Endovascular Treatment (EVT) of Acute Traumatic Lesions of the Descending Thoracic Aorta — 7 Years’ Experience


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Objectives. To present a single centers’ 7-year experience in the endovascular treatment of acute traumatic lesions of the descending thoracic aorta (ATL of the DTA).

Materials & methods. Between March 1999 and December 2006, 34 consecutive acute traumatic lesions of the descending aorta (23 men, mean age 44 years) were treated endovascularly. Stentgrafts used were TAG Excluder, Zenith TX2 and Talent. In 23 patients the Left Subclavian Artery (LSA) was covered. Mean procedural duration was 20 to 75 minutes.

Results. Exclusion of the rupture site was achieved in all cases with no conversion to open surgery. Overall 30-day mortality was 8.8%. Two patients died on post operative day (pod) 1 and one on pod 22 from cranial injuries. No death or neurological deficit related to the endovascular treatment was reported. Four type I endoleaks required treatment either by balloon reexpansion (n = 2) or by additional stentgraft implantation (n = 2). In two patients the stentgraft collapsed totally several days postoperatively. Two patients required secondary surgical procedures (iliac access complication and revascularisation of the left subclavian artery n = 1). The average follow-up was 43.8 months (1–93 months). No stentgraft related abnormality has been subsequently documented.

Conclusions. The endovascular treatment of ATL of the DTA may offer the best means of therapy in a polytrauma patient.

Keywords: Endovascular; Traumatic; Thoracic aorta; Stentgraft; Transection.

Introduction

Acute traumatic lesions of the descending thoracic aorta (ATL of the DTA) are usually accompanied by a set of severe concomitant injuries.1,2 The optimal time to repair such aortic injuries is debated.3–6 Even more debatable is whether to use classical open surgical treatment or the newly evolved endovascular treatment.7–13 Immediate open surgical repair carries a high risk of mortality in unstable patients.14–18

A low risk procedure to seal the rupture site, even if used as bridging technique, is an attractive option. From August 1995 to March 1999 we applied EndovascularTreatment (EVT) to 216 patients with different aortic pathologies.19,20 Relying on the experience gained, we decided to treat all incoming cases of ATL of the DTA by the EVT approach. We applied EVT in all the patients with documented ATL of the DTA in that period, with no exception. Centers with minimal EVAR experience, though, should follow carefully the limitations of use and contraindications for each particular stent graft, as these are provided by the manufacturer of each graft.

Since March 1999 we have performed EVT in 34 consecutive cases of ATL of the DTA, 30 of them presently alive. To our knowledge this represents the largest series of its’ kind reported in the English literature. In two cases a phenomenon which we call Acute Stent Compression Syndrome (ASCS) was encountered. Scattered reports have also addressed the same phenomenon in the literature21–23 and awareness seems to be the best mean of both prevention and treatment.

Materials and Methods

From March 1999 to December 2006 36 consecutive patients with ATL of the DTA were admitted to our department. 34 were treated endovascularly, while the other 2 died in the Emergency Room before any thoracic intervention could be initiated. The review of the files involved was approved by the Ethical Committee of our Institution. The patients were
victims of road traffic or occupational accidents and of falls from a great height and were either primarily admitted or after referral from another hospital. All patients were operated on within 16 hours (mean 8.6 \pm 7.5 h) of the initial injury.

Patients’ age varied from 12–79 years, 23 were men and the concomitant injuries were: Head and brain 80%, abdomen 73%, pelvis 33% and extremities 67%.

Spiral Computed Tomography (CT) scans showed circular (complete transection) or semicircular descending thoracic aortic injuries in 11 and 23 patients, respectively. Uni- or bilateral hemothorax were present in all cases.

