Descending Aortic Stent Graft Collapse During Frozen Elephant Trunk Repair: Detection Using Invasive Blood Pressure Monitoring and Intraoperative Transesophageal Echocardiography

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THE DIFFICULTY OF repairing continuous aortic disease from the ascending aorta and aortic arch through the descending thoracic aorta was addressed by Borst in 1983, when he described an "elephant-trunk" technique that joined ascending aorta and aortic arch replacement, followed by placement of a free-floating length of tube graft extended into the descending thoracic aorta.[1] This technique provided the advantage of having graft already in the descending thoracic aorta for correction of more distal disease at a later stage, thereby avoiding the hazards of a surgical approach to arch structures when completing distal thoracic aorta repair. In the 1990s, surgeons began combining ascending aorta and aortic arch repair with deployment of an endovascular stent graft into the descending thoracic aorta, called the frozen elephant-trunk (FET) procedure.[2-4] The benefit of an FET stent graft is a tight seal in the descending aorta at an area that is not accessed easily through an anterior approach (Fig 1C, *green arrow*). It also turns a complex, 2-stage procedure into 1 surgery. FET has been used for chronic aneurysms of the aorta, proximal and distal to the left subclavian artery,[5] and acute and chronic dissections of both Stanford types A and B, for which it primarily is used in patients with complicated type-B dissections.[6]

The authors report a case in which a stent collapse was detected after an FET procedure. This devastating complication can lead to distal organ hypoperfusion syndrome. The case highlights the fact that using proximal and distal arterial pressure reading discrepancies and intraoperative transesophageal echocardiography (TEE) can ensure timely diagnosis and guide effective surgical correction.

FET is performed via median sternotomy with tube graft replacement of the ascending aorta and aortic arch with the patient under deep hypothermic circulatory arrest. Arch reconstruction may involve supra-aortic debranching of the great vessels with tube graft prostheses anastomosis versus hemiarch technique anastomosis. For an FET procedure, the distal arch tube graft is joined to a descending endovascular stent graft deployed anterograde into the exposed descending thoracic aorta (Fig 2). Exclusion of the left subclavian artery by the endovascular stent is possible, which then would require bypass. However, using landing zone 3 of the descending aorta obviates the necessity for bypass (Fig 1A, *yellow arrow*).

This case report describes the events that led to the detection of stent graft collapse using intraoperative TEE during an FET procedure. The authors became suspicious after separating the patient from cardiopulmonary bypass when discrepancies between left radial and left femoral invasive pressure monitoring persisted stent graft collapse at the proximal descending aorta, showing a loss of more than 75% of internal stent diameter, with limited high-velocity, color-flow, and high-pressure gradients. These TEE views also were used to assess the effectiveness of balloon graft expansion and the efficacy of an additional endostent at the proximal descending aorta to re-expand FET. The University of Florida Institutional Review Board granted permission to publish this report.

CASE PRESENTATION

A 77-year-old, 70-kg, white male with known Stanford type-B dissection returned with intolerable chest discomfort radiating to his back. Continued medical management of blood pressure followed by a series of repeat chest computed tomography (CT) angiography showed little change in his descending aorta dissection. However, in comparison with a prior CT scan, an increased change in false lumen flow in the descending aorta and a secondary aneurysmal dilation of the ascending aorta to 5.5 cm and arch to 4.1 cm, respectively, were noted. Comorbidities included a known 4.0-cm fusiform, infrarenal abdominal aortic aneurysm with a 0.5-cm mural thrombus followed up without change for the past 5 years, a 40-plus pack-year smoking history, hypertension, ischemic colitis, and coronary artery disease status postdrug-eluting stent to the proximal right coronary artery. The patient's baseline creatinine was 1.2 mg/dL, and electrocardiography demonstrated sinus rhythm with multiform premature ventricular complexes. Left heart catheterization showed mildly reduced left ventricular function, estimated ejection fraction of 50%, and mild global hypokinesis. Using CT angiography, the patient was classified as experiencing chronic Stanford type-B dissection originating at the aortic wall distal to the left subclavian takeoff (Fig 1B, *blue arrow*), extending down to the level of the celiac plexus. The aneurysmal ascending aorta had a cross-sectional diameter of 5.5 cm, with preservation of root structures and an arch diameter of 4.1 cm.

Because the patient had little relief from chest and back pain after medical management and he experienced an interval increase in ascending aorta dilation, the decision for surgery was made. Because of his preserved cardiovascular function and the overall health of his organ systems, it was decided that the patient was a good surgical candidate. There was no significant carotid artery stenosis, history of cerebral vascular accident, or transient ischemic attack, and surgical mortality and stroke risk were believed to be reduced by the hybrid endovascular approach. The surgical plan for aorta reconstruction included an ascending graft from the sinotubular junction through the arch with graft side arms for arch vessel anastomosis, with distal graft connection to the descending aortic

