

A Review of New Thoracic Devices

A discussion of new stent graft designs for pathology of the thoracic aorta.

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Thoracic endovascular aneurysm repair (TEVAR) has proven to be a safe and effective therapy.¹⁻³ In the last 2 decades, TEVAR has been established as first-line treatment for most descending thoracic aortic pathology due to reductions in perioperative morbidity and mortality compared to open surgical repair.

Improvements in materials, reduction in delivery sheath size, improved conformability, tapered grafts, and a wider range of sizes have improved TEVAR applicability and outcomes over this initial decade of widespread use. Treatment of traumatic aortic transection, penetrating ulcerations, as well as acute and chronic type B aortic dissection is now routine.

Looking into the future, industry and physicians are working together to improve thoracic stent graft design to further improve safety, effectiveness, and applicability to a wider range of patients and aortic pathologies.

For this review, we will consider four different segments of the thoracic aorta: the ascending, the arch, the descending thoracic aorta, and the thoracoabdominal aorta. Each segment has specific pathologies and technical considerations, and each is the subject of ongoing device development. All of the devices discussed are investigational, and none of them are currently approved for use by the US Food and Drug Administration (FDA) outside of investigational protocols.

DESCENDING THORACIC AORTA

Current-generation TEVAR devices have undergone several rounds of design revision and improvement. Ongoing device improvements are intended to expand eligibility for patients with smaller-caliber iliofemoral arterial access, improve conformability with new proximal stent designs, and simplify deployment.

The Gore TAG thoracic endoprosthesis (Gore & Associates) has been in commercial use since 2005 in the United States, with approval of the Conformable

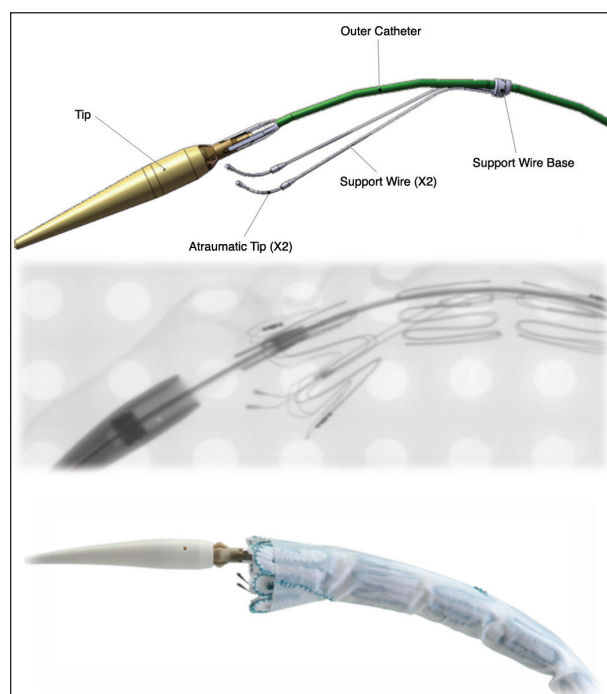


Figure 1. Relay NBS thoracic stent graft.

Gore TAG thoracic endoprosthesis in 2011. Gore & Associates is currently developing a new deployment system for the Conformable Gore TAG device that utilizes a multistage controlled release, analogous to the Gore C3 deployment system used for their Gore Excluder AAA endoprosthesis. Though details are limited, the system is designed to provide greater control and improve wall apposition even in complex anatomy.

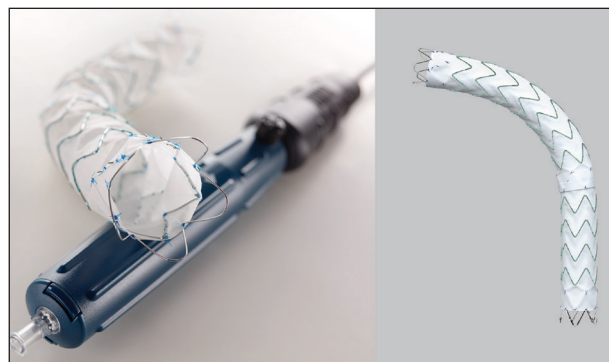
Medtronic's Valiant thoracic endograft has been in use since 2005. The device is available as both a FreeFlo device with proximal bare stents and as a closed-web design without proximal stents. The proximal FreeFlo device uses the Valiant Captivia delivery system to control the proximal stents and prevent distal migra-

Courtesy of Boston Medical.

tion during deployment. The closed-web design is approved for use as a distal component, and the device is deployed without separate control of the proximal end of the graft. Medtronic is working on an evolved design for enhanced applicability and increased patient customization, which will include a lower-profile delivery system and tip capture control for a proximal closed-web configuration. Controlled deployment of a stent without proximal bare stents may be beneficial in patients with acute aortic syndromes, where active fixation is rarely an issue and avoidance of new intimal injury is paramount.

