TEVAR for the Ruptured Thoracic Aorta

As operator experience increases and our approaches to treating branch vessels progress, the limitations associated with TEVAR will decrease.

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Acute rupture of the thoracic aorta can result from deceleration trauma, aortic dissection, or aneurysmal enlargement and is a life-threatening condition requiring urgent operative intervention. The traditional approach of open surgery and aortic replacement remains a technically challenging endeavor fraught with multiple complications, especially in the urgent or emergent setting. Since the first description of the use of endovascular stent grafts to repair thoracic aortic pathologies in 1994, the potential of a less-invasive modality to treat these catastrophic ruptures remains compelling.[1]

Mortality rates of up to 90% have been reported for patients sustaining traumatic injuries to the thoracic aorta.[2] Many of these patients are poor candidates for open repair via thoracotomy and systemic heparin administration due to the multiple associated traumatic injuries that they may have sustained. Patients who survive open operations still have high perioperative morbidity and mortality rates, with reported perioperative mortality rates in the range of 13.6% to 18.8% and spinal cord ischemia resulting in paraplegia in 9.3% to 22.7% of patients.[3,4] In patients surviving to undergo emergent operative repair of nontraumatic thoracic aortic ruptures, perioperative mortality rates approach 50%.[5,6]

Shortly after reporting the use of thoracic endografts in the elective setting, Semba et al published the first successful treatment of acute ruptures with thoracic endovascular aortic repair (TEVAR).[7] These initial grafts were cumbersome, handmade, individually tailored to each patient, and required a long sterilization period before implantation. In less than a decade, an FDA-approved thoracic endograft has become commercially available, and several additional thoracic stent grafts are available in clinical trials for aneurysmal disease and type B aortic dissections. As the experience of using an endovascular approach to treat acute thoracic aortic rupture continues to expand, it appears a promising alternative to traditional open surgery, especially in the high-risk patient.[8-12]

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ENDOVASCULAR TREATMENT OF AORTIC PATHOLOGIES

Patients presenting with acute rupture of the thoracic aorta fall into one of two broad categories. The first is patients with often nondiseased aorta, subjected to significant rapid deceleration injury due to a high-speed motor vehicle collision or fall from a great height.[13] The second is patients with a chronic disease of the aorta that has expanded and present with an acute rupture. These pathologies include such entities as thoracic aortic aneurysm (Figure 1) and thoracoabdominal aortic aneurysm, penetrating atherosclerotic

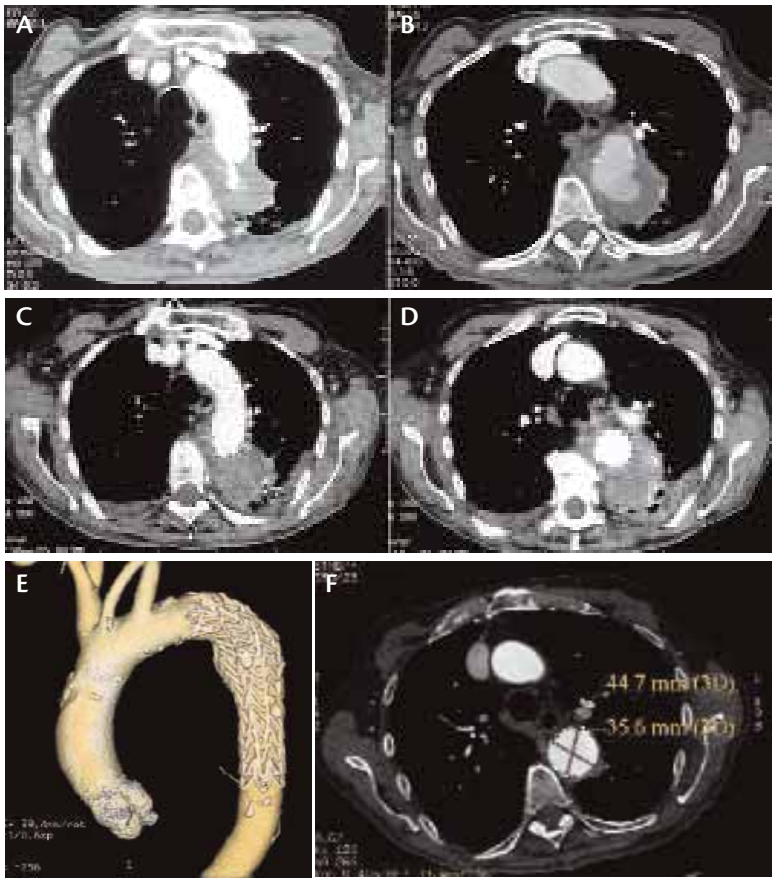

Figure 1. Ruptured thoracic aortic aneurysm. CT scan with evidence of hematoma surrounding the aorta (A,B). The patient presented with acute onset of severe back pain. Successful endograft coverage of the rupture with one endograft (C-E). Follow-up imaging at 2 years shows resolution of the hematoma and relatively normal-appearing aorta (F).

