

Identifying the Appropriate Thoracic Device Size

How to correctly size a thoracic device in diameter, landing zone, and length.

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Endovascular aortic stent grafts have forever altered the techniques and strategies for managing the pathology of the aorta. Although many cases still require open repair, large studies demonstrate that there has been a tremendous increase in the percentage of thoracic endovascular aneurysm repairs (TEVARs) of all descending thoracic aorta surgeries performed in the United States since 2005.¹ There are currently four TEVAR devices available for use in the United States: TAG conformable thoracic endoprosthesis (Gore & Associates), the RelayPlus system (Bolton Medical, Inc.), Valiant thoracic stent graft (Medtronic), and Zenith Alpha thoracic device (Cook Medical), each with unique characteristics that may affect device choice and operative planning. All four devices have US Food and Drug Administration indications for use in treating aneurysmal disease, and the TAG conformable thoracic endoprosthesis and Valiant thoracic stent graft have indications for the treatment of all descending thoracic aortic lesions.

START WITH A PLAN

Meticulous planning is often the most important part of a case; a good plan can help avoid the most common pitfalls associated with TEVAR (Table 1). The first step is to assess the patient's anatomy to determine suitability for endovascular repair according to each device's instructions for use. This is best accomplished through contrast-enhanced axial imaging of the chest, abdomen, and pelvis, preferably with 1- to 3-mm cuts.² CTA is readily obtainable at most medical facilities and can provide most of the information necessary for plan-

TABLE 1. MOST COMMON PITFALLS TO CONSIDER WHEN PLANNING A TEVAR CASE

When not given appropriate consideration, the following factors can lead to complications and failure:

- Undersizing and oversizing stent graft choice can have serious consequences
- Insufficient length and/or quality of chosen fixation zones (proximal/distal necks)
- Not placing the endograft proximally enough within the arch because of a reluctance deal with the branches
- Failure to anticipate access difficulties; it is best to avoid risk of iliac artery rupture altogether and resort to an iliac conduit when available

ning. Several postprocessing software programs, such as Aquarius Workstation (TeraRecon) (Figure 1), OsiriX (Pixmeo), and Preview (M2S, Inc.) can produce three-dimensional (3D) and orthogonal reconstructions from raw data, which are often helpful for making more accurate diameter and distance measurements. These imaging results can help obtain accurate diameter and length measurements as well as assess for calcium, plaque, and thrombus in landing zones, which may compromise the fixation or seal of the graft. MRI is also acceptable for 3D analysis, although it has limitations in its ability to accurately show calcium in the vessel wall. Digital subtraction angiography can provide adequate length measurements for graft selection, aid in decision making regarding landing zones, and help determine appropriate

