Current and Future Endovascular Treatment Options for TAAAs

New technologic developments have the potential to standardize procedures and offer treatment for challenging presentations.

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Surgical procedures for thoracoabdominal aortic aneurysms (TAAAs) represent some of the most challenging tasks for vascular surgeons today. Open surgical repair has been the treatment of choice, and refinement of operative techniques and perioperative management has led to improved outcomes in large-volume centers of excellence. However, results are still burdened by significant rates of spinal cord ischemia and other major complications, and many patients never return to independent living after surgery.

Endovascular aneurysm repair (EVAR) has been firmly established as the treatment of choice for infrarenal abdominal aortic aneurysms (AAAs) and descending thoracoaortic pathologies in the majority of suitable patients. Building on the platforms of infrarenal EVAR and thoracic endovascular aneurysm repair (TEVAR), techniques have been established to treat more extensive pararenal aortic aneurysms with fenestrated stent grafts, incorporating the visceral vessels in the endovascular reconstruction and achieving a stent graft seal in the paravisceral aorta. These techniques have also been used to bridge endovascular repair of the paravisceral aorta and the descending thoracic aorta, establishing repair of true TAAAs.

Virtually all techniques used to extend an infrarenal repair proximally or descending thoracoaortic repair distally (in the setting of an inadequate landing zone) have been used in the treatment of TAAAs. This article outlines the results and outcomes of different endovascular techniques in the treatment of TAAAs.

FENESTRATED AND BRANCHED STENT GRAFTS

The concept of stent grafts with fenestrations and branches to allow for continued perfusion of aortic side branches during TAAA repair has evolved from slightly different pathways. Fenestrations were first used to treat juxtarenal aortic aneurysms to preserve the renal artery when infrarenal sealing zones were too short and not suitable for standard EVAR. Fenestrations in this location were intended to have aortic wall apposition. To secure branch vessel flow, fenestrations were stented to secure their position to the target vessel, as early experience indicated that nonstented fenestrations had a high risk of misalignment during follow-up, leading to target vessel compromise. Data also subsequently indicated that the use of covered mating stents improved long-term patency of the target vessels by reducing in-stent stenosis. To prevent future target vessel intervention, mating stents were routinely ballooned and flared after deployment, and nitinol reinforcement rings were subsequently added to the fenestration designs to improve effectiveness. The combination of using covered mating stents and reinforced fenestrations thus effectively created a "branch fenestration." This technology was used to treat TAAAs where, in most cases, the fenestrations have no wall apposition, and the seal is created around the fenestration ring itself. The proximal and distal sealing zones for the stent graft are well proximal and distal to the visceral aortic segment.

Branched stent grafts for TAAAs had a different origin. Their use for TAAA treatment was first described by Chuter et al.[1] The main objective when using branches, or directional cuffs, was twofold: (1) a cuff would provide a better landing zone for a mating stent than a fenestration, and (2) the directional cuff would not need to match the target vessel with the accuracy needed with fenestrations. The directional branch establishes a more stable sealing zone for a mating stent, thus enabling the use of self-expanding covered stents if desired. These can also conceptually adapt better to target vessel anatomy. Because the directional branches are positioned a distance above the corresponding target vessel, target vessel catheterization is not as dependent on optimal position, as a branch fenestration and the use of self-expanding mating stents can also adapt better to this misalignment. There are three main trade-offs with directional branches compared with fenestrations. First, as the directional cuffs are placed 10 to 20 mm cranial to the target vessel, more extensive aortic coverage is achieved compared to using fenestrations, which could translate to a higher risk of spinal cord ischemia. Second, because the directional cuff often has an external component, a reasonably sized aortic lumen is required to accommodate it during stent graft repair. This can be a disadvantage in chronic aortic dissection aneurysms, for example, where the true lumen size is small. Third, the directional cuffs in most designs are directed caudally, and they might not follow the natural geometry of the renal vessels in particular (Figure 1). In fact, all of these factors can come into play depending on the anatomic extent of the TAAA. A type IV TAAA typically has the major aneurysm burden in the infrarenal aorta, which leads to a caudal renal vessel trajectory. Although repair with a device using directional branches would be suitable, a significant portion of the descending thoracic aorta would be covered by the repair compared to if a fenestrated device were used. In contrast, a type II TAAA typically has the major aneurysm in the thoracic aorta with upward-facing renal arteries. Although the aortic coverage now becomes less of an issue, the renal target vessel also becomes less suitable for a caudally directed cuff.

Thus, branch fenestrations and directional branches offer different technical features that might be more or less favorable depending on specific morphologic conditions and patient features. Ultimately, a combination of different branch types might be the best option to get a patient-tailored graft design. The superior mesenteric artery and the celiac artery are usually anatomically suitable for caudally oriented directional cuffs, whereas the renal arteries have a higher degree of anatomic variability.