Bolton Medical has two thoracic stent graft systems, the Relay Plus and the Relay NBS Plus. The Relay Plus system with a proximal bare-metal stent and proximal clasping mechanism is the only device currently approved for use in the United States and has been available since September 2012. The Relay NBS Plus system has no bare-metal stent on the proximal end and provides deployment control through the use of two internal nitinol support wires (Figure 1). The support wires allow for perpendicular deployment of the first covered stent, which improves wall apposition along the inner curve and reduces bird-beaking to maximize seal. Bolton Medical's next-generation descending thoracic stent graft, Relay Pro, maintains the characteristic features of the Relay Plus and Relay NBS Plus systems, but the profile is reduced (outer diameter [OD]) by 4 F across the portfolio, offering a profile of 19- to 22-F OD. The Relay Pro platform offers both the bare stent and NBS configuration and is made with the same materials as the Relay Plus and Relay NBS Plus. The reduced sheath size was achieved through modifications in the materials manufacturing and loading processes, as well as the addition of a mechanical advantage in the deployment system. The Relay Pro system is currently under investigation in Europe, and Bolton Medical is pursuing a clinical trial in the United States in 2016.

Cook Medical has a long track record with the Zenith TX2 thoracic endograft platform, having received FDA approval in 2008. This device uses stainless steel Z-stents and active proximal fixation with barbs. The graft has been redesigned with a nitinol Z-stents and proximal bare stent with barb fixation. The bare stents are designed to improve conformability. The device uses a precurved nitinol cannula to improve trackability around the genu of the aortic arch. The delivery process continues to have a manual deployment, but the trigger wire release has been changed to use a rotary dial. The device, called the Zenith Alpha thoracic endovascular graft (Cook Medical), has been commercially available in



Courtesy of Cook Medical.

Figure 2. Zenith Alpha thoracic endovascular graft.

Europe and Canada and just received FDA approval for commercial use in the United States in September 2015 (Figure 2). The device has a 2- to 4-F reduction in sheath size, now ranging from 16- to 20-F inner diameter. Grafts are available in diameters ranging from 18 to 46 mm, and indications include aortic aneurysm, penetrating aortic ulcer, and traumatic transection. Cook Medical is continuing the development of a combined proximal stent graft with a distal bare-metal stent for treatment of aortic dissection; this device is currently being studied in the United States.

If approved, the Relay Pro and Zenith Alpha would significantly lower the access sheath profile for the United States market. This is expected to improve treatment safety in patients with small or hostile iliac access, including women and younger trauma patients. Furthermore, improved conformability with these devices may improve safety and effectiveness for TEVAR when treating proximal descending thoracic pathology. The new devices with improved deployment control from Gore & Associates and Medtronic may also improve safety and effectiveness with improved deployment accuracy.

THORACOABDOMINAL AORTIC ANEURYSM

The first report of endovascular repair of thoracoabdominal aortic aneurysms (TAAAs) using branched endografts was published in 2001.⁴ Over the subsequent 14 years, reports from Europe and the United States using the Zenith t-Branch thoracoabdominal endovascular graft (Cook Medical) and custom-modified devices (CMDs) have shown consistent results in dedicated centers of excellence.⁵⁻⁷ However, the pathway to commercialization has been slow. At present in the United States, endovascular treatment of TAAAs is only available within physician-sponsored investigational device exemption (PS-IDE) studies, which has limited access to the technology. Three device manufacturers are currently working toward commercial devices for TAAAs.

