Treating Short and Angulated Necks

How to best use currently available technologies and a look at the enhancements that still need to be made.

BY W. ANTHONY LEE, MD

The proximal landing zone remains the last frontier in endovascular aneurysm repair (EVAR). Certain anatomic features, such as short length and angulation, pose formidable challenges to the currently available endovascular stent graft technologies (Figure 1). Operators are faced with the prospect of making do and hoping for the best when using proximal landing zones that are clearly ill suited to the mechanical properties of the endograft and/or constraints of the delivery system. However, in the context of advanced technologies such as fenestrated and branched grafts, discussions are frequently focused on juxtarenal or suprarenal aneurysms, although a significant subset of anatomically infrarenal aneurysms can benefit from a suprarenal landing zone for early and long-term stability and success. Today, at least in the United States, the bottleneck to better treatment is less technological than it is regulatory. Therefore, in this environment, necessity is truly the mother of invention, and imagination is the only limit to overcoming some of these anatomic challenges using commercially available conventional devices.

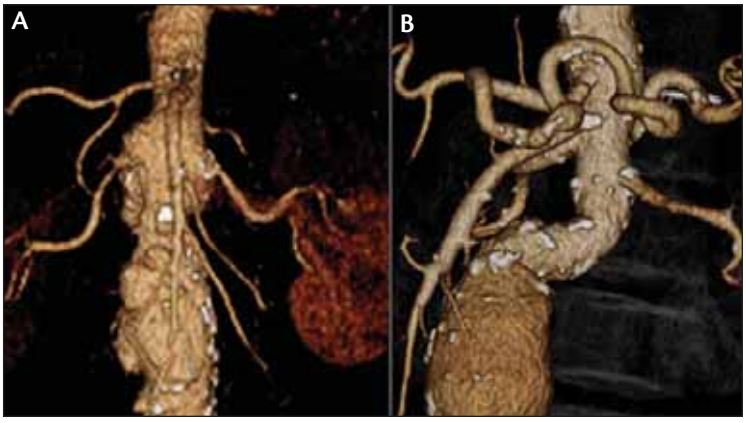

Figure 1. Examples of difficult proximal necks. Pararenal aneurysm (A); highly angulated infrarenal neck (B).

THE PROBLEM

The problem with difficult proximal necks in EVAR is typically not the absence of a (nearly) normal or somewhat suitable abdominal aorta. Instead, a suitable neck is often present but is in a more proximal segment of the aorta involving the origins of one or more branch vessels (renal arteries, superior mesenteric artery, celiac artery). Therefore, any solution to the problem must preserve flow to these critical branches while achieving a durable seal and fixation of the endograft to exclude the aneurysm. Currently, three endovascular options are available using standard commercial devices, and they comprise the subject of this article.

HYBRID REPAIR

Hybrid repair of aortic aneurysms utilizes open surgery and endovascular stent grafting to treat aneurysms that involve branch vessels or those that cannot otherwise be effectively treated using conventional endovascular techniques and devices (Figure 2).[1] The open surgical component of hybrid repair consists of bypassing one or more of the renal/visceral vessels from an inflow source that is remote from the aneurysm. After such debranching of the aorta, a new proximal landing zone becomes available to be used for conventional EVAR. Contrary to the initial perception of this procedure as a potential panacea to complex aortic aneurysms, it became rapidly evident that the debranching portion of the repair was associated with nearly as much morbidity and mortality as conventional open repair. The only gain that a hybrid