The most widely used platform for endovascular TAAA repair is based on the Zenith device (Cook Medical). In Europe, the E-xtra Design Engineering device (Jotec GmbH) is also available on a customized platform, but very limited data have been published on its use. Cook Medical has also commercialized the off-the-shelf Zenith t-branch device for endovascular TAAA repair (the device is currently undergoing trials in the United States). The t-Branch device has four standard, caudally directed branch cuffs and comes in a single graft configuration that mates distally with a modified bifurcated stent graft and standard iliac limbs and proximally with the standard Zenith TEVAR device. The stand-alone anatomical suitability covers about 50% of TAAA patients, but with adjunctive procedures to correct proximal landing zone or access vessel issues, suitability approaches 80% of patients.[2,3]

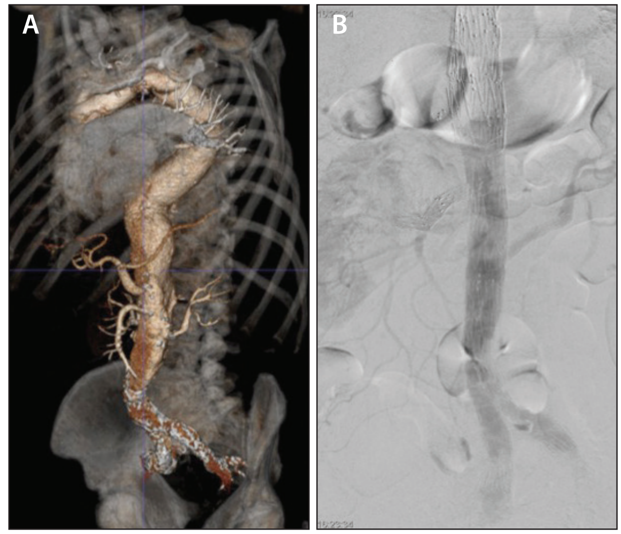

Figure 1. A three-dimensional (3D) rendering of a type II TAAA. Note the cranial trajectory of the left renal artery as well as the unusual cranial trajectory of the celiac artery (A). Final angiogram after endovascular stent grafting (B). The superior mesenteric artery, celiac artery, and right renal artery have been approached with directional cuffs, whereas the left renal artery has been approached with a fenestrated branch.

Recent Study Results

Overall, studies of fenestrated and branched endovascular TAAA repair have reported a very high technical success rate. One experience[4] using 600 fenestrations and branches in 166 TAAA repairs reported a 95% technical success rate, 30-day mortality rate of 7.8%, and 5-year survival rate of 66%. Another single-center series[5] of type II and type III TAAA repairs reported a 96% technical success rate, 30-day mortality rate of 4.7%, and 3-year survival rate of 57%. Rates of stroke, spinal cord ischemia, and permanent spinal cord ischemia were similar in both series at 1.2% to 2.3%, 8.8% to 9%, and 3% to 4%, respectively.

Spinal cord ischemia is a particularly devastating complication that significantly affects quality of life as well as overall survival during follow-up.[6] Recent evidence strongly supports staging of endovascular TAAA procedures to minimize the risk of spinal cord ischemia. The concept of spinal collateral network development has strong experimental support, and extrapolation to clinical practice seems to support this as well.[7,8] Staging can be performed by separating the TEVAR and branch/fenestrated portion of the procedure by several weeks or by using perfusion branches that can be kept patent during the initial repair and mated with the target vessel during a subsequent procedure. Intraoperative use of neuromonitoring can aid in the staging process. Because transient, perioperative hypotensive episodes can have a devastating effect on spinal cord blood supply, it is of utmost importance to avoid and correct blood loss aggressively.[9] If difficult iliac access and need for a conduit (either endovascular or open) is anticipated or carotid-subclavian bypass is required, it is recommended to perform these in a staged fashion as well to reduce the procedure time and blood.

In a series of endovascular TAAA repairs, the majority of reinterventions were related to endoleak.[10] Visceral branch patency was 94% to 98%. Renal branch cuffs seemed to have a higher occlusion rate (9.6% vs 2.3%) compared to renal fenestrations, and the renal reintervention rate was similar in both groups (4.7% vs 5.2%). However, when the type IV TAAA subgroup was excluded from this analysis, the occlusion rate was similar. This result was in agreement with a 98% secondary renal artery patency rate in a large single-center experience that used only fenestrations for renal arteries. Short-term outcomes of the Zenith t-Branch system have indicated similar results as using a custom-made device.

