Techniques for Optimizing Seal in a Compromised Neck

An overview of the etiology of suboptimal necks and the techniques and technologies that aim to maximize seal.

BY MISAKI M. KIGUCHI, MD, AND EDWARD Y. WOO, MD

Thoracic endovascular aortic repair (TEVAR) has largely replaced open repair as the preferred approach to treating thoracic aortic pathologies due to its lower rates of morbidity and mortality.[1,2] The success rate of TEVAR in optimizing seal and avoiding an immediate and/or delayed type I endoleak dramatically increases with the presence of at least 20 mm of proximal and distal landing zone in nonangulated, parallel, and thrombus-free aorta.[3] In clinical practice, however, such optimal anatomy is commonly absent in patients who present with thoracic aneurysms. In these patients with compromised anatomy, an understanding of the etiology of the suboptimal neck is crucial to determining the optimal anatomy-specific techniques available to maximize seal.

WHICH RISK FACTORS CONSTITUTE A "COMPROMISED" NECK?

Most commercially available devices can accommodate aortic diameters ranging from 16 to 42 mm, with device diameters ranging from 21 to 46 mm. Studies have shown that larger aortic diameters (> 38 mm) portend proximal seal failure and aortic sac enlargement at follow-up.[4,5] A shorter neck length also implies less seal zone, similarly leading to increased risk for seal failure. Sobocinski et al demonstrated a higher aneurysm sac expansion rate after TEVAR when proximal or distal landing zones were > 38 mm in diameter or < 2 cm in length.[6] Furthermore, the reverse taper neck configuration—where the distal aortic diameter immediately below the proximal landing neck is substantially larger than the aortic diameter at the proximal landing neck—decreases the parallel length of seal. Characteristics including neck angulation ≥ 60°, increased aortic curvature (especially of the inner curve) such as a type III aortic arch, neck calcification, and partial thrombus cause added difficulty in achieving circumferential wall apposition and have been shown to be independent risk factors for a type I endoleak.

DEVICE OVERSIZING

Choosing the correct device size and optimizing radial force can help prevent type I endoleaks. Due to the increased forces in the proximal aorta as compared with the infrarenal aorta, thoracic endografts should be sized 15% to 20% larger than the measured aortic diameter.[7] Oversizing is particularly important in compromised necks where seal zones may be short, angulated, and lined with thrombus. Undersizing in these suboptimal conditions causes incomplete endograft apposition to the aortic wall.

In trauma patients in whom the aortic pathology is not due to atherosclerotic degeneration, oversizing should be more conservative (up to 10%).[8] Similarly, for aortic dissections, oversizing should be more conservative to prevent retrograde dissections.[9] As a road map to plan for endograft sizing, thin (< 1 mm) CTA imaging slices should be acquired. Aortic diameter and length should be assessed by centerline reconstruction for greatest accuracy. It is also important to recognize that CT images are static during the cardiac cycle and the diameter measured could be representative of the aorta during diastole.

BALLOONING

Controlled ballooning of the proximal endograft often adds radial force to improve contact between the endograft and the aortic wall. Although ballooning is not necessary in all situations and may be contraindicated in some pathologies, ballooning may help graft-to-wall apposition. Gradual

ballooning is recommended and should be done under direct fluoroscopic guidance. Aggressive ballooning is never recommended, as it can lead to rupture or aortic dissection.

OVERCOMING THE COMPROMISED NECK USING ADJUNCT DEVICES

Large balloon-expandable stents, such as the Palmaz device (Cordis, a Cardinal Health company), have been used to treat type Ia endoleaks. The radial force of the stent assists in maximizing graft apposition and sealing any small spaces between the endograft and aortic wall. Care must be taken when deploying these stents to prevent migration and inaccurate deployment as well as aortic rupture.

Endoanchoring is a newer technology that can improve device fixation at the proximal and distal neck. The Heli-FX Thoracic EndoAnchor system (Medtronic) is an endovascular stapler used to fix the stent directly to the aortic wall to minimize endoleaks. The helical metal alloy screws are placed circumferentially around the endograft, mimicking a surgical anastomosis. This assists in maximizing graft/wall apposition. Kasprzak et al have demonstrated promising results with this stapling technology in treating either immediate or late type I endoleaks.[10] At 11-month follow-up, no stents migrated and no type I endoleaks were observed. Limitations of EndoAnchors include mural thrombus > 2 mm. The EndoAnchor has difficulty penetrating through the excessive thrombus to make contact with the aortic wall. Porcelain aortas with severe circumferential calcification also limit EndoAnchors from fixating to the wall.

CHOOSING THE OPTIMAL DEVICE

In 2005, the TAG thoracic endoprosthesis (Gore & Associates) was the first endograft to be approved by the FDA. The newer Conformable TAG device is designed to conform to the aortic wall, improving aortic wall apposition and minimizing bird-beaking. It deploys from the middle of the graft to prevent windsocking at the proximal device. A sealing cuff is also located on each end to reinforce apposition and reduce migration. This is useful in more angulated aortic arches where the device would otherwise sit up on the arch, leading to an endoleak on the lesser curve.

The Valiant thoracic stent graft with the Captivia delivery system (Medtronic) has an eight-peak bare-metal design to distribute radial force evenly across the proximal aortic neck. Medtronic gained FDA approval for the Valiant Navion thoracic stent graft system in October 2018. The system is based on the design of the Valiant Captivia system and is able to treat similar pathologies, but incorporates features aimed at broadening patient applicability, enhancing ease of use, and improving vascular access. Specifically, the delivery system profile has been reduced up to 4 F to facilitate treatment of smaller vessel diameters, as well as narrow, tortuous, and calcified iliac arteries.