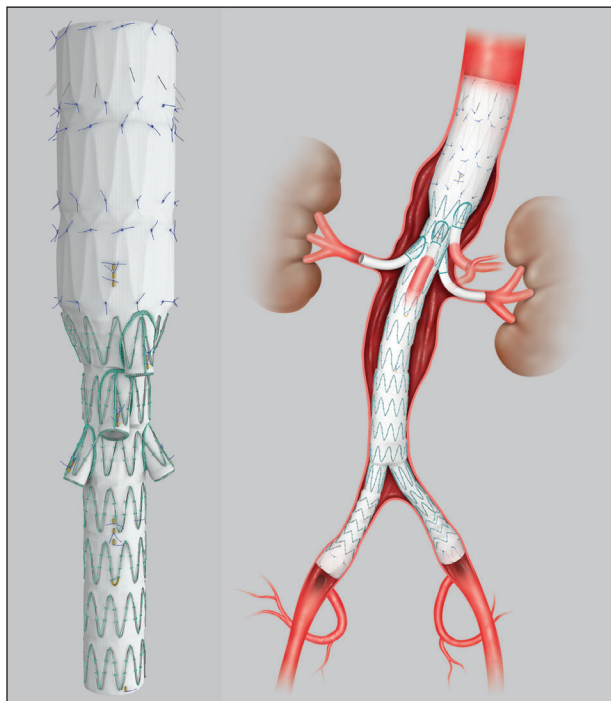


Figure 3. Zenith t-Branch thoracoabdominal endovascular graft.

The common challenge in device design for the thoracoabdominal aorta is the variability of the visceral branch anatomy. Fenestrated devices with custom fenestrations have been shown to work well in both commercial and physician-modified designs. However, device planning is time consuming and technically difficult. Commercially manufactured customized devices are more costly than off-the-shelf designs and take weeks or months to produce. As such, manufacturers are currently working to design off-the-shelf stent grafts with a “few-sizes-fit-most” approach.

Cook Medical was the first to develop a multi-branched aortic stent graft to treat the perivisceral aorta. The device has gone through multiple iterations over the last 14 years and currently consists of two device designs: t-Branch and CMD (Figure 3). The t-Branch design is intended to be a few-sizes-fit-most, off-the-shelf option with four downward-going external cuffs. The CMD devices are custom manufactured based on individual patient anatomy and utilize a combination of up- or downgoing branches and fenestrations. These two constructs have now been used in multiple centers in Europe and North America with excellent outcomes. Cook Medical is working toward a company-sponsored clinical study for a suite of thoracic-branched devices with both off-the-shelf and custom design options.



Figure 4. Gore Excluder thoracoabdominal branch endoprosthesis.

The Gore Excluder thoracoabdominal branch endoprosthesis is an off-the-shelf four-branched modular stent graft system (Figure 4). It uses a four inner-branched perivisceral aortic component. It has two downgoing branches for the mesenteric vessels and two upgoing branches for the renal arteries. The aortic devices are deployed, and then the renal arteries are selected using precannulated catheters from femoral access. Access is then obtained antegrade from brachial access to selectively catheterize and stent the mesenteric arteries through precannulated portals. The device is designed to be used with the Gore Viabahn endoprosthesis and Gore Viabahn BX endoprosthesis with balloon expandable technology (Gore & Associates). These stent grafts are flexible to improve performance in a variety of anatomy and the devices included the heparin-bonded antithrombotic surface coating, CBAS Heparin Surface. In-human deployments were first performed in Brazil in 2014, and therefore, clinical experience remains limited at this time. Gore & Associates is working toward initiation of an early feasibility study in the United States.

Medtronic is in development of a commercial device for TAAAs composed of a modular branched graft using a series of downgoing branches from a visceral manifold (Figure 5). The thoracic components are based on the Valiant platform, with a distal bifurcated device based on the Endurant platform. The system was designed in conjunction with Dr. Patrick Kelly (Sanford Health, Sioux Falls, South Dakota) and is currently in use in a PS-IDE study. Aortic devices are placed using femoral access, and all four target vessels are then selectively catheterized and stented from brachial access. The system is designed to allow the downgoing branches to be used for whichever target vessel best fits, so there is an added level of redundancy to this system provided there is sufficient aneurysm sac size to work within.

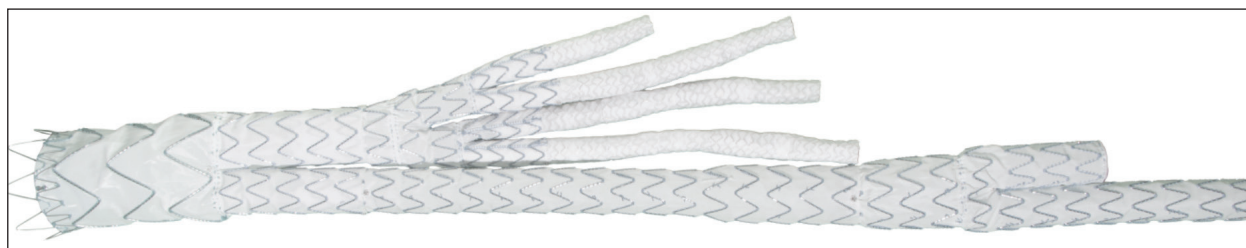


Figure 5. Thoracoabdominal stent graft.