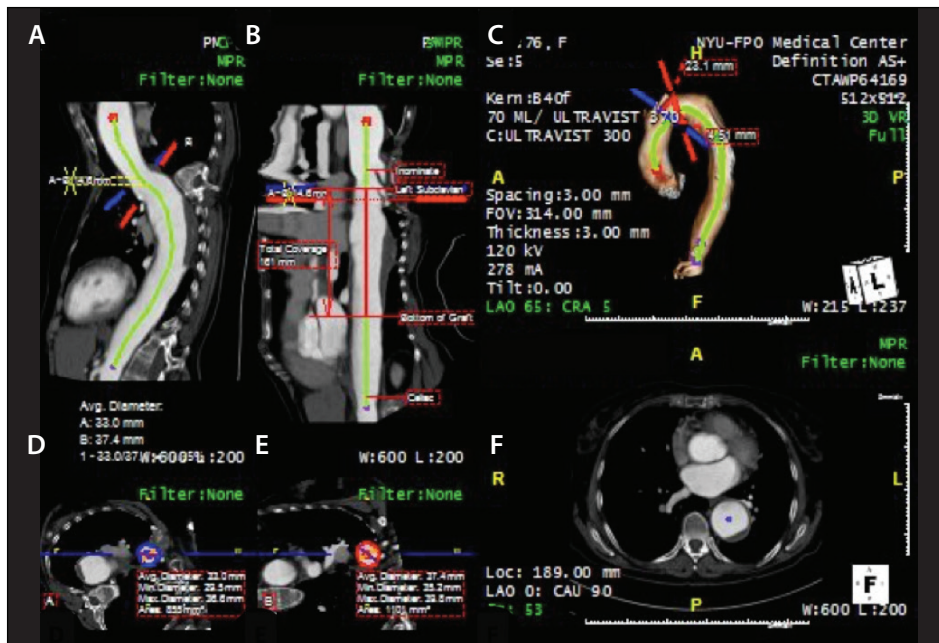


Figure 1. TeraRecon case planning view. Panels A and B show the centerline and straightened views, which allow for accurate placement of a centerline within the flow lumen and orthogonal measurements. Panel C shows a 3D rendering of the aortic aneurysm with the centerline overlay, which provides better spatial visualization of aneurysm morphology and branch vessel location. Panels D and E are orthogonal reconstructions with diameter and area measurements that correspond to the blue and red slices along the centerline in panel C, respectively. Panel F is a standard axial series of the CT.

management strategies for branch vessel management. Although it is possible to take measurements of the flow lumen, accurate wall-to-wall diameter measurement may be unreliable using digital subtraction angiography alone. Conversely, intravascular ultrasound may be a helpful intraoperative adjunct to accurately measure diameter but may be less reliable for length measurements.³ Noncontrast CT can be used preoperatively when planning for patients with chronic kidney disease and can be combined with intravascular ultrasound and digital

stent grafts are oversized by varying amounts depending on the indication, this allows for safe treatment of aortic diameters ranging from 16 to 42 mm (Table 2).

SELECTING A GRAFT SIZE

Choosing the appropriate size graft can prevent many complications associated with TEVAR. The best graft choice for descending thoracic aortic aneurysms and dissections is usually 15% to 25% larger than the aortic diameter in the landing zone. These patients are often

subtraction angiography using small amounts of contrast intraoperatively.

Imaging is then reviewed for several factors that will affect graft selection and the treatment plan. The first assessment must identify landing zones sufficiently long enough to create a 20-mm seal zone of the healthy aorta both proximally and distally. A healthy aorta has a uniform diameter over a straight segment of the vessel, is nonaneurysmal, and is relatively free of calcification or thrombus. The diameter in the landing zone may vary up to 15% within this segment without significant risk of endoleak or proximal fixation failure.² Devices currently range in size from 21 to 46 mm, and because

TABLE 2. CURRENTLY AVAILABLE, FDA-APPROVED STENT GRAFTS FOR TREATMENT OF THORACIC AORTIC PATHOLOGY

Product Name (Manufacturer)	Available Graft Sizes (mm)	Proximal Neck Diameter (mm)	Sheath/Introduction System Diameter (F)
TAG conformable thoracic endoprosthesis (Gore & Associates)	21–45	16–42	18–24 (inner diameter; sheath required)
The RelayPlus system (Bolton Medical, Inc.)	22–46	19–42	22–26 (outer diameter)
Valiant thoracic stent graft (Medtronic)	22–46	18–42	22–25 (outer diameter)
Zenith Alpha thoracic device (Cook Medical)	24–46	20–42	16–20 (inner diameter)

Abbreviations: FDA, US Food and Drug Administration.