The Zenith TX2 device (Cook Medical) is a two-piece Pro-Form modular graft that uses a trigger-wire release to improve proximal conformity and apposition to limit bird-beaking. In addition, the device remains in a trifold configuration during deployment, increasing accuracy and limiting windsocking. Barbs on each end provide active fixation to the aortic wall. Similar to TX2, the Zenith Alpha device (Cook Medical) is a two-piece modular graft that uses active fixation but with a low-profile delivery system.

The RelayPlus system (Terumo Aortic) provides precise endograft deployment with a two-sheath delivery system, taking advantage of every available millimeter in length to achieve a better seal. Bare or covered stents provide active fixations at the proximal end. Scallops can also be added proximally to improve endograft conformability at the steepest portion of the arch and "hug" the inner curvature of the arch for better apposition.[11]

All of the previously mentioned devices are excellent in treating thoracic aortic pathologies and have been designed for optimizing seal.

OVERCOMING THE COMPROMISED NECK USING A HYBRID APPROACH

To increase proximal neck length for optimal landing of the aortic stent graft in short necks or angulated arches, a left common carotid artery (LCCA)–to–left subclavian artery (LSA) bypass or LSA transposition can be performed. Clearly, this has direct benefit for lengthening the proximal seal zone in a short neck. For the type III aortic arch, a steeper arch angle exists in which many endografts cannot easily conform. Thus, a longer seal length to the LCCA with the LCCA-to-LSA bypass overcomes the hazards of a compromised neck by extending the proximal seal zone to a more favorable angle.

If a distal landing zone is compromised, open revascularization of the celiac artery should be considered to enable extension of the endograft's distal sealing zone. Often, adequate collaterals between the celiac and superior mesenteric artery allow uncomplicated coverage of the celiac artery.[12-14] However, in circumstances in which collaterals are compromised, open extra-anatomic bypass from the healthy infrarenal aorta or iliac arteries to the celiac can be performed. This will allow for extension of the distal landing zone to the level of the superior mesenteric artery.

SNORKEL TEVAR FOR THE COMPROMISED NECK

For select patients, another elegant solution to a compromised neck is to extend the seal zone of the thoracic endograft in the proximal aorta while maintaining side branch patency through parallel covered stents. These parallel grafts extend beyond the proximal edge of the aortic endograft, maintaining flow to the aortic arch arteries. First described by Greenberg et al in 2003[15] and origi-

nally intended for emergent EVAR in lieu of fenestrated or thoracic branched endografts, the experience has since grown and has been widely applied to the elective setting and to the thoracic aorta. Careful planning is necessary to determine how much extension is needed and thus how many parallel grafts are necessary. It is important to recognize that the main failure mode for parallel grafting is a gutter leak, and > 2 cm of parallel overlap with the endograft is typically needed to circumvent this issue. However, parallel grafting offers an excellent minimally invasive alternative to hybrid debranching procedures.

When performing parallel grafting, the choice of the endograft and parallel graft are important, as varying radial forces can lead to crushing of the parallel grafts. The proximal and distal extent of the parallel graft is also critical. They must extend proximal to the aortic endograft to ensure patency and perfusion but not too far as to potentially fold over. The distal extent needs to allow for long-term purchase but also not extend too far as to cover critical branches.

INVESTIGATIONAL DEVICES

As endovascular technology continues to evolve, endografts are being modified to treat even the most complex of pathologies, including hostile compromised necks. Numerous investigational studies have shown technical success of aortic arch branch devices, improving seal in even the most compromised necks. Several devices from numerous manufacturers are at varying levels of investigational evaluation. Each device extends the proximal landing zone, without the need for open surgical revascularization, by utilizing branch stents from fenestrations or internal/external branches. Data on the Zenith arch branch graft (Cook Medical) shows technical success of 100%, with an 11.1% stroke rate.[16,17] Results were similar with early feasibility studies of the Valiant Mona LSA device (Medtronic), with 100% technical success and no major disabling strokes.[18] The preliminary data from the TAG thoracic branch endoprosthesis (Gore & Associates) demonstrate 100% technical success, with no strokes at 30 days.[19] The RelayBranch thoracic arch system (Terumo Aortic) allows for zone 0 deployment while maintaining perfusion to the innominate and left carotid arteries through its two tunnels. Fifteen patients were treated in the preliminary studies, with 100% aortic-related survival and no type Ia endoleaks.[20] It is important to recognize that these studies are all very early with different extents of treatment (ie, arch pathology and number of branch stents).

SUMMARY

Conventional TEVAR offers an effective and often superior alternative to open repair but can be constrained by compromised aortic neck anatomy. Although open or hybrid repair still has its role in certain patients, the evolution of these endovascular stent technologies and techniques for compromised necks have achieved significant success in making complex TEVAR safer and more durable. ■

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Misaki M. Kiguchi, MD
Assistant Professor of Surgery
Georgetown University School of Medicine
Department of Vascular Surgery
MedStar Washington Hospital Center
MedStar Georgetown University Hospital
MedStar Health at Chevy Chase
Washington, DC
misaki.m.kiguchi@medstar.net
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Edward Y. Woo, MD
Director, MedStar Vascular Program
Chairman, Department of Vascular Surgery
MedStar Heart and Vascular Institute
Professor of Surgery
Georgetown University School of Medicine
Washington, DC
edward.y.woo@medstar.net
Disclosures: None.