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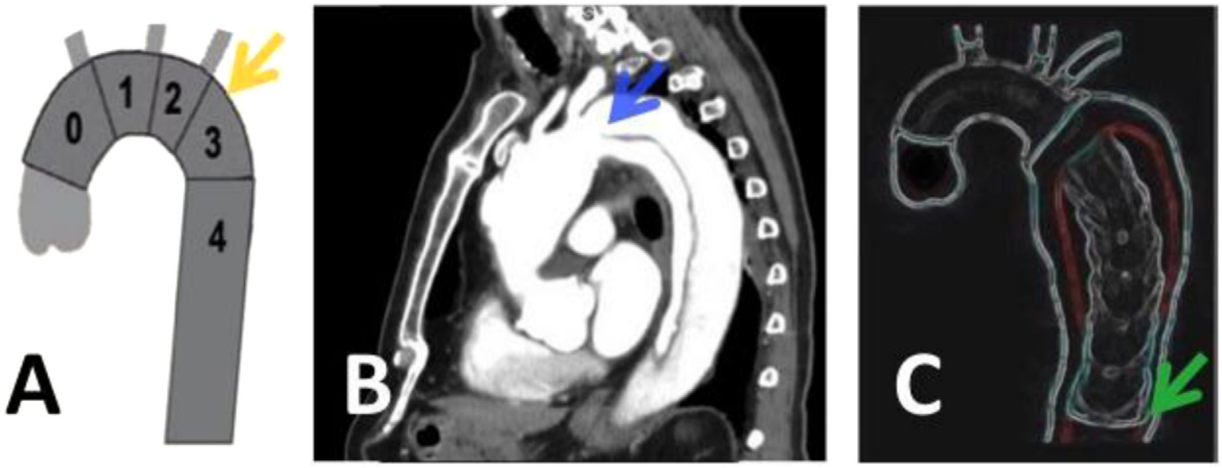

Fig 1. (A) Ishimaru classification of thoracic aortic landing zones for repair with endovascular stent graft; *zone 3*, distal to left subclavian artery (*yellow arrow*). (B) Sagittal view of chronic Stanford type-B dissection with aneurysmal ascending aorta; descending dissection flap originates distal to the left subclavian artery takeoff (*blue arrow*). (C) Schematic of tube graft reconstruction of ascending aorta and aortic arch joined to the endovascular stent graft with frozen elephant trunk landing zone distal to the left subclavian takeoff and tight seal in descending thoracic aorta (*green arrow*).

stent deployed antegrade through the exposed aorta (Fig 1C). For consideration of hybrid debranching versus open arch repair, data on long-term durability and survival are lacking.[7] The hybrid approach was selected as a less-invasive alternative, although 4 observational studies showed a nonsignificant trend toward increased neurologic events and late-term mortality in hybrid debranching groups.[8]

General anesthesia was induced with propofol, fentanyl, and vecuronium and was maintained with isoflurane in a 50% oxygen/air mixture. Oral intubation was uneventful, and hemodynamics were stable without the need for vasodilator or vasopressor support. Baseline lactate was 0.6 mmol/L. Invasive blood pressure monitoring was measured via left radial and left femoral arteries and central pressures by right internal jugular vein pulmonary artery catheter; right arm circulation was reserved for antegrade cerebral perfusion. A baseline TEE examination was performed with no signs of valvular regurgitation and normal biventricular function.

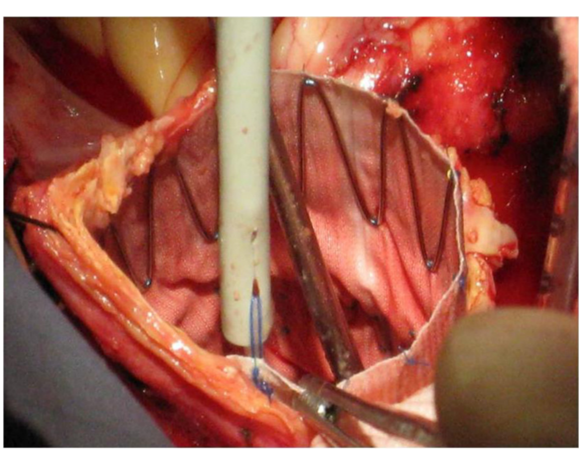

Fig 2. Anterograde deployment of frozen elephant trunk TX-2 stent graft over stiff guidewire in exposed descending thoracic aorta.

After sternotomy and systemic heparinization, a 2-stage venous cannula was placed in the right atrium and a retrograde cardioplegia catheter was placed the coronary sinus. The right axillary artery was cannulated with a catheter (EOPA,Medtronic, Minneapolis, MN) for antegrade cerebral perfusion during hypothermic circulatory arrest. At this point, the patient was placed on cardiopulmonary bypass and his temperature was cooled to 26°C. Circulatory arrest commenced with the patient in the deep Trendelenburg position, and bilateral electroencephalography showed sustained isoelectric burst suppression.

Dissection of the innominate, left carotid, and left subclavian arch arteries was completed for arch reconstruction with a 34-mm Gelweave prosthesis, 14 × 10 × 10 mm (Vascutek-Terumo, Renfrewshire, Scotland), with a side-arm branch for attachment to the cardiopulmonary bypass circuit. A wire then was passed from the left femoral artery into the thoracic aorta true lumen, confirmed using TEE with descending aorta short-

Fig 3. Intraoperative vital signs with invasive arterial blood pressures, showing a 15 mmHg mean arterial pressure gradient difference between left radial artery of 79 mmHg (*red circle*) and left femoral artery of 64 mmHg (*white box*).