TAAA Repair for Patients With Chronic Dissection

Patients with chronic dissection aneurysms are a specific subgroup that might require endovascular TAAA repair. These patients pose some specific problems that distinguish them from patients requiring conventional aneurysm repair. A thoracoabdominal aortic dissection displays multiple connections between the true and false lumen of the aorta, particularly in the visceral artery segment. In addition, the visceral arteries can arise from either true or false lumen or sometimes from both (Figure 2). The true lumen is often significantly compressed by aneurysmal development in the false lumen. In a chronic dissection, the dissection membrane is rigid and might provide an obstacle in introducing and orienting a thoracoabdominal stent graft. For these reasons, planning is of utmost importance to achieve a successful outcome. Precise identification of the access route to the target vessel must be identified so that the graft can be planned accordingly. Usually, placement of a fenestration or branch is directed toward the natural fenestration rather than the target vessel itself, which is the default in conventional aneurysm repair.

Some authors advocate that preoperative angiography should be performed to make certain that all target vessels can be reached from the false lumen. Indeed, if the entry tear is too small, a larger tear can be created by balloon angioplasty between the true and false lumen, and in some cases, a stent can be placed into the target vessel, across the false and into the true lumen and used as both a marker and access route during the main procedure. The limited maneuverability of a device in a small true lumen makes use of various methods for intraoperative marking of target vessels important for precise placement before graft deployment. Placement of marker catheters inside the target vessel has been proposed, but with the development of intraoperative fusion technology, the target vessel can be marked with help of the preoperative CT. The addition of preloaded catheters in a fenestrated device has also been useful to aid in accessing the fenestration and/or branches when the stent graft is severely compressed.

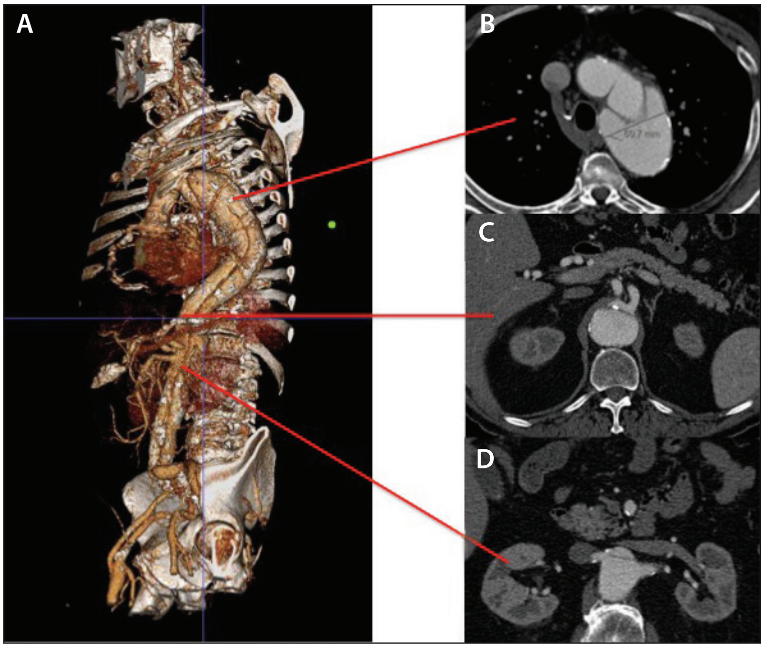

Figure 2. A 3D rendering of a type II TAAA (A). The corresponding axial slices show proximal aneurysm after previous elephant trunk repair (B), celiac artery origin from compressed true lumen (C), as well as the left renal artery arising from false lumen and the right renal artery with perfusion from both true and false lumen (D).

In fact, experience has shown that once the fenestration or branch is accessed, finding the target vessel is often very straightforward because of the limited space in the true lumen. There is simply no other way for the wire to go than into the target vessel. There have been limited reports on fenestrated/branch repair for chronic aortic dissection, but the available results are very promising, with technical success rates approaching 100%. Follow-up is limited, and long-term follow-up is warranted to establish the exact role of endovascular repair in this group of patients.

Devices on the Horizon

A number of branched devices for TAAA treatment are under evaluation in trials. The TAMBE device (Gore & Associates) comes in two configurations: one with four antegrade cuffs (or portals) and one with two antegrade and two retrograde portals (the latter for the renal arteries). A specifically designed mating stent, Viabahn BX, is used.

Medtronic is currently testing an endovascular TAAA device that is constructed around its Endurant AAA platform. It uses multiple bifurcated grafts to create a visceral manifold system, which in turn extends with self-expanding mating stents. No results from the dedicated Medtronic device have been published to date.

