Endovascular Treatment of Thoracic Aortic Pathology:
Feasibility and Mid-term Results

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Objective: to report our experience with 21 consecutive patients treated with a thoracic stent-graft.
Design: retrospective analysis.
Materials and Methods: Between October 1998 and February 2002, 21 patients (12 male), mean age 55.6 years (range 19–86 years), were treated for aorticortic pathology localized to the descending aorta (18 patients), the aortic arch (2 patients) and the ascending aorta (1 patient) and comprising true aneurysms (8 patients), false aneurysms (6 patients), traumatic rupture (4 patients), mycotic aneurysms (2 patients), and ruptured aneurysm (1 patient). Plain chest X-rays and computed tomography was performed at 3, 6 and 12 months postoperatively and then annually.
Results: the median (range) operation time was 85 min (50–305 min), hospital stay 6 days (3–63 days) and follow-up 24 months (5–44 months). Complications occurred in 5 patients and comprised intraoperative migration (1), type I endoleak (1), type II endoleak (1), ischemic myelopathy (1), pneumonia (2), suture granuloma (1) and common femoral artery dissection (1).
Conclusions: stent-grafting can be successfully employed to treat a wide range of thoracic aortic pathologies with a mortality, morbidity and resource utilization that is considerably less than that associated with conventional surgery. However, long term follow-up on safety and efficacy is needed.

Key Words: Endovascular stent-graft; Endoprosthesis; Thoracic aortic aneurysm; Aortic rupture.

Introduction

Surgical treatment of thoracic aortic aneurysms was first described by DeBakey in 1953.1 During the last several decades the mortality of this procedure has dropped significantly from approximately 20% in the 1960s2 to 2–3% nowadays.3 These are however the most favorable results in literature.4

Only 10 years ago a new minimally invasive technique for treating aortic aneurysms, transfemoral placement of an endovascular graft, was introduced by Volodos5 and Parodi.6 The stent-graft technique has mainly been used for the treatment of abdominal aortic aneurysms but, from the start it was evident that it could also be used for thoracic aortic pathology.5–8

Nowadays, the thoracic aortic stent-graft is used for treating a variety of aortic pathologies such as aneurysms,9–11 traumatic ruptures12–15 and dissections.11,16–18

It has been shown that the endovascular procedure reduces morbidity and mortality when compared to open repair.19 In this paper we describe the feasibility and mid-term results of thoracic stent-grafts in 21 consecutive patients treated either electively or acutely with a thoracic endovascular stent-graft between October 1998 and February 2002.

Materials and Methods

Patient selection

Patients were selected based on spiral computed tomography (CT) angiography.20 Patients were considered anatomically suitable if there was a proper anchoring site for the stent-graft both proximal and distal to the aortic lesion. These anchoring sites should have a maximum diameter of 36 mm and a minimum length of 10 mm, with the distal anchoring site cranial to the visceral arteries. Furthermore, access through the abdominal aorta either by a transfemoral route or by direct exposure of an iliac artery or the abdominal aorta should be feasible.
Preoperative imaging

Our imaging protocol consisted of contrast enhanced spiral CT angiography with use of dedicated post processing software (Mx View V3.51, Marconi Medical Systems). The scan delay time was determined based on a “delay test run”. This is followed by a series without contrast (120 kV, 150 mAs, increment 10, thickness 10, pitch 1.25, filter C, window W300, C30) and a contrast series (0.5 s rotation time, 120 kV, 200 mAs, increment 2.5, thickness 5, pitch 1.25, filter B, window W300, C70). Typically, we would construct a central lumen line in the aorta and perform diameter measurements in planes reconstructed perpendicular to this vascular axis. Length measurements were also calculated based on the central lumen line and no additional angiography was performed prior to surgery. In complex patients, e.g. pathology in the aortic arch, additional Shaded Surface Projections (SSP) were reconstructed to help us understand the anatomy. Patients with emergency indications, e.g. traumatic aorta ruptures, were treated based on quick analysis of the axial CT images and the intra-operative angiography.

