Thoracic Aortic Endograft Collapse after Endovascular Treatment of a Traumatic Pseudoaneurysm

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ABSTRACT

Aortic endograft placement is evolving into the standard of care for treatment of patients with anatomically suitable thoracic aortic aneurysms. Application of this technique and these devices in other thoracic aortic pathology, such as traumatic pseudoaneurysms, symptomatic type B aortic dissections, penetrating ulcers, and even mycotic aneurysms, appears to be promising. We report a case in which a stent graft was used to treat a post-traumatic pseudoaneurysm of the thoracic aorta. The case was complicated by delayed collapse of the endograft, which led to hypoperfusion of the extremities, kidneys, and intestines. Reestablishment of endograft patency and distal reperfusion was achieved by placement of two balloon-expandable stents within the endograft. Potential factors leading to the development of this complication are discussed.

KEYWORDS: Thoracic aorta, trauma, endograft, collapse

Objectives: Upon completion of this article, the reader should be familiar with endovascular management of traumatic thoracic aortic injuries.

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Traumatic thoracic aortic rupture is often a lethal injury, accounting for 18% of deaths associated with motor vehicle accidents. It is estimated that only 25% of patient who sustain a significant aortic injury due to blunt trauma survive the initial event.¹ Of those that survive the initial injury, ~30% of them die within the first 6 hours.² If left untreated, patients with traumatic aortic rupture have survival rates < 20%.³ Accurate and rapid diagnosis is essential to enable prompt treatment. Over the past 5 years, the gold standard for the diagnosis

of traumatic aortic injuries has evolved from catheter-based angiography to computed tomographic angiography (CTA).⁴ CTA is a rapid and accurate diagnostic modality that is readily available at most institutions. CTA can be easily repeated for follow-up and is also helpful in treatment planning. Intravascular ultrasound is complementary to catheter-based angiography in delineating thoracic aortic injury, but its most helpful role may be in the detection of subtle intimal injuries of the aorta.^{5,6} Transesophageal echocardiography has also

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Case-Based Complications in Interventional Radiology: Lessons

Learned; Guest Editor, Sue Weeks, M.D.

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DOI 10.1055/s-2007-985735. ISSN 0739-9529.

been utilized in the diagnosis of aortic pathology⁷; however, it is not readily available in most institutions and is very operator dependent.

The traditional treatment of traumatic thoracic aortic ruptures has been open surgical repair.⁸ Due to the presence of multiple concomitant injuries sustained by patients with traumatic thoracic aortic injury, open surgical repair is associated with mortality rates as high as 28% and paraplegia rates up to 14%.^{9,10}

Dake et al¹¹ pioneered the utilization of endografts for management of thoracic aortic aneurysms. Their study demonstrated lower mortality and morbidity rates compared with surgery in treatment of thoracic aortic aneurysms. More recently, utilization of endografts in the management of traumatic thoracic aortic injuries has been reported, with good technical and clinical success rates and less mortality and morbidity than open repair.^{12,13}

We report a case in which an endograft was used to treat a traumatic thoracic aortic injury. A delayed complication related to collapse of the aortic endograft occurred and resulted in symptomatic hypoperfusion of the lower extremities, kidneys, and intestines and the need for a secondary procedure, prolonging the patient's hospitalization.

CASE REPORT

A 36-year-old man was brought to the emergency department (ED) after a motor vehicle accident. On arrival at the ED, his blood pressure was 81/39 mm Hg, with a pulse rate of 82 beats per minute. The patient was intubated, and his oxygen saturation was 94% with an FIO_2 of 100%. A left pneumothorax was present and managed by placement of a chest tube. A portable chest X-ray (CXR) demonstrated a left-sided diaphragmatic hernia, a persistent left pneumothorax, the left chest tube, a widened mediastinum with obliteration of the aortic knob, and 6th and 7th posterior rib fractures (Fig. 1). A computed tomography (CT) scan demonstrated a pseudoaneurysm originating from the inferior, medial aspect of the aortic arch at the level of the isthmus and an associated mediastinal hematoma (Fig. 2). A left diaphragmatic rupture with herniation of the stomach, spleen, and splenic flexure of the colon into the left hemithorax, a grade 2 laceration of the spleen, and a left pneumothorax with a left chest tube were also seen on the CT scan. The patient also had multiple broken teeth, facial lacerations, and a comminuted right proximal femur fracture. Trauma surgery, cardiovascular surgery, orthopedics, and plastic surgery were all involved in the management. After discussion among the surgical teams, it was decided initially to manage the aortic pseudoaneurysm medically. However, the patient was taken to the operating room for emergent repair of his diaphragmatic rupture.