ulcer of the thoracic aorta (Figure 2), and acute and chronic aortic dissection with aneurysmal dilatation and intramural hematoma (both often in the setting of chronic hypertension) (Figure 3). The distinction among the groups is important when considering the patient for endograft repair. Traumatic disruption of the aorta occurs predictably near the ligamentum arteriosum, in the setting of an otherwise normally sized aorta.[13] These patients will often have other significant associated injuries at the time of presentation.[14] More chronic aortic pathologies can rupture anywhere along the length of pathologic aorta, which may be substantial. In the latter case, the aorta proximal and distal to the aortic pathology may also be calcific or mildly ectatic. Additionally, these patients are often older with significant medical comorbidities, including significant cardiopulmonary and renal dysfunction.[14-16]

Patients with traumatic injuries have a more focal pathology at a known location, surrounded by a normal-caliber aorta, and often have nondiseased distal vasculature and a nonatheromatous aortic arch. The intercostal arteries are generally preserved and are not well collateralized, such that coverage can lead to spinal cord ischemia. This differs from patients with ruptured thoracic aneurysms and dissections who have debris-laden aortas subject to embolic complications during endografting, atherosclerotic disease of the vessels intended for endovascular access, and/or dissected vessel walls complicating the true lumen in which the endoprosthesis is to be deployed. In this light, it is not surprising that patients with traumatic aortic tears have been found to have more favorable outcomes compared to those with ruptured chronic aortic pathologies after TEVAR.[14]

Aortic dissection presents a unique challenge when considering endovascular therapy. Uncomplicated descending (Stanford type B) aortic dissections should be treated medically with aggressive blood pressure control, whereas those demonstrating radiologic or clinical deterioration warrant intervention.[17-19] Evidence of continued expansion, impending rupture (extravasation or hemothorax), intractable pain despite maximal medical therapy, or branch vessel compromise are all factors that would be indications for either surgical or endovascular intervention. Preoperative imaging, as well as intravascular ultrasound (IVUS), should be employed to determine which lumen of the dissection is perfusing the viscera and the extremities before excluding that lumen with a stent graft. Initial reports show that TEVAR may reduce mortality and paraplegia rates when compared to conventional surgery for the treatment of complicated type B dissections.[16,20]

TECHNICAL CONSIDERATIONS FOR ENDOGRAFT PLACEMENT

Suitability for Endografting

Before making the decision to perform TEVAR, imaging of the thoracic aorta should be obtained to delineate the patient's anatomy and assess suitability for endovascular repair. The sizes of the aorta and access vessels are best evaluated via thin-slice (≤3 mm) CTA