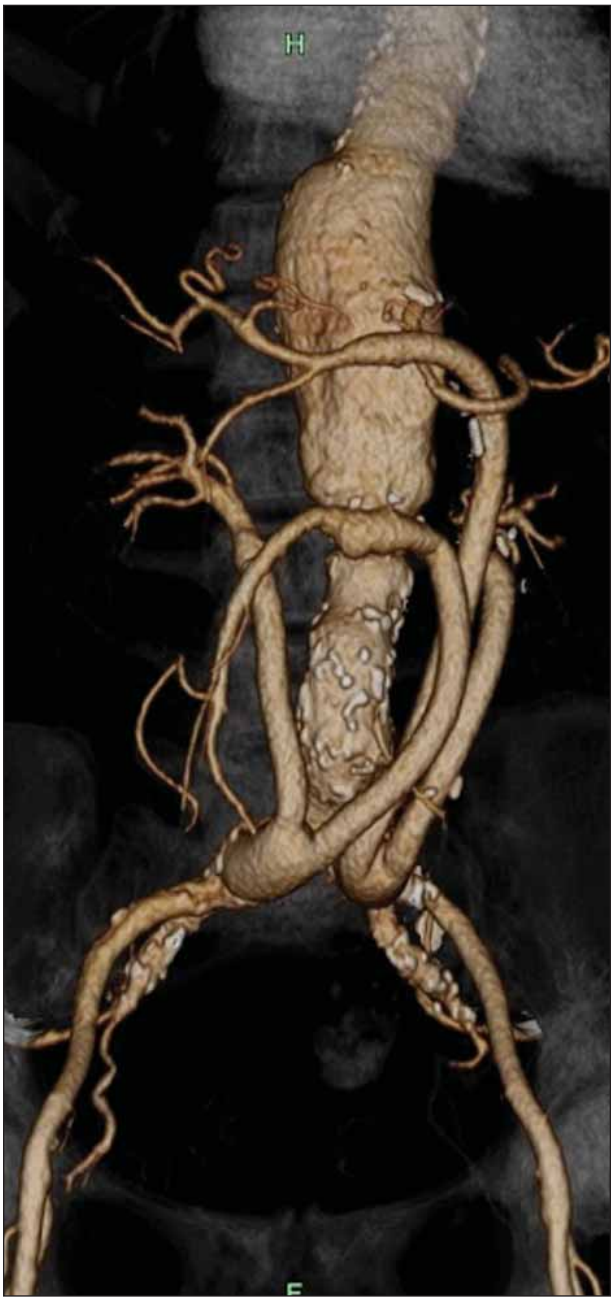

Figure 2. Visceral/renal debranching as part of a hybrid repair.

repair allowed was avoidance of a dual-cavity (chest and abdomen) incision, aortic exposure, and aortic cross-clamping. Today, hybrid repair of complex aortic aneurysms has lost much of its original enthusiasm and is reserved for a very select subset of patients who pose a unique combination of being at good surgical risk but with poor aortic anatomy for conventional open repair (eg, redo aortic surgery).

BACK-TABLE MODIFICATIONS OF FENESTRATED AND BRANCHED ENDOGRAFTS

Commercially manufactured fenestrated and branched endografts have been available for human implantation for more than a decade around the world, depending on the regulatory milieu of the respective country. In the United States, although fenestrated devices are undergoing clinical trials, the process has been slow, and the timeline and strategy for dissemination of the technology remain undefined. In answer to this, operators have started constructing their own versions of fenestrated and branched endografts by altering commercially available endografts and delivery systems and using parts cannibalized from other medical devices (Figure 3).[2] Such "back-table" modifications of conventional endografts allowed for an off-the-shelf solution compared to the 6 to 8 weeks required for custom-manufactured commercial devices. Off-label use of medical devices has always been tacitly condoned by local (hospital-based) and governmental (US Food and Drug Administration) regulatory bodies as long as they are used with informed consent by a qualified physician and not as part of a formal clinical study. However, such drastic physical alteration of a medical device involving the creation of holes and attachment of additional graft and/or stent components, as well as modification of delivery systems, pushes the boundaries of off-label use to another level altogether. Issues of quality control such as durability, consistency, and reliability are all brought into question.

Enhancements to current devices to facilitate such complex back-table modifications are difficult to enumerate and, when pushed to their logical extreme, beg the question, "Why not just manufacture the endograft instead of making the pieces so that they can be assembled by the operator on the back table?" Therefore, I offer the following wish list of enhancements or ancillary devices that might facilitate this type of technique:

- Radiopaque rings and semicircles of various sizes to mark the location of fenestrations and scallops and obviate the need to measure the diameter with a ruler or use the tips of guidewires or snares;
- Devices to facilitate resheathing of an endograft into its original delivery system without damaging the device or the modifications;
- Delivery systems that are designed to allow the endograft to be unsheathed and resheathed easily;
- Improved variable stiffness for guidewires to facilitate secure access into a branch vessel;
- Improved introducer sheaths with regard to trackability and flexibility to allow secure access and delivery of bridging stents into the branch vessels;
- Improved bridging covered stents with regard to profile, flexibility, radial force, and resistance to fracture.

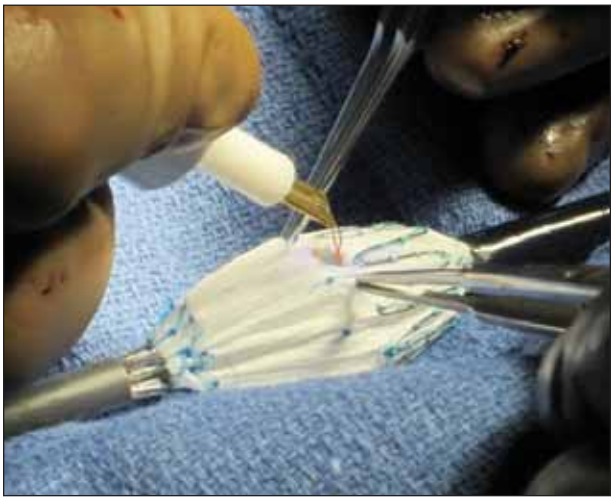

Figure 3. Intraoperative creation of a fenestration in a partially deployed endograft.

THE CHIMNEY TECHNIQUE

The "chimney" (or "snorkel") technique is an advanced endovascular technique to preserve perfusion to branch vessels when the endograft is placed in the suprarenal position to gain additional neck length.[3] Basically, peripheral stents are placed into the branch vessel(s) before full deployment of the aortic endograft. The branch vessel stent is then deployed alongside the endograft (parallel position between the inside of the aortic wall and outside the endograft) (Figure 4). Since its original description,[4] the technique has been refined and modified with respect to the number of chimney stents, types of stents, and configuration of the stents relative to the endograft. Variations from the original technique include a multilayered ("terraced") technique for three- to four-vessel chimney repairs and down-going ("periscope") chimney stents. Similar to the back-table fenestrations of endografts, the chimney technique has emerged as a potential off-the-shelf solution to the delays inherent in the custom manufacturing process.

