leq 20^{\circ}\text{C}$) provides a safe duration of cerebral arrest for approximately 30 minutes; however, this is usually too short for complex repairs. As an alternative, most surgeons apply antegrade selective cerebral perfusion (either unilateral or bilateral) at moderate systemic hypothermia ($\leq 28^{\circ}\text{C}$), providing a safe duration of systemic arrest for > 1 hour, which is long enough for most extensive arch reconstructions. However, the latter approach requires direct manipulation of the cerebral vessels, risking embolic stroke. Nonetheless,

following a strict protocol for heart, brain, and systemic protection, aortic arch surgery can be performed at a very acceptable risk.^{1,2}

OPEN SURGICAL REPAIR

The extensive range of standard polyester vascular grafts enables surgeons to individualize their approach to the respective arch pathology to be treated. All specifications of the Gelweave Siena vascular graft (Terumo Aortic) can be selected upon ordering (Figure 1). For instance, the side branch (Gelweave Siena Ante-Flo) permits antegrade perfusion to minimize circulatory arrest time. The four-branch design (Gelweave Siena Plexus) with complimentary diameters facilitates individual arch vessel reimplantation as an alternative to the “island technique,” as well as antegrade perfusion. The Gelweave Siena collar compensates for diameter mismatch between the distal aorta and graft and allows the surgeon to leave a short segment of graft floating in the residual downstream aorta (ie, elephant trunk) for staged extension. The radiopaque markers define the proximal safe landing zone in case of endovascular completion. However, completion of the elephant trunk by either staged open or endovascular means is necessary to fully exclude the pathology. Aside from the cumulative risk of both procedures, interval mortality up to 4% has been observed.³

HYBRID REPAIR

As an alternative specification, the polyester segment distal to the collar is also available in a stented configuration (ie, frozen elephant trunk).⁴ The Thoraflex Hybrid device (Terumo Aortic) comprises a proximal single- or multibranched surgical graft and distal stent (Figure 2). The diameter varies between the polyester graft proximally and the stent distally, which has a covered length of either 10 or 15 cm. In cases where the arch pathology extends into the proximal descending aorta, the patient can be treated in a single stage only using this midsternal hybrid approach (Figure 3). To reduce

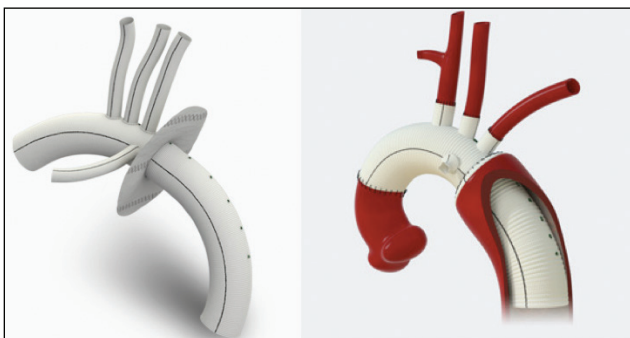


Figure 1. Gelweave Siena graft. A comprehensive range of product designs catering to a variety of both surgical techniques and patient needs for use during aortic arch and first-stage elephant trunk procedures.

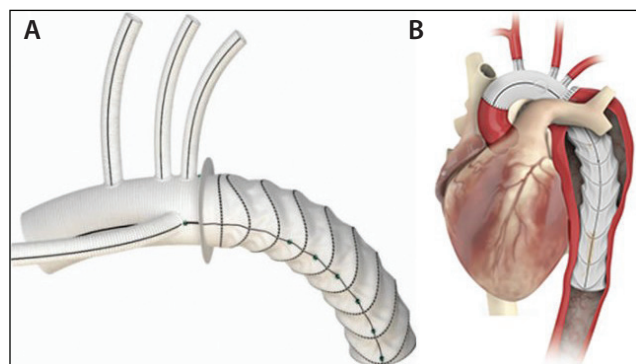


Figure 2. Thoraflex Hybrid device (A). Multibranched hybrid device that enables single-stage repair of extended arch pathology by combining endovascular treatment with conventional surgery (B). Reprinted from Di Marco L, Pacini D, Murana G, et al. Total aortic arch replacement with frozen elephant trunk (Thoraflex). *Ann Cardiothorac Surg.* 2018;7:451-453.



Figure 3. A 76-year-old man with concomitant two-vessel coronary artery disease and a moderately dilated ascending aorta presenting with hoarseness due to a large distal arch aneurysm. In the absence of other comorbidities, he was considered a good candidate for open surgical repair using the Thoraflex Hybrid device.

intraoperative complexity and thus the duration of systemic arrest risking spinal cord ischemia, the Plexus configuration enables proximalization of the distal suture line and also avoids the recurrent nerve. The anastomosis to the deep-lying left subclavian artery (LSA) can be managed with either single-stage or staged revascularization in the neck.

In addition to using this hybrid prosthesis for single-stage procedures, it is widely applied in more extensive downstream pathology. Using an endovascular trans-femoral approach, a RelayPlus stent graft (Terumo Aortic) can be used to complete the stented segment of the Thoraflex Hybrid device. The RelayPlus stent graft is designed with a spiral support strut (ie, S-bar), which provides longitudinal support; a precurved inner catheter;

and a dual-sheath system, consisting of a hydrophilic-coated reinforced outer sheath and flexible inner sheath for optimal aortic navigation. Proximal clamping allows for precise and perpendicular deployment.