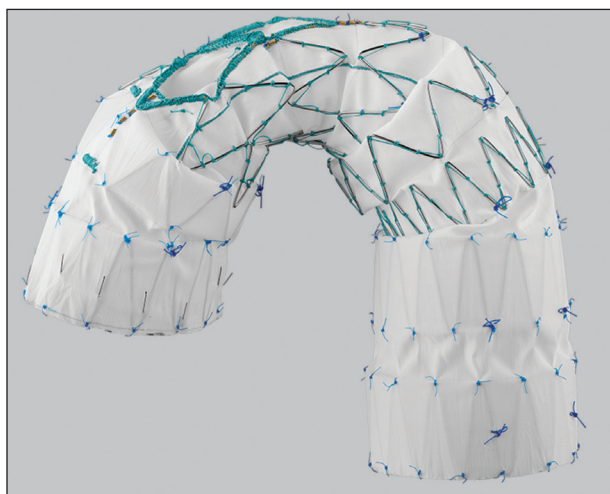


Figure 6. Arch branched stent graft.

Clinical experience with the grafts from Gore & Associates and Medtronic are limited at this time, but ongoing studies should provide data in the next few years. The design by Cook Medical has been the benchmark for safety and effectiveness of endovascular treatment of TAAAs, but several questions remain to be answered. It is unclear what percentage of patients will be eligible for an off-the-shelf design. Results thus far have been achieved in high-volume centers of excellence. Given the technical complexity of the cases, such centralization may be an important element to procedural safety. With approval of such devices, however, diffusion of the technology may allow access for more patients but with uncertain consequences for implantation success. Spinal cord injury remains a devastating complication of the procedure, and the incidence remains high at 7% to 8% in most series.⁵⁻⁷ Further efforts to reduce the incidence of spinal cord injury are needed.

AORTIC ARCH

Endovascular treatment of the descending and thoracoabdominal aorta has proven successful. The aortic arch is likely to be the next anatomic region approached with endovascular means.



Figure 7. Thoracic branch technology with Relay NBS Plus.

Two devices are currently under investigation in the European Union (EU) for treatment of aortic arch pathology. Both devices are designed for a zone 0 deployment in the ascending aorta with either one or two branches to the innominate alone or the innominate and left common carotid artery. Both designs are self-orienting to ensure that the branches align on the outer curvature of the aorta, and both have similar overall designs with an off-the-shelf, few-sizes-fit-most concept and modular branch components. Also, both designs utilize retrograde deployment of the aortic device with retrograde stent graft deployment from the carotid/subclavian vessels.

Cook Medical's arch-branch thoracic device is available in the EU, Canada, and South America and has been used in several PS-IDE studies in the United States (Figure 6). The system uses two inner-branch gates that are cannulated from cervical or arm access. Thus far, over 100 patients have been treated with this system, and the initial results are promising.⁸ The device is designed with a precurved nitinol cannula to facilitate conformability and tracking and to ensure device orientation, like that used in the Zenith Alpha thoracic device. Ascending aortic diameters must be ≤ 38 mm to ensure good proximal fixation and seal. Cook Medical is currently pursuing a company-sponsored study.

The other device with an initial in-human experience is the thoracic branch technology with Relay NBS Plus

Courtesy of Medtronic, Inc.

Courtesy of Bolton Medical.



Courtesy of Medtronic, Inc.

Figure 8. Valiant Mona LSA thoracic stent graft.

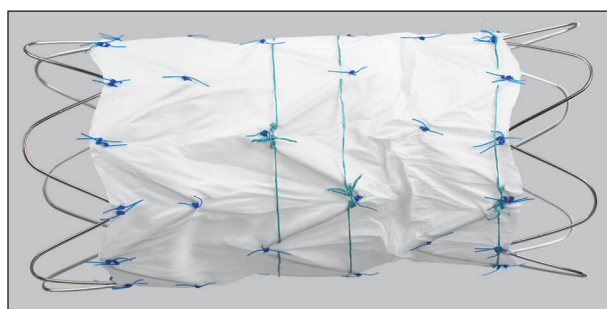
(Figure 7). This device is based on the Relay NBS Plus platform, so there is no proximal bare stent, and the same nitinol inner support wires are used to aid orientation of the device and improve device apposition to the inner curve of the aorta. The main graft utilizes Bolton Medical's precurved inner catheter to self-align the branch tunnels. Custom devices have been designed with one or two branches for an innominate or innominate and left common carotid branch. A standard device design for an off-the-shelf graft has not been finalized. Thus far, 47 patients have been treated with these custom devices in Europe (11 with single branch, 36 with double branches). Formal data from this initial in-human experience are not available at this time. The device is not currently studied in the United States; however, Bolton Medical is pursuing an early feasibility study.