Stent-grafts

Three makes of stent-grafts have been used: the GoreTM Thoracic Aortic Graft (W.L. Gore & Associates, AZ, U.S.A.) in 17 patients, the TalentTM thoracic endoprosthesis (Medtronic AVE, Ca, U.S.A.) in 3 patients and the AneuRxTM stent-graft (Medtronic AVE, Ca, U.S.A.) in 1 patient. For optimal fixation a minimum of 20% oversizing of the stent-graft diameter as compared to the diameter of the anchoring site in the aorta was applied. In total, 28 stent-grafts (median length 12.0 cm (range 7.5–15.0 cm), median diameter 3.4 cm (range 2.6–4.0 cm) were placed in 21 patients; in 18 patients we placed 1 stent-graft, in 3 patients we placed 2 stent grafts. In 2 patients stent-grafts were placed in both the thoracic and abdominal aorta in one operation.

Endovascular procedure

All procedures were performed by a vascular surgeon and an interventional radiologist under general anesthesia. Vascular access was preferably gained through surgical exposure of the right common femoral artery and placement of a 7 french sheath (Cordis, Miami, FL, U.S.A.). Preoperative imaging was performed using a mobile C-arm (Exposcop 8000, ZIEHM GmbH, Neurnberg, Germany, later replaced by the OEC 9800 mobile intensifier, GE Medical Systems, Salt Lake City, U.S.A.). A double J guide-wire and 5 french 90 cm pigtail catheters (Altaflow, Optimed, Ettlinger, Germany) were positioned in the ascending aorta, with subsequent replacement by a heavy-duty guide-wire (Back-up Meier, Boston Scientific-Schneider, Bülach, Switzerland). In patients with aneurysms in the ascending aorta or aortic arch an additional angiography catheter was inserted in the ascending aorta through the right brachial artery and intermittent contrast injections were made prior to and during graft deployment. If required, the stent-grafts could be gently dilated at the proximal and distal anchoring zones using a compliant balloon. At the end of the procedure a completion angiography was made to confirm aneurysm exclusion and assess possible endoleaks.

Follow-up

Follow-up consisted of 4 directional (anterior–posterior, lateral and 2 oblique) plain chest X-rays and CT angiography with contrast enhancement followed by delayed scanning 1 min after completion of the contrast series (120 kV, 200 mAs, 0.75 rotation time, increment 5, thickness 5, pitch 1.25, filter B, Window W300, C50) to improve endoleak detection. Success was defined as successful exclusion of the aneurysm. Follow-up was performed at 3, 6 and 12 months post-operatively and yearly thereafter.

Results

General results

Between October 1998 and February 2002, 21 consecutive patients (12 male, 9 female) with a mean age of 55.6 years (range 19–86 years) underwent endovascular treatment of the thoracic aorta. All consecutive patients are listed in Table 1.

The aortic pathology was mainly localized in the descending aorta (18 patients), followed by the aortic arch (2 patients) and ascending aorta (1 patient). Four traumatic aortic ruptures were located in either the isthmus or proximal descending aorta. In all patients implantations were performed through the transfemoral route; except for patient 1, where a retroperitoneal route was used because of occlusion of the left, and subtotal stenosis of the right iliac artery. The stent-graft could successfully be placed in all patients. Median duration of the endovascular procedure was 85 min (50–305 min).
In 3 patients we created a carotid-to-subclavian artery bypass. In two of these the aortic stent-graft intentionally covered the origin of the left subclavian artery in order to increase the proximal sealing zone for the endograft. This resulted in decreased blood pressure in the ipsilateral arm. In the other patient the aneurysm originated from a previous endarterectomy of part of the aortic arch and subclavian artery. Median duration of hospital stay was 6 days (3–63 days). No patient died as a result of complications of endovascular treatment during 24 months mean follow-up (range 5–44 months). Mid-term results are summarized in Table 2. No immediate conversion to conventional open thoracic aortic surgery was needed.

There were several indications for endovascular treatment: 8 patients had an aneurysm of the descending thoracic aorta (TAA) (Fig. 1a and b). The median age was 59.5 years (range 48–86 years). In 3 of these patients, 2 stent-grafts were used for aneurysm exclusion. Median operation time was 65 min (range 60–305 min). In patient 9 (operation time 175 min) we implanted an additional stent-graft for an abdominal aortic aneurysm. In patient 11 we performed a left sided carotid-axillary bypass, because of extension of the aneurysm up to the subclavian artery. Stent deployment was complicated by migration and a subsequent type I endoleak which was resolved by implanting a second stent-graft during the same procedure.