Figure 1 Chest X-ray demonstrates a left-sided diaphragmatic hernia (black arrows), a left-sided pneumothorax (black arrowhead), with placement of a chest tube, a widened mediastinum with obliteration of the aortic knob, and 6th and 7th posterior rib fractures (small curved arrowheads).

Two days later, the hemodynamic status of the patient was improved. Therefore, it was decided to pursue repair of his thoracic aortic pseudoaneurysm. He was taken to the interventional radiology (IR) suite for endovascular repair of the aortic pseudoaneurysm as part of a clinical trial approved by the institutional review board (IRB) and the Food and Drug Administration (FDA). The thoracic aortogram confirmed the presence of a large pseudoaneurysm originating from the inferior aspect of the distal aortic arch (Fig. 3A). A

Figure 2 Computed tomographic angiography demonstrates hematoma (black arrow) adjacent to aorta and formation of a pseudoaneurysm (arrowhead) at inferior medial aspect of the distal aortic arch.

Figure 3 (A) Thoracic aortogram shows a large pseudoaneurysm (black arrows) distal to the left subclavian artery at the curvature of the arch. (B) Post-stent graft deployment angiogram shows complete exclusion of the pseudoaneurysm (black arrow), incomplete approximation of the endograft to the inferior aspect of the aortic arch (arrowhead), and persistent antegrade flow in the left subclavian artery despite good coverage of the origin by the stent graft.

28 mm × 100 mm Gore TAG thoracic stent-graft (W.L. Gore, Flagstaff, AZ) was advanced via the right common femoral artery after preclosure of the access site artery with a Prostar XL closure device (Abbott Laboratories, Abbott Park, IL). Due to the proximity of the pseudoaneurysm to the left subclavian artery, coverage of the left subclavian artery was planned to obtain a better proximal seal with the endograft. A prior CTA of the head and neck showed codominant right and left vertebral arteries, which united to form the basilar artery. Therefore, no left subclavian artery revascularization procedure was performed prior to endograft placement. The device was deployed across the left subclavian artery. The superior aspect of the endograft was well opposed to the greater curvature of the aortic arch; however, the inferior aspect of the endograft did not completely oppose the lesser curve of the arch. There was complete exclusion of the pseudoaneurysm by the endograft. Although the left subclavian artery was covered, there was some persistent antegrade flow in the left subclavian artery (Fig. 3B). The procedure was terminated, and the right common femoral artery access site was successfully closed with the Prostar XL closure device. The left common femoral artery access site, which was used for insertion of the diagnostic pigtail catheter, was successfully closed with an Angio-Seal Vascular Closure device (St. Jude Medical, Memphis, TN).

The next day (hospital day 4), the orthopedic injuries were repaired in the operating room. A follow-up CTA was obtained 2 days (hospital day 5) after endograft placement, which revealed persistent exclusion of the thoracic pseudoaneurysm. Mild narrowing of the

endograft at the level of the pseudoaneurysm was attributed to the mass effect caused by the pseudoaneurysm (Fig. 4).

On the 19th day of hospitalization, the patient developed diminished femoral and pedal pulses, worsening renal function, increasing abdominal distention, and an elevated lactic acid level. A noncontrast CT scan showed infolding of the endograft (Fig. 5). The patient was immediately brought to the IR suite, and a thoracic angiogram was obtained that confirmed the presence of a significantly collapsed endograft. The pseudoaneurysm

Figure 4 Sagittal reformatted computed tomographic angiography image demonstrates patency of the graft with some narrowing at the level of the pseudoaneurysm due to mass effect by the completely excluded pseudoaneurysm (black arrow).

Figure 5 Two axial images from a noncontrast computed tomography demonstrate infolding of the stent graft.

was also filling with contrast (Fig. 6A). A 14-mm Atlas balloon (Bard Peripheral Vascular, Tempe, AZ) was used initially to reexpand the lumen of the stent graft and also to ensure that the guidewire was positioned within the lumen of the endograft (Fig. 6B). An 11F sheath (Cook, Bloomington, IN) was placed. A Palmaz 4010 balloon-expandable stent (Cordis Endovascular, Warrenton, NJ) was hand mounted on an 18-mm Maxi-LD balloon (Cordis Endovascular) and was advanced through the introducer sheath into the endograft to the level of the lesser curve of the aortic arch and deployed (Fig. 6C,D). A second 4010 Palmaz stent was then deployed in the distal segment of the endograft (Fig. 7A,B). The proximal Palmaz stent was further balloon dilated to 25 mm (Fig. 6D), and the distal stent was balloon dilated to 20 mm (Fig. 7B). The postprocedure angiogram demonstrated a good result with complete exclusion of the pseudoaneurysm (Fig. 7C) and no pressure gradient across the stents and endograft. An en face view of the stents within the endograft demonstrated widely patent devices (Fig. 7D). Groin access site was closed with a Prostar XL closure device. At the end of the procedure, the patient had excellent

femoral and pedal pulses. The patient's abdominal distention, lactic acidosis, and renal function all improved.