Medtronic and Gore & Associates have designed stent graft systems for zone 2 deployment with a



Courtesy of Gore & Associates.

Figure 9. Gore TAG thoracic branch endoprosthesis with new branching stent graft.



Courtesy of Cook Medical.

Figure 10. Ascending aortic stent graft..

branch to the left subclavian artery (SCA). These systems are designed to obviate the need for surgical revascularization of the left SCA, with device implantation from femoral access and wire/catheter access to the SCA. With the Medtronic system, through-and-through wire access is obtained from brachial and femoral access, whereas the Gore system only requires femoral access. This wire is precannulated through the branch, which aids in device alignment and advancement/deployment of the branching graft.

The Valiant Mona LSA stent graft system (Medtronic) uses a "volcano" type cuff that projects externally from the aortic endograft (Figure 8). The cuff can pivot, allowing for 20° to 30° of malalignment between the cuff and the SCA. Nine patients were successfully treated in an early feasibility study. The device is now being evaluated in a feasibility trial enrolling 24 patients at seven sites in the United States. These data will be used to support a pathway toward commercialization.

The Gore TAG thoracic branch endoprosthesis has a new branching stent graft designed to accommodate the significant motion forces that occur in the arch (Figure 9). The device is currently being studied in the United States for a zone 0–2 deployment. As with the Gore Excluder thoracoabdominal branch device, this system uses a precannulated retrograde inner portal. The retrograde branch orientation has several advantages and disadvantages. The retrograde orientation of the cuff likely facilitates advancement of the branch grafts from femoral access and would allow for deployment of a more proximal cuff if needed. However, there are few clinical data describing the durability and flow dynamics of retrograde branches available at this time. Furthermore, a retrograde branch may be challenging in a very steeply angulated aortic arch. Gore & Associates has a similar design in an earlier phase of development for zone 0/1 deployment with initial human implantations completed this year in an early feasibility study in the US; data are not yet available for this construct.

ASCENDING AORTA

The final frontier of endovascular treatment of aortic pathology is the ascending aorta. This segment of the aorta is truly unique in terms of its morphology, hemodynamic forces, and lack of proximal seal zone in the conventional sense. Furthermore, ascending aortic pathology is rarely isolated to this short segment of the aorta and usually occurs with concomitant aortic valve, coronary artery, and distal aortic pathology. As such, endovascular treatment of the ascending aorta is likely to remain applicable in a small number of patients until technologic advances create new methods of seal, fixation, and interface with other devices designed to treat the adjacent valve, coronary, or arch pathology.

Bolton Medical has the largest experience to date. Using a custom program on the Relay NBS Plus platform, 32 patients have been treated for isolated ascending aortic pathology in the EU. Results are not yet available. Bolton Medical reports that they are investigating a pathway to commercialization in the United States, but thus far it may be limited to selected pathologies.

Medtronic has an ongoing PS-IDE study with Drs. White and Khoynzhad (Harbor UCLA and Cedars Sinai, Los Angeles, California) using a modified Valiant device with the Captivia delivery system. The study is intended to treat all pathologies other than ascending aortic aneurysm, including dissection, pseudoaneurysm, penetrating ulceration, and intramural hematoma. Initial experience in six patients is in press and should be available soon. Medtronic is working toward

expanding the PS-IDE study enrollment at other sites, which will hopefully shed more light on the safety and effectiveness of this system.

Cook Medical has also developed a device for the ascending aorta that uses bare stents proximally and distally to aid in conformability and fixation (Figure 10). Accurate deployment is achieved using multiple trigger wires, which allow for a specifically controlled deployment. Thus far, there is limited in-human experience with this device in patients with ascending aortic pseudoaneurysms (at prior cannulation sites or anastomoses) or type A dissection. Cook Medical reports that they are assessing the feasibility of the device.

SUMMARY

Endovascular therapy for pathology of the thoracic aorta is evolving with the advent of new stent graft designs. TEVAR for descending thoracic aortic pathology remains the most frequently performed procedure, with active investigations ongoing to assess new low-profile designs and designs without active proximal fixation. Commercial studies of arch branch grafts and thoracoabdominal branched grafts are expected to initiate in 2016 in selected centers. Treatment of the ascending aorta remains less established but is expected to evolve as technology allows integration of valve, coronary, ascending, and arch devices. ■

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