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origin of the subclavian artery was treated successfully by placing a Palmaz stent, pushing the fabric cover of the stent-graft somewhat backwards, leaving the bare spring in place. Patient 15 was operated 19 years earlier because of aortic co-arctation, 7 years earlier a reoperation was necessary because of a large aneurysm at the native aortic arch. Now he presented with a large false aneurysm at the distal anastomosis between the aortic graft and descending aorta. This aneurysm was successfully excluded by a thoracic stent-graft and the patient was discharged after 2 days (Fig. 2a and b).

The other patient who was treated for false aneurysm (patient 3), was operated at age 16 for Steal syndrome due to stenosis of the left subclavian artery. This was resolved by a thrombo-endarterectomy (TEA) of the left subclavian artery. When during follow-up an asymptomatic aneurysm of the origin of the subclavian artery was found, he underwent a side-to-end carotid-subclavian bypass followed by stent-grafting of the aortic arch. At follow-up the aneurysm is now diminished from 4.5 to 3.7 cm.

Two patients had a mycotic aneurysm for which they received antibiotal treatment (Vancomycin and Ciprofloxacin). Patient 8 probably developed a mycotic aneurysm due to previous Clostridium sepsis. Impression of the aneurysm on the esophagus caused an aortic-esophageal fistula. Stent-grafting of the descending thoracic aorta successfully repaired this aneurysm. Three days later, this procedure was followed by a transhiatal esophagectomy. Both patients, now 26 months after successful exclusion of the aneurysm, show no signs of residual infection. The patient with the esophageal rupture needed a late right-sided mini thoracotomy for drainage of an aneurysm sac hygroma at 18 months.

One patient with a ruptured descending aortic aneurysm was referred to our hospital. Immediately, 2 thoracic stent-grafts were placed, followed by evacuation of 1.5 l of blood from the right hemithorax. She was discharged after 10 days (Fig. 3a–c).

We implanted thoracic stent-grafts for false aneurysms in 2 patients with Marfan syndrome. Patient 10 underwent replacement of the aortic valve and ascending aorta (Bental procedure) for an aortic aneurysm 14 years earlier, followed by thoracoabdominal aortic grafting 9 years later. At follow-up we observed an aneurysm at the distal anastomosis of the ascending aortic prosthesis, which was successfully sealed with a stent-graft. Patient 20 had an operation for scoliosis via anterior-lateral approach 20 years earlier. On a routine X-ray examination by the orthopedic surgeon, a saccular aneurysm of the thoracic aorta was seen. A CT scan showed a close connection between the aneurysm and retained material from the previous osteosynthesis. The aneurysm was successfully excluded with a thoracic stent-graft and the patient was discharged after 2 days (Fig. 2a and b).
rib fractures. These patients were treated with single stent-grafts. Due to concomitant lesions median hospital stay was relatively long for this subgroup (22.5 days (range 15–55 days)).

Stent-related complications

Stent-related and general complications are listed in Table 3. In patient 11 we observed migration of the stent-graft during deployment; this was treated by placing a second stent-graft during the same procedure. Unfortunately, 6 months postoperatively CT angiography revealed a persisting type I endoleak. This endoleak was successfully treated by coil embolization and thrombin injection, as measured by unchanged volume of the aneurysm.

In patient 15 a type II endoleak was diagnosed at 6 months follow-up. Due to the complex vascular

Fig. 2. (a) Detail of postoperative chest X-ray of patient with Marfan syndrome and operation for severe scoliosis. The material from the osteosynthesis has caused a lesion of the aorta at the position of the uppermost screw. This screw is compressing the endovascular graft. (b) Detail from a lateral chest X-ray of the same patient.

Fig. 3. (a) Postoperative lateral chest X-ray of a patient with a ruptured TAA. Two endografts were used to exclude the aneurysm. (b) Axial CT image of the patient with the ruptured TAA made two days after surgery. The hemathorax on the right side has been drained, the bright metal components of the endograft are surrounded by hematoma. (c) Axial image at the same position 3 months after surgery. The peri-aortal mass is shrinking.
supply of the endoleak, it was impossible to exclude the endoleak by coil embolization. We decided on a conservative treatment and now, 9 months after the discovery of the endoleak, there is no progression in endoleak or aneurysm size.