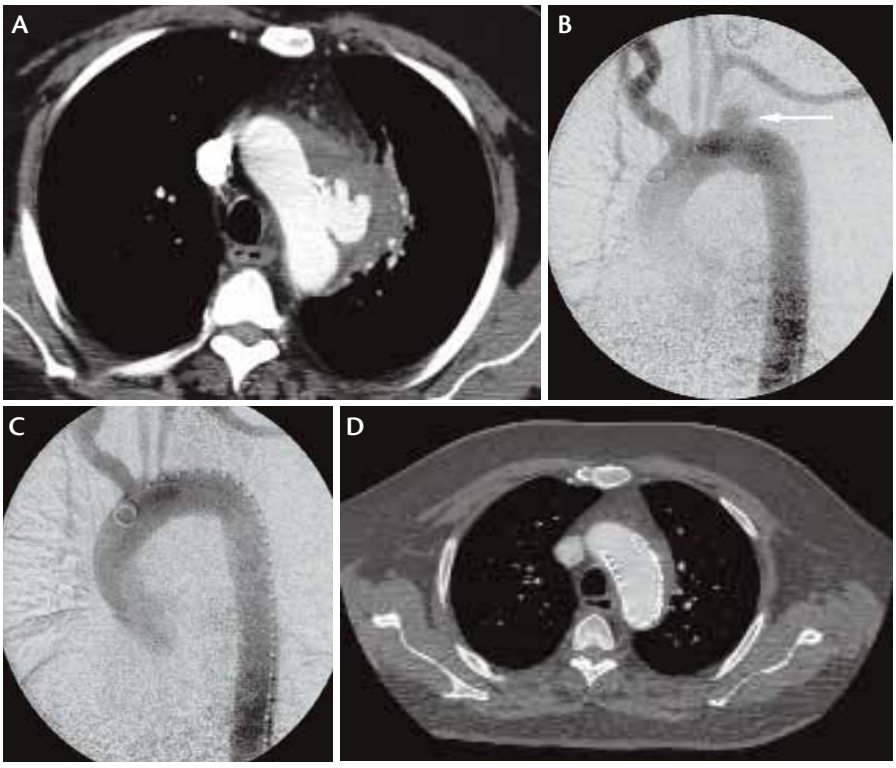

Figure 2. Ruptured penetrating ulcer of the thoracic aorta. CT scan obtained after the patient presented with chest pain and hemoptysis, demonstrating a ruptured penetrating ulcer with hematoma around the aorta (A). Angiogram confirming location of the ulcer before endograft implantation. Two endografts were implanted with coil embolization of the left subclavian artery, successfully excluding the rupture (C). One-year follow-up CT shows regression of the hematoma and continued exclusion of the rupture (D).

with three-dimensional reconstruction, if possible. The proximal and distal extent of the pathology treated must be assessed with particular attention to the relationship of the aortic branch vessels to the pathology and to the angulation of the aortic arch. Severe aortic arch angulation can limit the accurate placement of the thoracic stent as well as limit the approximation of the stent graft to the aorta itself. This poor apposition to the lesser curve wall can lead to aortic stent graft collapse and devastating thoracic stent graft occlusion.

Proximal and Distal Fixation

Essential to proper treatment of ruptured aortic pathology is exclusion of the diseased segment by adequate sealing both proximally and distally when deploying the endograft. FDA-approved grafts are available in diameters of 26 mm to 40 mm and lengths varying from 10 cm to 20 cm. Other grafts still under FDA investigational device exemption investigation will have graft diameters up to 46 mm in size. To achieve an adequate seal against the aorta, it is suggested that the device should be oversized by 7% to18%, allowing for a maximum-diameter landing zone of 37 mm. These proximal and distal landing zones are often dictated by the location of the supra-aortic and mesenteric branch vessels. It is recommended that 20 mm of normal-caliber aorta flanks the pathology longitudinally on which to fix the device both proximally and distally. In acutely angulated aortas (<60˚), longer distances may be needed to achieve an adequate seal.

In the elective setting, extra-anatomic bypass to the mesenteric vessels or the arch great vessels have been used to allow extension of the proximal or distal landing zone of the thoracic endografts.[21] A limited study has described safely covering the celiac origin without previous bypass to extend the distal landing zone during elective TEVAR, relying on collateral circulation from the superior mesenteric artery distribution.[22] This technique should be reserved for the patient with adequate preoperative workup in the elective setting, including preoperative angiography documenting adequate collateral circulation. Proximal placement can also be adjusted by consciously planning to cover the left subclavian artery. Studies have shown that covering the left subclavian artery is well tolerated by patients, and they can be managed in an expectant fashion with carotid-subclavian bypass or subclavian transposition, as clinically indicated.[23-25] These patients must be closely followed for signs and symptoms of upper-extremity ischemia or subclavian steal syndrome, at which point further operative intervention is indicated. The increasing data regarding the safety of this approach support its use in the emergent setting if necessary.

Access Considerations

The iliofemoral vessels must be assessed for the ability to pass the device, which requires a minimum of a 20-F introducer (approximately an 8-mm vessel) and up