All patients admitted without appropriate imaging from a referral hospital had a CT-angiography performed in our department (Brilliance 64, Philips Medical Systems, Hamburg, Germany). Emergency whole body scanning was performed utilizing trauma adapted protocols developed in our radiology department. The protocol allows the generation of both vascular and parenchymal contrast in a single helical scan acquisition. This is achieved with a low flow pre-injection of contrast (70 ml \@ 2 ml/s, Iomeprol 400, Bracco, Milan, Italy) and subsequent high flow injection of the same agent (50 ml \@ 3.5 ml/s) and a final saline flush (40 ml \@ 3 ml/s). The low flow phase guarantees sufficient parenchymal contrast equivalent to a separate portal venous phase. The ensuing high-flow phase generates vascular contrast as available from early enhancing arterial phase scans. The scan is initiated with an automated ROI threshold technique (Bolus Pro, Philips Medical Systems, Hamburg, Germany) utilizing a region of interest placed in the descending thoracic aorta. Breathhold command (cessation of ventilation for intubated patients) is triggered according to Hounsfield density measurements in the ROI. A threshold of 150 HU is usually applied.

Mean aortic diameters were found in the range from 12 to 30 mm, measured at the distal aortic arch between the left common carotid (LCC) and left subclavian artery (LSA) ostium. In 22 patients the lesion was found exactly opposite the LSA origin, in 11 patients it was found 10–20 mm distal to the LSA ostium and in one patient the lesion was 50 mm distal to the LSA ostium. Stentgrafts used, were 23 TAG Excluder (26–34 mm diameter) plus one tapered 16.5 to 14 mm iliac limb extension (W.L. Gore & Associates, Putzbrunn, Germany), 6 Zenith TX2 (22–34 mm diameter, Cook Incorporated, Bloomington, IN, USA) and 5 Talent (20–24 mm diameter, Medtronic Worldwide Medical, Sunrise, FL, USA). Three parameters determined graft selection. Availability, graft diameter required and most of all personal experience. In our center we have a pool of grafts of different sizes from two of the aforementioned companies. As mentioned above, the smallest available endoprosthesis diameter of the Gore TAG graft was 26 mm. We came across cases where the aortic diameter was as small as 18 mm. Even after adding a 10% oversizing to that measurement we still need a graft with an endoprosthesis diameter of 20 mm, namely a graft constructed by Medtronic. Some authors believe the TAG is suited to angulated arches as it appears to be more conformable. In addition they propose that the TAG is low profile and can be inserted through smaller diameter access vessels and that the TAG is available in different diameters compared with the Talent. We have reported in 2003\cite{24} the Gore Excluder to be uniquely flexible and equipped with a simple deployment mechanism. The Medtronic graft also has a very precise and delicate deployment mechanism.

In 22 patients the proximal covered edge of the stentgraft was positioned close to the distal margin of the LCC ostium with complete coverage of the LSA ostium. Free LCC perfusion was verified in all patients by completion angiography. In all other patients stentgraft deployment was close to LSA ostium, hence orthograde LSA perfusion was preserved.

All operations were performed under general anaesthesia in the surgical suite under fluoroscopy control by a C-arm image intensifier (OEC 9600 Vascular, GE Medical Systems Germany). Transesophageal echo (TEE) was additionally applied, whenever available, as an adjunct in the estimation of the correct placement of the stent in the true lumen of the vessel. 5000 IU of Heparin (Leo Pharmaceuticals) were administered once, before guide wire insertion. Stentgrafts were introduced over a super stiff Amplatz guide wire (Boston Scientific, Ratingen, Germany) through a 20, 22 or 24 F sheath. Stentgraft deployment was performed under respiratory arrest but without pharmacologically induced hypotension or cardiac arrest. After the stentgrafts were successfully deployed, a completion angiography was performed to confirm the exact position of the graft and the total exclusion and coverage of the traumatic aortic lesion. The mean duration for the entire endovascular procedure was 20 to 75 minutes. Some patients required simultaneous operations for concomitant lesions (e.g. laparotomy for spleen/liver rupture, stabilization of third grade open fractures etc.) and thus spent up to 320 minutes on the operating table. The imaging time varied between 3 and 20 minutes and the average contrast medium used was 140 ml, range 60–220. The estimated blood loss was less than 500 ml.

As soon as patients’ condition allowed, preferably on the same day of the procedure or the day after, a control angio-CT evaluated the exclusion of the...
lesion and the position of the stentgraft. Additional postoperative angio-CTs were conducted on the 3rd, 6th and 12th month postoperatively and yearly thereafter. Observation time is up to 7 years.