Over the ensuing 4 weeks, the patient continued to improve clinically and was eventually discharged home after a total of 10 weeks of hospitalization. Postero-anterior, lateral, and oblique CXRs and a CTA was obtained 4 months later (6 months post trauma). CXRs showed no change in endograft or stent configuration, and CTA showed that the endograft was patent with persistent exclusion and resolution of the post-traumatic pseudoaneurysm (Fig. 8). At this time he was clinically doing well. One month later (7 months post trauma), he encountered an episode of small bowel obstruction due to postsurgical adhesions and underwent uneventful surgical lysis of the adhesions. The patient is currently being followed as an outpatient and will undergo 1-year follow-up CTA and CXRs in January 2007.

DISCUSSION

Although open surgical repair is currently the gold standard in managing acute thoracic aortic injuries, the use of endovascular technique is gaining popularity.

Figure 6 (A) Thoracic angiogram shows a collapsed stent graft (black arrowheads) and filling of the pseudoaneurysm with contrast (black arrow). (B) A 14-mm balloon inflated inside the stent graft to confirm intraluminal positioning of the 0.035-inch guidewire. (C) A Palmaz stent (Cordis Endovascular, Warrenton, NJ) (black arrow) hand mounted on a balloon advanced to the proximal stent graft. (D) Dilation of the stent graft to 25 mm with a balloon catheter.

Emergent or even delayed operative repair of traumatic aortic injuries is associated with significant cardiopulmonary, neurological, and hemodynamic complications.^{8-10,14}

The advantages of an endovascular management of this problem include no need for aortic cross-clamp-

ing, therefore avoids inducing hypoperfusion and hemodynamic disturbances to the brain, spinal cord, and other vital organs; no need for circulatory bypass or assistance; no need for single-lung ventilation in a patient who may have severe pulmonary compromise due to concomitant lung trauma; no need to perform a thoracotomy; and the

Figure 7 (A) Placement of another Palmaz stent (black arrow) to the distal stent graft. (B) Balloon dilation of the distal stent to 20 mm. (C) Final angiogram showing reexpansion of the stent graft with good flow through its lumen and exclusion of the pseudoaneurysm. (D) Fluoroscopic en face spot view of the stents and stent graft demonstrates no evidence of infolding.

ability to perform the endovascular procedure within close proximity to the day of injury without creating significant physiological disturbances.

Although there are numerous published case series or retrospective comparisons between surgery and endovascular therapy documenting the effectiveness of endograft therapy in the management of acute thoracic aortic injuries, there are no prospective, randomized, controlled data that demonstrate its supe-

riority to surgical management.^{8,12,13,15} In addition, there is no specific endograft device that is approved by the FDA for this application. Indeed, much of the initial experience with the use of endografts in the treatment of post-traumatic thoracic aortic injuries was obtained with homemade devices.¹⁶ However, with the FDA approval of the Gore TAG device for treatment of thoracic aortic aneurysms in March 2005, interventionalists now have a device readily available for

Figure 8 Sagittal reformatted computed tomographic angiography image demonstrates patency of the two Palmaz stents (Cordis Endovascular, Warrenton, NJ) (arrowheads) and endograft. Note outpouching of the endograft into the cavity previously occupied by the pseudoaneurysm (arrow).

off-label use in the setting of post-traumatic aortic injuries. In our particular patient, the Gore TAG device was used as part of an IRB and FDA-approved clinical trial.

When endovascular repair of a traumatic thoracic aortic injury is considered, several anatomical issues should be closely evaluated. The morphology of the thoracic aorta in young patients who have aortic injuries is often very different from the aortic contour of older patients with atherosclerotic thoracic aortic pathology. The site of injury is usually in close proximity to the origin of the left subclavian artery, and the proximal landing zone is often very short. Most devices currently need a minimum landing seal zone of 20 mm. Therefore, coverage of the left subclavian artery is often needed to obtain a good proximal seal. In addition, posterior fossa collateral circulation should be known prior to exclusion of antegrade flow in the left vertebral artery. In contrast to patients with atherosclerotic disease, patients with traumatic aortic injury often have smaller aortic diameters and smaller radius of arch curvature, making it difficult for the endograft to expand fully and approximate the lesser curve of the aortic arch. Given the high hemodynamic shear stress and forces in the region of the aortic arch, incomplete endograft expansion and poor vessel wall approximation may predispose devices to collapse and/or migration.