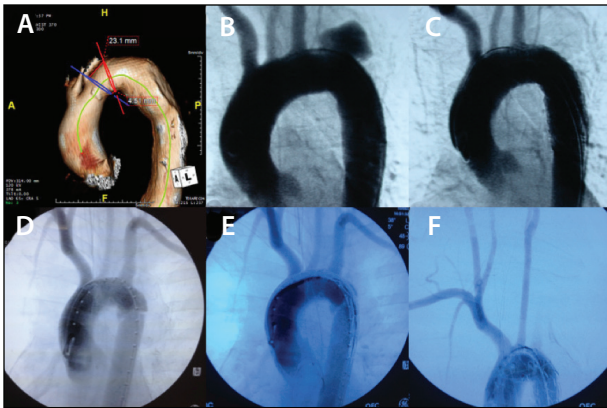


Figure 2. Case examples of various arch anatomies and aortic pathologies and treatment. 3D reconstruction with centerline of fusiform aneurysm (A). Centerline distance does not reliably connote seal length in tortuous anatomy. Note: discrepancies in the seal length along the inner versus the outer curve of the aortic arch require coverage of the left subclavian artery to achieve adequate seal in this case. Saccular aneurysm originating along greater curve of arch (B, C). TEVAR can be deployed just distal to aberrant left vertebral artery, as the seal zone is along greater curvature and does not rely on graft apposition with lesser curve. Aortic transection shown at level of left subclavian artery (D). Coverage of subclavian is often necessary to ensure coverage of intimal tear (E, F). Care should be taken not to aggressively oversize or postballoon such cases.

older, and their landing zones require more radial force in the proximal stents, which is achieved through oversizing.⁴ In trauma applications, the aorta is often healthier and smaller than in aneurysmal disease, and oversizing should be more conservative, ranging from no oversizing up to 10% according to the Society for Vascular Surgery guidelines.⁵ Special consideration must be given to the morphology of the proximal landing zone. The angulation in a tortuous landing zone may be so severe that the graft will not land orthogonally but will instead have an oblique orientation, therefore compromising the seal. Furthermore, it may be challenging to achieve a proper seal along the inner curve of a severely angled aortic arch (Figure 2). Failing to land the graft appropriately may result in a type Ia endoleak or bird-beak sign on imaging, which can lead to infolding and graft collapse.^{6,7}

Improvements in newer-generation devices and endovascular techniques continue to address these challenges. Devices such as the RelayPlus have unique features built into the design and deployment sequence that help achieve optimal location and orientation. Cook Medical has also made changes

to its thoracic graft product line by employing the Pro-Form technology into its TX2 line. This modification in proximal stent deployment allows for the first stent to seat along the lesser curve to ensure a better seal. More recently, the Zenith Alpha product line has replaced the TX2 line and introduced a nitinol cannula and a precurved sheath to help conform the graft to the aortic arch for deployment. In addition, technical maneuvers such as rapid atrial pacing have also been employed to help facilitate accurate deployment in the proximal landing zone.⁸ If an orthogonal orientation cannot be achieved, the graft's leading edge will not adequately appose the aortic wall. In such cases, it may be especially prudent to oversize sufficiently to ensure that the graft properly seals along the vessel wall with enough radial force to prevent a type I endoleak or graft migration.

EVALUATE POTENTIAL LANDING ZONES

The proximal landing zone may also present a challenge due to the location of brachiocephalic vessels. If the distance between the left subclavian artery and the proximal extent of pathology is < 20 mm, consideration may be given to covering the left subclavian artery with the graft to achieve adequate sealing length.² Management of the left subclavian artery in this situation is an area of ongoing debate, as some centers advocate a hybrid procedure employing routine subclavian revascularization in conjunction with the aortic stent graft placement, and others do this selectively based on anatomic and clinical factors.^{9,10} The absolute criteria requiring bypass before covering the left subclavian artery include a dominant left vertebral system or absent right vertebral system, incomplete circle of Willis, a patent coronary artery bypass graft originating from the left internal mammary artery, and a functioning hemodialysis fistula in the left upper extremity.¹⁰