PARALLEL GRAFTS

Chimney and periscope (retrograde) grafts provide target vessel perfusion via a parallel peripheral stent graft outside the main aortic stent graft. The technique was developed as a bailout in cases in which visceral arteries were accidentally covered by a stent graft during EVAR. Subsequently, the technique was described for use in emergency and ruptured cases in which there was an insufficient infrarenal sealing zone and no fenestrated or branched off-the-shelf systems were available. Initially, the only limitation to parallel graft seemed to be the imagination of the operator. For TAAA repair, the sandwich technique has been described, which is really an extension of the chimney technique. It confines peripheral stent grafts between two main aortic stent grafts in either an antegrade or retrograde direction. The number of chimney or periscope grafts needed depends on the extent of aneurysm and number of patent side branches.

Reports of chimney and sandwich grafts outcomes for TAAAs are very limited. In the TAAA subgroup from a series of sandwich procedures that included 15 TAAA repairs, 30-day mortality was 20%, which included two deaths in two patients who required emergency repairs. The combined type I and III endoleak rate was 13%. Estimated freedom from all-cause and aortic-related mortality was 70% and 92%, respectively, at 3 years.[11] In another study of chimney and/or periscope grafts, TAAA accounted for 31% of included cases.[12] At 4 years, all-cause and aneurysm-related survival rates were 79% and 90%, respectively. Freedom from type I or III endoleaks was 94%, whereas the primary and secondary patency were 93% and 96%, respectively. There was no significant difference between TAAAs and pararenal aortic aneurysms in terms of mortality, parallel graft patency, or reintervention rates.[12]

CONCLUSION

Endovascular repair of TAAAs is still evolving but has currently reached a level where the short- and midterm outcomes match those of open repair in centers of excellence. The importance of meticulous planning and the aid of intraoperative imaging cannot be underestimated in these complex procedures. The outcomes of endovascular TAAA repair rely on optimizing the entire chain of perioperative management, including planning, appropriate staging of procedures, using an established spinal cord ischemia protocol, intraoperative image guidance, and careful postoperative surveillance. New developments including off-the-shelf devices have the potential of standardizing procedures and offering treatment in the setting of emergent presentations. ■

1. Chuter T, Gordon RL, Reilly LM, et al. Multi-branched stent-graft for type III thoracoabdominal aortic aneurysm. J Vasc Interv Radiol. 2001;12:391-392.
2. Gasper WJ, Reilly LM, Rapp JH, et al. Assessing the anatomic applicability of the multibranched endovascular repair of thoracoabdominal aortic aneurysm technique. J Vasc Surg. 2013;57:1553-1558; discussion 1558.
3. Bisdas T, Donas KP, Bosiers M, et al. Anatomical suitability of the t-Branch stent-graft in patients with thoracoabdominal aortic aneurysms treated using custom-made multibranched endografts. J Endovasc Ther. 2013;20:672-677.
4. Verhoeven EL, Katsargyris A, Bekkema F, et al. Editor's Choice—ten-year experience with endovascular repair of thoracoabdominal aortic aneurysms: results from 166 consecutive patients. Eur J Vasc Endovasc Surg. 2015;49:524-531.
5. Eagleton MJ, Follansbee M, Wolski K, et al. Fenestrated and branched endovascular aneurysm repair outcomes for type II and III thoracoabdominal aortic aneurysms. J Vasc Surg. 2016;63:930-942.
6. Conrad M, Ye J, Chung T, et al. Spinal cord complications after thoracic aortic surgery: long-term survival and functional status varies with deficit severity J Vasc Surg. 2008;48:47-53.
7. Etz C, Kari F, Meuller C, et al. The collateral network concept: a reassessment of the anatomy of spinal cord perfusion. J Thorac cardiovasc Surg. 2011;141:1020-1028.
8. O'Callaghan A, Mastracci T, Eagleton M. Staged endovascular repair of thoracoabdominal aortic aneurysms limits incidence and severity of spinal cord protection J Vasc Surg. 2015;61:347-354.
9. Dias NV, Sonesson B, Kristmundsson T, et al. Short-term outcome of spinal cord ischemia after endovascular repair of thoracoabdominal aortic aneurysms. Eur J Vasc Endovasc Surg. 2015;49:403-409.
10. Martin-Gonzalez T, Mastracci T, Carrell T, et al. Mid-term outcomes of renal branches versus renal fenestrations for thoraco-abdominal aneurysm repair. Eur J Vasc Endovasc Surg. 2016;52:141-148.
11. Lobato AC, Camacho-Lobato L. Endovascular treatment of complex aortic aneurysms using the sandwich technique. J Endovasc Ther. 2012;19:691-706.
12. Wilson A, Zhou S, Bachoo P, Tambyraja. Systematic review of chimney and periscope grafts for endovascular aneurysm repair. Br J Surg. 2013;100:1557-1564.

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