**Results**

Complete exclusion of the rupture site was achieved primarily in all cases. No conversion to open surgery was required. No patient developed temporary or permanent neurological deficit related to the endovascular treatment, peri- or postoperatively. Overall 30-day mortality was 8.8%. No aortic rupture related death was documented. Two patients died on pod 1 and one on pod 22 from cranial injuries. Autopsy showed an intact stent-graft repair of the thoracic aortic injury. Another patient died on pod 50, following ASCS and will be discussed separately.

Four type I endoleaks in the early post-operative period required treatment either by balloon reexpansion \( n = 2 \) or by additional stentgraft implantation \( n = 2 \). Two patients developed Acute Stentgraft Compression Syndrome (ASCS) and were treated accordingly. Another two patients required secondary surgical procedures (ilio-femoral bypass for iatrogenic external iliac artery trauma \( n = 1 \) and revascularisation of the left subclavian artery \( n = 1 \)).

Follow up of all patients included angio-CT and simple chest X-Ray performed at 3, 6, 12 months postoperatively and yearly thereafter. The average follow-up time was 43.8 months (1–93 months). 24 patients were followed for ≥2 years, 14 for ≥5 years and of 8 for ≥7 years. (Fig. 1) No stentgraft migration, wire fractures, in stent stenoses or relevant shape changes, post traumatic aneurysms or any other stentgraft related abnormalities have been documented.

**Acute stent compression syndrome (ASCS)**

In two of our patients a safe coaxially centred position of the stentgraft within the aortic arch lumen could not be achieved. In both cases the stents were not passed all the way up to the vertex of the aortic arch but rather stopped at the origin of the LSA. Despite repeated balloon manoeuvres neither a smooth alignment nor improvement of the position could be achieved (Fig. 2). In the first patient, a 24 year old severely polytraumatized female, the aortic diameter was estimated from the CT to be approximately 20 mm and a 26 mm Zenith TX2 stentgraft was selected. Due to her extremely bad general condition further manipulations to improve the positioning of the positioned stentgraft were abandoned, after the on table completion angiography documented complete sealing of the aortic rupture site, no endoleaks and retrograde flow to the LSA. The control CT on the first postoperative day revealed an unchanged stent positioning with lack of graft attachment to the inner curvature of the aortic arch, thus forming a triangular space between the stent graft and the aortic wall. Despite the extremely severe concomitant injuries, the patient recovered within the next 10 days and was released from the ICU to the trauma ward. A second control CT 6 weeks later (day 41 postop.) documented unchanged stentgraft position and the patient was asymptomatic with no signs of malperfusion or aortic stenosis. On day 43 however she developed an acute abdomen and spinal syndrome. An emergency angio-CT was performed, confirming complete stent compression and total aortic occlusion (Fig. 3). 60 minutes later the aortic flow was restored by proximal overstretching with a 24 mm Optimed Stent. She survived subsequent small bowel resection and right hemicolectomy but finally died 7 days later from diffuse intracerebral haemorrhage.

A second case of ASCS occurred to a 57 polytrauma victim. He was treated with a 28 x 150 mm TAG Excluder for a 24 mm aorta. Ten days later he developed signs of acute abdomen. Only one hour latter aortic flow was restored by balloon dilation of the proximal stentgraft segment. Continuous monitoring with TEE however revealed stentgraft recompression within the next 40 seconds. Therefore a second stentgraft (31/100 mm Gore TAG Excluder) was introduced and deployed identically to the proximal position of the first graft, aiming to double the radial expanding force of the proximal end of the former stent (Fig. 4). This patient also underwent small bowel surgery and right hemicolectomy but survived. The yearly follow up CTs thereafter have revealed no stent dislocation or stent recompression up today.

**Discussion**

The percentages of on scene, in hospital, perioperative and postoperative mortality of ATL are known to most thoracic surgeons from numerous previous publications.14–15 Many centers25,26 worldwide have reported their experience on EVT of ATL of the DTA.

EVT of ATL of the DTA was technically successful in all of our cases. Four type I endoleaks presented at least 24 hours postoperatively and were easily addressed. Only one death \( (1/34 = 2.9\%) \) could be indirectly related to the procedure and that occurred 50 days after the initial operation. The cumulative survival rate is presented in Fig. 5. Because ASCS, as
Fig. 1. Representative images of stentgraft behaviour after 2, 5 and 7 years. Top series: stentgraft after 2 years from implantation, Middle series: after 5 years, and Bottom series: after 7 years. Note that stent configuration depends on complete (middle, bottom) or incomplete (top) aortic rupture/transection. In complete transection (bottom) oversized stentgrafts may open to full size at the level of transection with no unfavourable sequel observed so far.
we have defined it, is potentially lethal unless treated immediately, all efforts have to be made to safely abolish it.

