

Aortic Arch Reconstruction

Synergy of open and endovascular techniques.

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The patient is a 71-year-old woman who presented with the incidental finding on chest CT of three separate saccular aneurysms of the thoracic aorta. The first of these originated just opposite the left carotid and subclavian artery (60-mm diameter), the second just distal to the left subclavian (62-mm diameter), and the third approximately halfway down the thoracic aorta (50-mm diameter) (Figure 1).

The patient was asymptomatic with respect to these aneurysms, but each was greater than twice the contiguous aortic diameter and very focal in nature. The patient's medical history was significant primarily for hypertension and chronic obstructive pulmonary disease, requiring occasional home oxygen therapy. Her medications included two antihypertensive drugs and several inhalers. She denied any previous cardiac, cerebrovascular, or other arterial vascular symptomatology. A cardiac stress test was negative for inducible ischemia.

TREATMENT CONSIDERATIONS

This patient was very concerned about the aneurysms, and we agreed with her referring physicians that there was sufficient cause to recommend repair, given their saccular eccentric nature and their size.

The open surgical approach to these lesions would have been complicated by the need to replace all of the arch vessels and to extend the graft to the distal thoracic aorta. This cannot be achieved through the same surgical exposure and would also require circulatory arrest with its attendant high morbidity and mortality. These factors in combination with her pre-existing chronic obstructive pulmonary disease made this option prohibitive from a risk-benefit standpoint. The purely endovascular approach was not possible either for two reasons: common iliac arteries were of insufficient diameter to accept the delivery sheath needed for the thoracic endografts required, and the thoracic endograft would have to cover all of the arch vessels to achieve adequate seal zones requiring transposition of these vessels

to alternate inflow sources. For these reasons, we designed a procedure that would address the patient's elevated risk and still achieve the complete exclusion of the three saccular aneurysms.

OPERATIVE PLAN

This approach involved a series of open and endovascular steps. Our first goal was to remove all of the aortic arch tributaries (eg, the innominate, left common carotid, and left subclavian arteries), thus rendering the arch amenable to available thoracic tube endografts. This was accomplished by performing an ascending aortic graft with a trifurcation to three separate limbs (Gelweave Thoracoabdominal Trifurcate, Vascutek, a Terumo Company, Scotland, United Kingdom). A careful examination of the preoperative three-dimensional CT reconstruction (M2S, Lebanon, NH) demonstrated a long, disease-free segment of ascending aorta that we felt would be amenable to a side-biting clamp, thus avoiding the morbidity or cardiopulmonary bypass and full aortic cross-clamp. A median sternotomy was performed, and the ascending aorta, innominate, left carotid, and left subclavian arteries were all dissected free of surrounding tissues. A side-biting clamp was placed on the ascending aorta, and an end-side anastomosis of the body to the trifurcated graft was sewn in place with a continuous 3-0 prolene suture. This graft had been altered just before implantation by sewing a 10-mm Dacron limb to the body of the graft angulated away from the limb trifurcation. It was our plan to introduce the thoracic endografts through this conduit in an antegrade fashion through the aortic arch. This avoided the second complicating factor of inadequate iliac access in this case (Figures 2 and 3).

Once the ascending aortic graft was sewn in place, we sequentially ligated, divided, and reanastomosed the innominate, left carotid, and left subclavian arteries to the limbs of the trifurcated polyester graft (Gelweave Thoracoabdominal Trifurcate) in an end-to-end fashion. This technique allowed full cerebral perfusion throughout

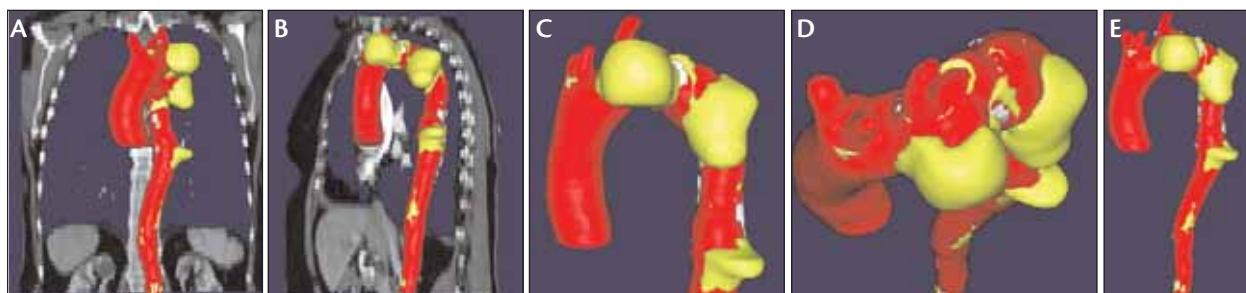


Figure 1. A coronal CT superimposed by three-dimensional model of thoracic aorta. Note early takeoff of left common carotid near innominate origin and proximity of first aneurysm (A). Sagittal view (B). Magnified sagittal view (C). Cranial-caudal view (D). Sagittal view of entire thoracic aorta (E).

the case. We followed arterial pressures in both arms and maintained a systolic pressure of >70 mm Hg even when the primary inflow to each extremity was clamped, indicating the adequacy of collateral circulation (Figures 4 through 6).