If the left subclavian artery is to be covered and none of these absolute criteria exist, there are some relative indications for carotid-subclavian bypass or carotid-subclavian transposition that must be considered. TEVAR has been associated with spinal cord ischemia and paraplegia in up to 4% to 5% of treated patients. There are several recognized risk factors predisposing patients to this complication, which include previous abdominal aortic aneurysm repair, coverage of > 20 cm of descending thoracic aorta, and a relative lack of collateral vessels to the spine such as the hypogastric arteries.⁹ The anterior spinal artery is supplied by the left vertebral artery, and maintaining perfusion through a carotid-subclavian bypass may reduce

the risk of spinal cord ischemia, as well as posterior cerebral circulation ischemia when used with other adjuncts. In addition, up to 2% of patients may experience ischemic symptoms in the left upper extremity following left subclavian artery coverage, with these patients benefiting from a bypass procedure. The origin of the vessel must be occluded to prevent a type II endoleak if the left subclavian artery is covered. This may be accomplished using an open or endovascular approach. The proximal subclavian artery may be ligated at the time of subclavian bypass or transposition taking care to preserve flow to the internal mammary and left vertebral arteries. If access to the proximal subclavian artery is not feasible through the surgical exposure, or if no bypass is employed, the left subclavian artery occlusion may be accomplished through retrograde brachial artery access to place coils or an Amplatzer vascular plug (Abbott Vascular, formerly St. Jude Medical), again taking care not to occlude flow to the critical branches (Figure 3).³

ASSESSING LENGTH

The length of coverage must also be evaluated using preoperative imaging to aid in graft selection. The orthogonal reconstructions can be helpful in determining the overall length required to cover the affected aorta and achieve sufficient landing zones. However,

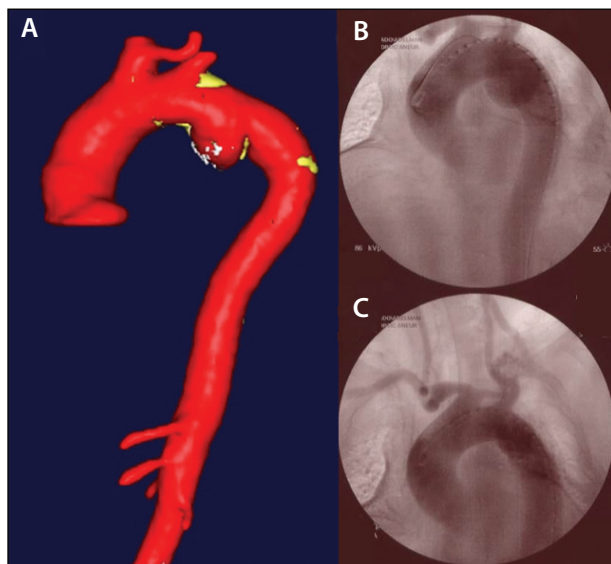


Figure 3. Saccular aneurysm of the aortic arch. M2S reconstruction of aneurysm along inner curve of the aortic arch distal to the left subclavian artery origin (A). Angiogram showing aneurysm with marker catheter in place (B). Postdeployment angiogram with coverage of left subclavian artery and carotid-subclavian bypass (C).

while assessing the length, it is also imperative to consider the course of the aorta within the intended coverage area. Excessive tortuosity may lead to difficulty in navigating the graft up to the aortic arch. Moreover, extreme tortuosity in aneurysm segments of the aorta can result in erroneous length measurements because the course of the stiff wire and graft do not necessarily follow centerlines. As such, preoperative length measurements may be inaccurate. Consideration should be given to having a longer graft or distal extensions available at the time of surgery to avoid risking a type Ib endoleak. As is the case proximally, a 20-mm landing zone with orthogonal graft orientation is necessary for optimum seal. Choosing a relatively straight segment of aorta for the landing zone will help facilitate a good seal, but this must be balanced against the risk of spinal cord ischemia associated with covering long aortic segments as described previously.²

There may be a significant discrepancy in the aortic sizes between the proximal and distal diameters, and it is very important to avoid oversizing in the distal landing zone, especially in a small aorta, as this can lead to type B dissection or aortic injury distal to the graft. Endograft choice and strategy must effectively address this. All graft companies have tapered grafts that generally have a 4- to 5-mm reduction in diameter over the length of the graft, and if the graft is sufficiently long to exclude the pathology, this is an excellent strategy. When a single graft is insufficient to achieve adequate seal, proximal and distal extension components may be used with varying lengths of overlap to tailor overall graft length to the patient's needs. Employing a telescoping technique by starting with the smaller graft and extending proximally or distally with a larger graft is an acceptable strategy if the size discrepancy is > 4 to 5 mm, such that a tapered graft would be insufficient to achieve a seal.