Despite the growing worldwide collective experience with this technique, a number of unanswered questions remain. Techniques vary based on operator familiarity and institution. The exact mechanism of sealing chimney stenting remains mostly a mystery to many operators. Early rates of type Ia endoleak are consistently low at < 10% in most series, and most of these spontaneously seal within 6 months. Mechanistically, seal is likely achieved as a combination of the number, position, type, and length of chimney stent(s); type of endograft; degree of oversizing; and local aortic wall conformance. Flow impedance through the gutters, which are formed between the chimney stent and the endograft and are the source of endoleak, is a function of their cross-sectional area and length. Therefore, better conformance of the endograft around the chimney stent (smaller cross-sectional area of the gutter) and a longer proximal landing zone (increased length) should theoretically reduce the chance of a type Ia endoleak. This must be balanced against the incremental complexity of each additional branch vessel that is chimney stented.

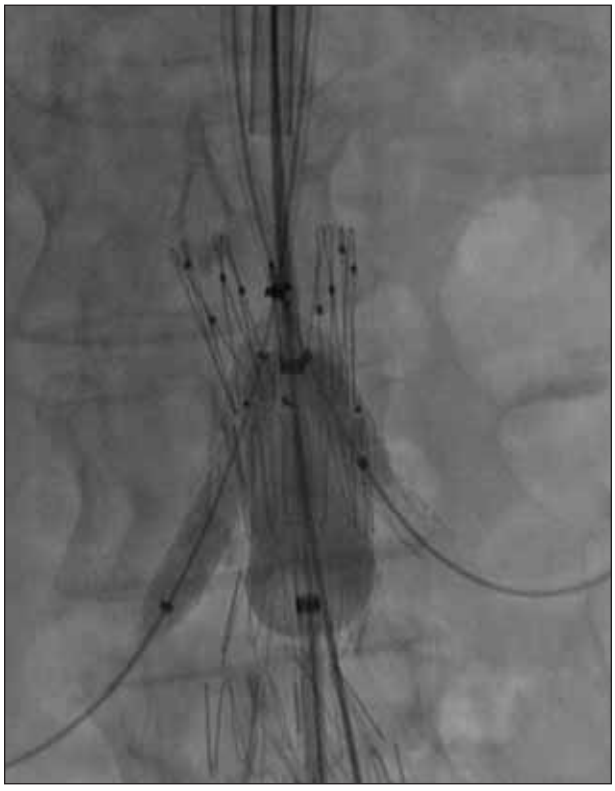

Figure 4. Bilateral renal chimney stents during endovascular repair of a juxtarenal aneurysm.

Other unknowns include the optimal type of stent (ie, balloon-expandable vs self-expanding and covered vs uncovered), the maximum number of chimney stents that can be used, optimal endograft design and materials that will conform to the chimney stent, and the minimum length of the proximal neck. But most importantly, the long-term data are lacking—namely durability of the chimney repairs with regard to patency of the chimney stents and late stability and migration of the aortic endograft given the partial separation of the endograft from the aortic wall. With that said, chimney stents may be more stable and resistant to deformation from endograft pulsatility and branch vessel motion because the two devices are mechanically decoupled. Interestingly, the endovascular techniques and ancillary devices that are used for a chimney repair can be directly transferred to endovascular repairs using branch endografts.

Enhancements to the current array of devices that would facilitate the chimney stenting technique revolve around an ideal chimney stent. Clearly, mechanical performance of this single component is the principle determinant of the early and late success or failure of this technique. An ideal chimney stent would be low-profile, covered, and employ a hybrid design that would have the radial force of a balloon-expandable stent in its proximal end and the flexibility of a self-expanding stent in its distal end and can be deployed like a balloon-expandable stent. The available lengths (30–200 mm) and diameters (5–10 mm) of the stent should be broad. The properties of the fabric material covering a chimney stent likely do not need to meet the same standards of mechanical durability as an aortic endograft. Furthermore, the stents should have unique markers that are easily distinguishable from the aortic endograft. The sheer density of metal in the region of the proximal neck makes clear visualization of the chimney stent important. Finally, a flared proximal end may be useful to facilitate catheterization of the chimney stent for reinterventions.

Introducer sheaths are another element that needs improvement with regard to trackability and flexibility to allow secure access and delivery of chimney stents into the branch vessels. Lastly, enhanced guidewires with variable stiffness are needed to facilitate secure access into a branch vessel.

CONCLUSION

In conclusion, a number of techniques have been developed to treat adverse proximal landing zones in EVAR. However, technologies must evolve along with endovascular techniques. All of these techniques represent makeshift solutions to problems that would be best managed using technologies that presently exist but due to regulatory constraints are not commercially available in the United States. ■

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