With the ascending aortic graft in place and the three arch branches successfully revascularized, we turned to the endovascular portion of the procedure. The 10-mm polyester graft limb was tunneled from the base of the median sternotomy subcutaneously to a point just superior and to the right of the umbilicus. It was sewn to the abdominal wall for stability, and then a small transverse graftotomy was made to insert the Gore TAG thoracic endograft sheath (Gore & Associates, Flagstaff, AZ). With the dilator still in place, a zero Prolene ligature was secured around the conduit and sheath to provide a hemostatic juncture between the sheath and the conduit. The thoracic endograft plan was devised to accommodate a total of three separate thoracic endografts. This was necessary to accomplish the diameter differential between the mid-descending

aorta and the distal-ascending aorta. The length of the needed endograft was determined by a careful measurement of the outer curvature of the arch and descending aorta rather than a traditional centerline measurement that often suffices in infrarenal endograft planning. The importance of careful assessment and measurement of the outer curvature of the thoracic aorta cannot be overemphasized in the planning of these cases, as the ratio of the outer curvature to the centerline and inner curvature can be very large (ie, $>30\%$). We used intravascular ultrasound to confirm our diameter measurements.

We now sequentially implanted three Gore TAG thoracic endografts. The first was placed most distally and was 28 mm in diameter X 10 cm long. The second and third grafts were 34 mm X 15 cm and 40 mm X 15 cm, respectively. Finally, each of these endografts was postdilated with a compliant Coda balloon (Cook Medical, Bloomington, IN). Completion angiography revealed excellent patency of both the ascending aortic graft and its branches and the thoracic endografts with exclusion of all of the aneurysms.



Figure 2. Operative view of ascending aorta, innominate vein (white vessel loop), and three arch vessels: innominate, left carotid and left subclavian, respectively, left to right



Figure 3. The Gelweave Thoracoabdominal Trifurcate graft with the 10-mm sidebranch conduit.



Figure 4. The ascending aortic graft in place with the conduit clamped before tunneling.



Figure 5. The conduit tunneled to the abdominal wall for stability and to remove the operators from the fluoroscopy field. Umbilicus visualized in lower right corner of photograph.



Figure 6. The TAG thoracic endograft sheath inserted into the conduit.

The proximal end of the endograft was just proximal to the former origin of the innominate artery and was in a section of the ascending aorta less angulated than the arch to prevent endograft infolding and its devastating complications. The distal-most aspect of the endografts terminated approximately two thirds of the way down the descending thoracic aorta. The median sternotomy was closed after ligating the conduit at its junction with the ascending aortic graft (Figure 7).

HOSPITAL COURSE

The patient was taken to the intensive care unit and was extubated the next morning. A spinal cerebrospinal fluid drain had been placed and was removed 24 hours after the operation when there was no evidence of neurologic compromise. The patient did not require blood transfusions and was discharged to home on the fifth postoperative day.

DISCUSSION

Thoracic aortic pathology has posed a major challenge for aortic reconstruction since the first attempts at open reconstruction. Although cardiopulmonary bypass and the development of advanced techniques for total circulatory arrest expanded the realm of what was possible, the morbidity of these procedures remained considerable.

The introduction of thoracic endografts has renewed the enthusiasm for the detection and treatment of the large variety of thoracic pathologies encountered. Although aneurysmal pathology in the infrarenal aorta is almost always degenerative and fusiform in nature, the thoracic aorta is affected by fusiform and saccular defects, as well as from the sequelae of aortic dissection. The presence of the vital aortic arch branches and the severe curvature of the aortic arch have limited and complicated the application of tube endograft technology that remains the only option for endovascular reconstruction in these patients. Although the benefits of an endovascular approach in the reduction of morbidity are undeniable, the ability to adequately address the more complex and dangerous lesions is very limited.