The aortic pathology may not simply be limited to the descending thoracic aorta, which highlights the importance of obtaining preoperative abdominal and pelvic imaging. In the case of aneurysmal disease or a dissection that extends into the proximal abdominal aorta, it may be necessary to consider coverage of the celiac trunk to achieve the required 20 mm of seal.² Abdominal imaging will allow for assessment of the gastroduodenal artery, which may provide adequate collateral flow to the hepatic, gastric, and splenic arteries to allow coverage of the celiac trunk without requiring bypass.¹¹ Intraoperative injection of the superior mesenteric artery can be helpful in assessing for optimal collateral flow if consideration is given to covering the celiac trunk (Figure 4). However, if the aortic disease extends caudally and involves the superior mesenteric

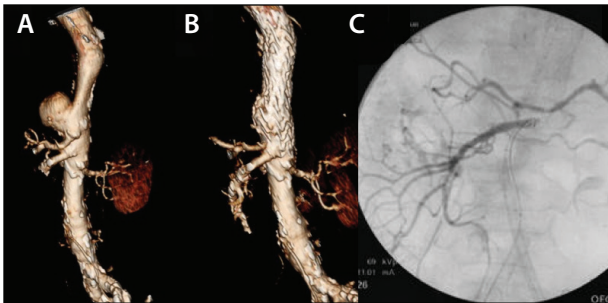


Figure 4. Distal thoracic aortic aneurysm adjacent to the celiac trunk. Preoperative TeraRecon 3D reconstruction showing aneurysm and adjacent vessels (A). Postoperative CTA showing coverage of the celiac trunk with collateral filling via the gastroduodenal artery (B). Visceral arteriogram injected through the superior mesenteric artery showing patent gastroduodenal artery and retrograde flow filling the celiac trunk vessels (C).

artery or renal arteries, an abdominal debranching procedure could be necessary to achieve sufficient coverage. Other devices under investigation may facilitate total endovascular approaches to these challenging cases, but those are beyond the scope of this article.³

Finally, the access sites and iliac vessels must be assessed to ensure that endovascular repair can be safely performed, further highlighting the importance of obtaining imaging through the abdomen and pelvis.² Thoracic endografts are larger than abdominal grafts, and they require larger access for placement. Table 2 details the graft sizes and corresponding required access vessel sizes. The lowest-profile device on the market in the United States is the Zenith Alpha device with 24- to 30-mm sizes, which employs a 16-F inner diameter introduction system or a 6-mm outer diameter with a hydrophilic coating. Other devices require vessels that accommodate systems of 18 to 24 F, or up to 7.6 mm. Tortuous iliac vessels and stenotic lesions must be recognized and planned for in advance. Serial dilatation or probing of the iliac arteries with Coombs dilators as well as balloon angioplasty of focal stenotic lesions can serve to prepare the vessels for delivery of larger sheaths. Alternatively, physicians should never hesitate to place an iliac conduit or an endoconduit before device insertion to minimize the risk of catastrophic injury to the iliac vessels through traumatic device insertion.¹²

CONCLUSION

There are many exciting changes coming in the realm of thoracic aortic interventions. New stent grafts (ie, Zenith dissection endovascular stent [Cook Medical])

to treat aortic dissections are being developed that employ a combination of covered and bare-metal stents, which will likely lead to new sizing strategies and requirements. Additional devices available in other countries and on trial employ arch branch stents and fenestrations to address the need to land proximal to the left subclavian artery. Nevertheless, despite all these exciting advances in technology, careful preoperative planning and sizing will forever be the key to success in treating thoracic aortic pathology. ■

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