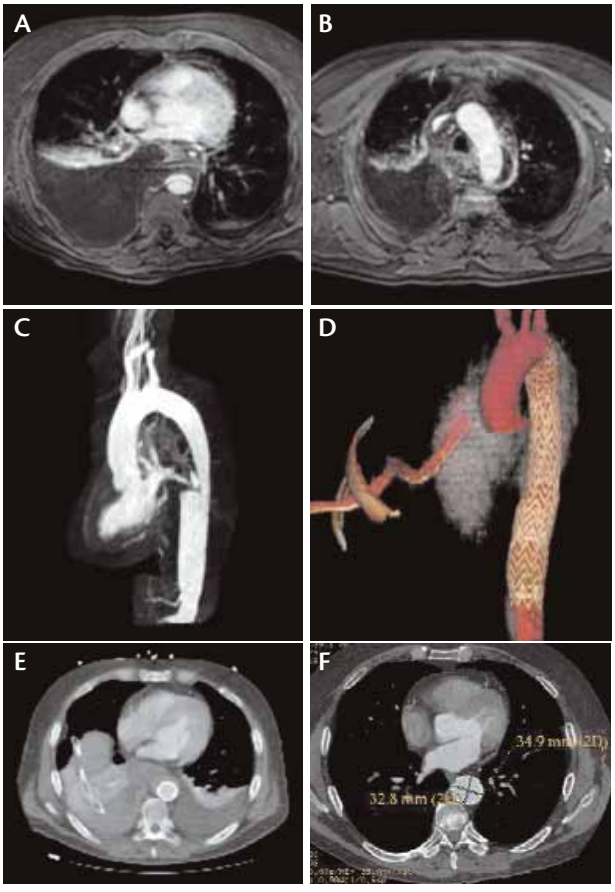

Figure 3. Acute aortic dissection with rupture. MRI demonstrating an intimal flap in the thoracic aorta with a large hemothorax (A-C). Successful endografting of the entire descending thoracic aorta with two endoluminal grafts and right chest tube thoracostomy (D,E). Six-month follow-up with complete resolution of the dissection and hemothorax (F).

to a 24-F introducer for the largest grafts. If the patient's anatomy is such that the femoral vasculature precludes insertion of the device, direct exposure of the iliac vessels via a retroperitoneal approach can be obtained for insertion. Alternatively, a surgically created prosthetic conduit can be used to introduce the device should the patient's native vasculature not adequately support the introduction of the sheath.[9,26] Systemic anticoagulation should be employed throughout the implantation of the device.

Device Deployment

Introducing the device into the aorta should be performed under direct fluoroscopic guidance and should be met with no significant resistance when advancing the device. The use of IVUS and transesophageal echocardiography can be useful adjuncts when localizing the device as it is advanced, especially in the setting of aortic dissection when confirmation of the correct luminal placement is paramount.[8,20,23,27] A left anterior oblique fluoroscopic view should be employed to enable optimal visualization of the aortic arch and branch vessels during placement.

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Patients with known contained rupture of the aorta should be managed preoperatively with blood pressure management in preparation for the operating room. Permissive hypotension can be used as long as the patient is adequately mentating and blood products are being prepared. During the procedure, once the device has been localized, pharmacologically lowering mean arterial pressure can help to prevent device dislodgement or malposition during deployment. With the current stent graft technology, there does not appear to be a benefit for graft implantation of either rapid ventricular pacing or brief asystolic arrest. Appropriate sizing of the graft components is critical, and several different graft diameters may be required. Generally, the small segment is implanted first, followed by the larger component telescoping into the smaller component. Either a fine-cut infused or noninfused CT scan can assist with graft sizing, or IVUS can be used in more acute situations. Once the endograft is implanted and the patient is hemodynamically stabilized, further investigation for endoleak can be carried out. Late CT drainage of a thoracic hematoma is rarely required after successful thoracic endograft implantation.

It is also critical the institution has the infrastructure to deal with a ruptured thoracic aneurysm and the associated complications and that the implanting interventionist has significant experience with elective TEVAR and endovascular repair of abdominal aortic aneurysms.

CONCLUSIONS

Thoracic aortic aneurysms have a devastating natural history with high perioperative morbidity and mortality rates. Outcomes worsen when repair is attempted in the emergent setting, highlighting the need for a less-

morbid approach to this pathology in patients who often have multiple medical disorders. The recent introduction of thoracic aortic endografts into the armamentarium of endovascular specialists is an encouraging advancement for these patients.

When directly compared to open repair in the emergent (ruptured) setting, endografting has been shown to be a safe, effective alternative.[12,16,28] Although there is much enthusiasm surrounding this significantly less-invasive method for treating this vascular disaster, it is important to temper this enthusiasm with careful consideration and sound judgment regarding patient anatomic characteristics as well as individual and institutional experience. There is still significant debate regarding the long-term effectiveness of thoracic aortic stent grafting, even when placed in the elective setting, because most studies show only a few years of follow-up data.[11,26,29,30] One multicenter trial showed an endoleak rate as high as 9% at only 2-year follow-up.[26] The clinical significance of a late endoleak in the setting of a previous rupture is not currently known. If it is anticipated that there will be difficulty obtaining a good proximal or distal seal, the patient may well be served best by open repair in the setting of rupture and instability. Additionally, patients will be subjected to a lifetime of follow-up imaging after endograft treatment, which many not be appropriate for all patients, especially if their medical conditions would preclude future contrast imaging.

Finally, the luxury of offering an endovascular repair to a patient in the emergent setting relies on the availability of devices at the institution. Having a selection of grafts with different diameters and lengths allows the creation of an appropriately sized device for the patient's anatomy. As the number of available devices increases and the technology improves, the number of patients for whom endovascular repair is available will increase. Additionally, the limitations associated with this technology will decrease as the delivery systems decrease in size, interventionist experience increases, and innovative approaches to branch vessels are developed. ■

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