In one series, the angiographic morphology of 50 trauma patients with aortic injuries was analyzed. The mean aortic diameter adjacent to the area of injury was found to be only 19.3 mm, again highlighting the anatomical challenges for current endografts in this patient population.¹⁷ The smallest Gore TAG device is currently 26 mm in diameter. Because oversizing of this device more than 20% may lead to incomplete device expansion and device infolding, use of this device in patients with aortic diameters < 23 mm may be problematic. In addition, all currently available endograft devices are somewhat rigid and lack good conformability, flexibility, and vessel wall approximation, especially around areas of acute angulation. All of these factors should be considered in treatment planning.

In our case, the aortic diameter was 24 mm at the proximal landing zone and 20 mm in diameter at the distal landing zone. Additionally, the radius of curvature of the lesser curve of the aortic arch was small. Although deployment of the 28-mm diameter endograft device resulted in good approximation of the device along the greater curvature of the aortic arch, the device did not conform well to the lesser curve of the aortic arch, and it was also moderately oversized for the distal landing zone. It is likely that the high shear stress forces along the inferior surface of the endograft at the level of the aortic arch, where the endograft was poorly approximated to the aortic wall, in combination with distal landing zone oversizing predisposed the endograft to collapse. Once partial collapse of the endograft occurred, in effect, a hemodynamic equivalent to an aortic dissection with hypoperfusion below the level of the endograft occurred. When collapse of the endograft was recognized, surgical versus endovascular repair options were considered to reestablish adequate distal perfusion while excluding the aortic pseudoaneurysm. Due to the tenuous clinical status of our patient, we elected to use balloon-expandable stents to treat the collapsed endograft.

Collapse of a thoracic aortic endograft is a rare complication with only a few case reports in the literature.^{15,18–20} Immediate or delayed (months later) collapse of the Gore TAG thoracic endograft device can occur when it is placed in an aortic arch with a small radius of lesser curvature of the aortic arch, resulting in poor approximation of the endograft along the lesser curve of the aortic arch (Fig. 9). Placement of an endograft in this so-called no-man's-land should be avoided whenever possible. In addition, collapse of an endograft placed in this region of the thoracic aorta is also more likely to occur if the diameter of the endograft is oversized more than 20%. To overcome the limitations in device availability, interventionalists have been employing a variety of homemade devices or aortic cuffs from abdominal aortic endograft devices with good clinical success. Lin and Lumsden¹⁵ recently published

Figure 9 Two configurations of the aortic arch: A narrow radius (r) of the lesser curvature of the arch seen more commonly in younger patients, making full approximation of the endograft difficult at the lesser curvature (black arrow). In contrast, a longer radius (R) of the lesser curvature of the arch seen mostly in elderly patients with aneurismal disease makes approximation of the endograft to the lesser curvature more likely.

a nice compilation of various series. In situations in which collapse of an endograft occurs, clinical outcomes can be catastrophic if the problem is not recognized and treated immediately.

Treatment of this problem is directed toward providing extra hoop strength to the endograft to facilitate its reexpansion by the use of large balloon-expandable stents or placement of a new endograft inside the existing endograft. Placement of a second endograft requires the use of a larger introducer sheath (at least 20F) and also the presence of a suitable proximal landing zone.^{18–20} By extending the endograft proximally, the hope is that with two endografts, the overall radial force and hoop strength will be adequate for endograft reexpansion, and long-term patency and the proximal extension will facilitate better approximation of the device along the inner curvature of the aortic arch. If the first device has already been placed to the level of the left carotid artery, placement of a second device cannot be performed unless a right-to-left carotid artery bypass is performed.

Use of a balloon-expandable stent to reexpand and reinforce the hoop strength of the endograft has also been used with success.²⁰ The advantage of this technique is that it can be performed with an 11F introducer sheath and does not require the availability of an additional proximal landing zone.

In summary, endovascular solutions to traumatic thoracic aortic injuries remain promising but challenging with currently available devices. Until more flexible,

conformable, and smaller diameter devices become available, both early and late device-related complications will continue to occur. The best way to avoid the complication of endograft collapse and to optimize technical and clinical outcomes is to select appropriate patients for this therapy by paying close attention to the specific anatomical issues during treatment planning. Whenever possible, application of this technology for traumatic thoracic aortic injuries should be employed by centers with experience with thoracic endografting, preferably as part of a clinical trial to allow for prospective data acquisition. In our particular case, in retrospect, we could have probably used a 26-mm diameter TAG endograft to minimize the oversizing, and once poor approximation of the endograft to the inferior surface of the aortic arch was noted, immediate placement of a balloon-expandable stent may have obviated the occurrence of endograft collapse. We were fortunate that the patient was still in the hospital when endograft collapse occurred, so that the problem could be immediately detected and treated. Obviously, if this complication had arisen under different circumstances, a more serious adverse outcome could have resulted.

ACKNOWLEDGMENTS

The authors thank D. Laurie Persson, B.A., B.Sc., A.A.M., for his contributions in image preparation and artwork.

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