In addition to its use in degenerative aneurysmal disease, the Thoraflex Hybrid device is also widely applied in acute and chronic dissections. The stented segment may act as a scaffold, inducing false lumen thrombosis and eventual aortic remodeling.⁵ However, the frozen elephant trunk technique may add to the complexity in this already complex subset of emergent patients. Attention should be paid to the potential increased incidence of spinal cord ischemia, and a careful comparative assessment is indicated in contrast to routine use. Nevertheless, in many selected patients at our center, the use of the Thoraflex Hybrid device in postdissection aneurysmal disease (ie, post-type A dissection repair by limited hemi-arch replacement only) has resulted in exclusion of the downstream false lumen and its remodeling and has avoided the otherwise-indicated second-stage repair of the descending aorta after conventional elephant trunk.

Because of all the necessary invasive adjunctive procedures, open surgery of aortic arch pathology may not be the best treatment option for all patients. Older patients with comorbidities may benefit from a less invasive approach that allows for quicker recovery.

ENDOVASCULAR REPAIR

Although most patients with descending thoracic aortic pathology can be easily and safely treated using a non-customized RelayPlus stent graft,⁶ the involvement of the arch vessels in arch pathology requires additional measures. Fortunately, there is a broad range of standard sizes and tapers that can be customized to the precise needs of the individual patient. Multiple designs are available with respect to diameter, taper, length, and body, requiring 3 weeks' delivery time. As an alternative to surgical revascularization of the LSA (or more complex endovascular alternatives such as in-situ laser or chimney grafts), a scalloped gate on the main body can proximally ensure blood flow while at the same time lengthening the landing zone (Figure 4).⁷ When combined with surgical debranching, a single scallop can be used to accommodate the left common carotid artery or the innominate artery more proximally. The pathology to be treated should be opposite the scallop to lower the risk of proximal endoleak. The maximum width of the scallop is limited by the stent graft diameter. In wide arch vessels, a fenestration on the main body can be an alternative if the anatomy allows proximal seating of the stent graft in the ascending aorta (Figure 5). A mechanical aortic valve may exclude its use due to interference with the nose

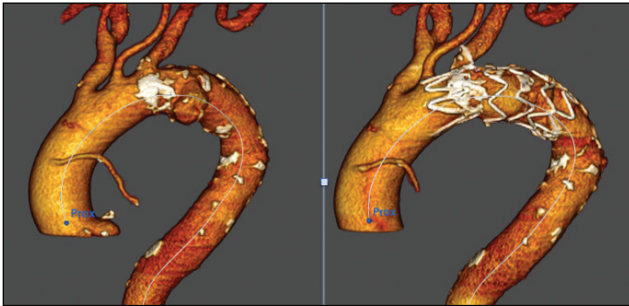


Figure 4. A 76-year-old man presented with a progressive distal arch saccular aneurysm. He had previously undergone endovascular aneurysm repair and coronary artery bypass grafting with a patent left internal mammary artery graft and had moderate left ventricular function. Given the medical history and aneurysm anatomy, he was considered a good candidate for a customized RelayPlus with a proximal scallop accommodating the LSA.

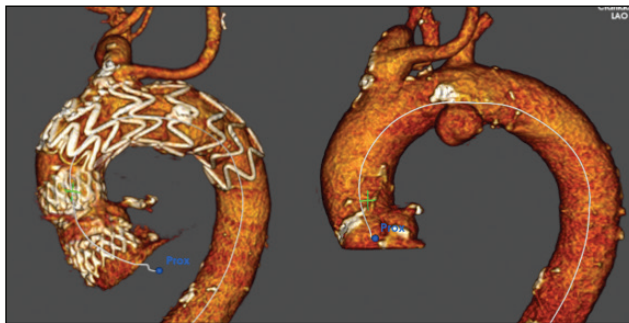


Figure 5. An 80-year-old man with severe chronic obstructive pulmonary disease and symptomatic severe aortic valve stenosis presented with a large arch aneurysm. Wide bovine trunk, excluding the use of a proximal scalloped RelayPlus. The patient was considered a good candidate for staged transfemoral transcatheter aortic valve implantation and fenestrated RelayPlus with concomitant surgical LSA revascularization.

cone. A moderately dilated ascending aorta (≥ 40 mm) may increase the risk of retrograde aortic dissection, and the presence of proximal anastomoses of aorta-coronary bypasses are also considered a contraindication for zone 0 seating.

More recently, the RelayBranch thoracic stent graft system (Terumo Aortic) was introduced as an alternative to open surgical repair in inoperable or high-risk patients.⁸ It consists of a main body graft that includes a large covered window with two internal tunnels designed to mate with branches that provide perfusion to the innominate and left carotid arteries. Usually, the LSA is surgically revascularized in this setting. Its use may be

limited by the anatomic requirements of a nondilated, lengthy proximal landing zone in the ascending aorta and nondilated, nondiseased supra-aortic vessels, together with adequate iliac access for the large-bore introducer sheath. Initial results are promising and demonstrate its effectiveness in excluding aortic pathology. Due to the required manipulations, the risk of neurologic injury is present. Careful patient selection and procedural handling are of the utmost importance, and its introduction should be carefully monitored.

CONCLUSION

The wide variety of standard surgical grafts, including graft (Gelweave Siena) and hybrid (Thoraflex Hybrid) devices together with the RelayPlus stent graft and its extensive custom-made program with scallops, fenestrations, and branches offer physicians the necessary range of options to solve a substantial amount of the challenges encountered in total and distal arch pathology. Thanks to currently available technology, the optimal mode of repair can be individually chosen after carefully weighing all available treatment options, preferably in a multidisciplinary setting at an aortic center of expertise.⁹

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Robin H. Heijmen, MD, PhD

Department of Cardiothoracic Surgery
St. Antonius Hospital
Nieuwegein, the Netherlands
r.heijmen@antoniusziekenhuis.nl

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Hector W.L. de Beaufort, MD, PhD

Department of Cardiothoracic Surgery
St. Antonius Hospital
Nieuwegein, the Netherlands

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