EVT of ATT has its own specific problems different from those already known from treating complex aneurysms and dissections, mainly due to the younger age index of the trauma victims population.

The main problems include graft size, graft bending and pulsatile movement of the aortic arch. The tight curvature of the aortic arch of young patients requires a very flexible graft. The graft tends to be pushed away from the inner curvature of the aortic arch due to the tendency of the graft to return to its straight form. In some cases the graft may be unable to follow the sharp curving of the aortic arch. In those cases the graft configures itself in a non concentric non coaxial fashion, leaving a small portion of its inner wall protruding into the aortic lumen. This results in the graft having no contact to the aortic wall and creating a triangular space between itself and the aortic wall. The angle between the inner curvature of the arch and the stentgraft may be as much 35–45° (Fig. 2).

Fig. 2. Discoaxial non-centered malposition of a 26 mm Xenith-X2 in a 20 mm aorta. The stentgraft at the inner curve is disattached and protrudes into the lumen. No improvement of alignment could be achieved by repeated balloon expansions of the stentgraft.

Fig. 3. Compression of stentgraft by the systolic jet and infolding of its’ inner-curvature. Large thrombus mass within the stentgraft leads to total aortic flow obstruction.

Fig. 4. Central overtenting by a 31×100 TAG Excluder reinforces the proximal stent and keeps it open; Note: both stentgrafts are congruent at the proximal end.

Fig. 5. Cumulative survival rate (Kaplan-Maier) for EVT of ATL.
At end-systole both left and right ventricles are maximally contracted and decreased in size, thus pulling down the ascending aorta and bending the aortic arch even more, forcing it to assume an even sharper configuration. Stentgraft attachment force is lowest at the inner curvature of the aortic arch. During systole the bursting flow of the stroke volume may hit this weak point thus forcing the proximal end of the stentgraft which is attached to the inner curvature to infold towards the centre of the graft, causing a partial or complete occlusion of the stent graft.

During systole, the juvenile thoracic aorta dilates up to 15–20% in order to accommodate the ejected stroke volume. A stentgraft anchored to the thoracic aorta has to follow the pulsatile movement of the aortic wall and even in end-systole, when the thoracic aortic wall (and the stentgraft with it) is dilated to its’ maximum, it should still possess some reserve to expand. Otherwise, during end-systole, there will not be sufficient radial force left to maintain wall anchainment and anchoring. Migration or endoleak should then be expected.

On the other hand, a markedly oversized stentgraft in a sharply curved juvenile aorta could wrinkle, thus leading to type I endoleak or even worse infolding and total stentgraft collapse and obstruction. Therefore the optimal stentgraft for each patient has to be selected not only on the basis of aortic diameter and lesions’ length but based on patients’ age and anatomy as well. Today, we tend to oversize the diameter of the stentgraft used by about 10%, in contrast to the former common practice of 20%. The endovascular repair of the 12-year old child we performed, undoubtly tests the limits of the EVT method, as the growth potential of the boy may render the stentgraft insuffi- cient for use in the aortic arch. A precurved graft would better align itself concentrically within the aortic lumen, would better follow the curvature of the aortic arch and would present minimal debending tendency. A reinforced, precurved stentgraft could become the procedure of choice in the future for the polytrauma victim.11,29

In the future, the radial expanding force of the proximal end of the stentgraft should be increased by the implantation by the manufacturers of an extra circumferential spring just at the beginning of the proximal graft. In both our cases of ASCS stent compression was abolished by increasing radial force through proximal overstenting.

A precurved graft is currently under manufacture, for use in the aortic arch. A precurved graft would better align itself concentrically within the aortic lumen, would better follow the curvature of the aortic arch and would present minimal debending tendency. A reinforced, precurved stentgraft could become the procedure of choice in the future for the polytrauma victim.11,29

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Conflicts of interest

The authors have no conflicts of interest to disclose.

References


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