In this case, we chose to use major open vascular reconstruction but avoided the elements of traditional open thoracic reconstruction that are implicated in the high morbidity of these procedures, namely cardiopulmonary bypass, aortic cross-clamp, and total circulatory arrest. Although most laypersons would not consider a full median sternotomy minimally invasive, the low morbidity rate and rapid recuperation from this incision is well documented in the surgical literature. By sequentially bypassing each of the aortic branches, we were able to have a zero ischemic time despite a rather long operative procedure.

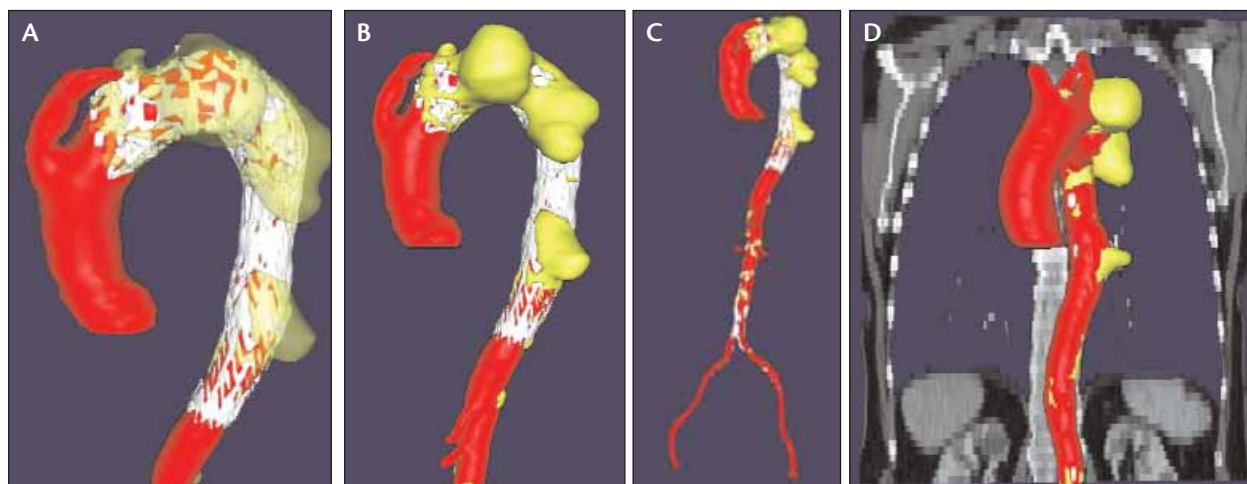


Figure 7. Sagittal view of postoperative CT scan. Preview reconstruction (A). Sagittal view of entire thoracic aorta after the procedure (B). Complete aortic three-dimensional reconstruction after the procedure. Note the diminutive iliac size and infrarenal aortic calcification (C). Cephalad view of postprocedure aortic arch and ascending aortic trifurcated bypass graft (D).

The planning of these complex interventions cannot be overemphasized. The inability to complete one of the steps in a highly integrated procedure can result in failure of the entire procedure or devastating consequences. To that end, we routinely employ detailed high-resolution CT scanning with software reconstruction that will allow the operating surgeon to place virtual grafts and perform detailed custom measurements of the dimensions that will define the parameters necessary to make appropriate graft choices. In our facility, that is best achieved using Preview software (M2S, Lebanon, NH) and PEMS (patient evaluation and management software) that accompanies this product with quantitative follow-up and volume measurements on each reconstruction. We confirm these measurements with intraoperative angiography and intravascular ultrasound. Our preoperative assessment utilized standard ultrasound to assess the carotid and vertebral arteries. We did not pursue further imaging with preoperative angiography because we did not believe that any other information not present on the CT and ultrasound would change our operative plan.

We were very pleased with the outcome of this case but would not underestimate the potential for disaster in these complex anatomies in patients with multiple and severe comorbidities. Although it may have been possible to land the graft somewhat more distally with respect to the origin of the thoracic endograft, we decided it was important to get past the more angulated sections of the arch because of the aorta's large diameter and the predilection for graft infolding when an endograft terminates in an angulated area. Postoperative CT scans demonstrate excellent apposition of the graft both proximally and distally to the aortic inner circumference.

The use of debranching the aorta to facilitate endografting can result in a more robust and secure vascular reconstruction than either open or endovascular techniques alone can provide. This emphasizes the utility of employing the full armamentarium of surgical techniques on a problem, particularly for more complex pathologies. Our team used both the vascular (Deaton, Babrowicz) and thoracic (Carter) surgical services to ensure a high degree of familiarity and facility with each component of the procedure. It is highly advisable to recruit a team that encompasses all of the skill sets necessary, rather than stretching to do one or more elements that fall outside the primary surgeon's skill set. ■

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