Another early stent-related complication occurred in patient number 6 with a TAA between T5–T9. A few hours after surgery the patient complained of pain in the left hemi-thorax without neurological symptoms. Fourteen hours after the endovascular procedure, paralysis and paresis, respectively, of the left and right leg and sensibility deficit from T10 downwards developed. Emergency conversion to conventional surgery was performed. The stent-graft was removed with consequent graft interposition with revascularization of 3 intercostal arteries. After the procedure, we observed gradual improvement of the neurological deficit. Now, almost 3 years postoperatively, the patient can walk, with minimal paresis of the upper leg muscles on the right side. His major problem is chronic pain in the legs.

**Table 3. Complications.**

<table>
<thead>
<tr>
<th>Complications</th>
<th>Patients (n)</th>
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<tbody>
<tr>
<td>Stent-related complications</td>
<td></td>
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<tr>
<td>Migration</td>
<td>1</td>
</tr>
<tr>
<td>Endoleak</td>
<td>2</td>
</tr>
<tr>
<td>Spinal cord ischemia</td>
<td>1</td>
</tr>
<tr>
<td>Access dissection</td>
<td>1</td>
</tr>
<tr>
<td>General complications</td>
<td></td>
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<tr>
<td>In-hospital mortality</td>
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</tr>
<tr>
<td>Pneumonia</td>
<td>2</td>
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<tr>
<td>Suture granuloma</td>
<td>1</td>
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<tr>
<td>Cardiac (arrhythmia)</td>
<td>1</td>
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</table>

**Discussion**

Since stent-grafting avoids thoracotomy and cross-clamping, the operative insult is markedly reduced leading to a lower morbidity and mortality. Operation time, ICU and hospital stay were less when compared to results from conventional surgery from literature. Our results are comparable to recently published reports.

In our patients, preoperative imaging of the aortic aneurysm was supplemented by additional SSP. This digital reconstruction gives the surgeon a better perception of the three-dimensional structure of the aneurysm. However, creating the SSP reconstruction is time consuming and its additional value to the CT can be debated.

Migration of the stent-graft can occur either intra- or postoperatively. In patient 11 intra-operative migration during deployment of the stent-graft was encountered. Probably, this reflects misdeployment rather than stent migration. We had to place a second stent-graft in this patient to improve the proximal seal.

Spinal cord ischemia occurs when the stent-graft covers Adamkiewicz artery or other vital intercostal arteries. Recently published early and mid-term studies of endovascular TAA repair have reported paraplegia rates varying from 0–4%. In our series, 1 of the 23 patients had a partial reversible myelopathy. We performed a thoracotomy with interposition graft, although this choice can be debated. Various methods have been described to aid in the prevention of spinal cord ischemia, such as medication, generalized or local hypothermia, hyperbaric oxygen treatment, reattachment of intercostal arteries and cerebrospinal fluid (CSF) drainage. Presumably, drainage of CSF to a pressure of less than 10 mmHg favorably alters the pressure gradient, thus maintaining myelum perfusion. Thus, a re-thoracotomy can be prevented.

Apart from the use of the thoracic aortic stent-graft for elective aneurysms, we have used it for a variety of other pathologies.

Traumatic ruptures of the aorta are often associated with extensive accessory lesions due to the nature of the trauma. Only 15–20% of the patients reach the hospital alive. Of the patients reaching the operating theatre alive, an average of 7.8% die during the operation, and another 13.5% in the postoperative period. In the acute phase of the blunt aortic trauma thoracotomy is associated with major blood loss and operation risks and can cause additional damage. As in elective aneurysm repair, the minimal invasive endovascular treatment in this patient group is a fast and
relatively easy to perform procedure. A disadvantage is that the time for optimal calculation of the stent-graft length and diameter is reduced; on the other hand, the endovascular procedure allows quick stabilization of the patient. Mortality and morbidity rates in a (semi-)selective phase are lower than in the acute phase. So by placing a stent-graft, mortality might be diminished, even if patients might need an endovascular or open reintervention at a later stage due to non-optimal fitting of the stent-graft.

For patients with anatomical difficult localization of the pathology (e.g. aortic arch) or previous thoracic surgery, an endovascular procedure is an improvement in treatment saving patients a lengthy and difficult thoracotomy. Potential disadvantages of the endovascular treatment must not be underestimated. Lack of long-term results and prospective (randomized) studies still prohibit unconditional implementation. Material deficits of predominantly abdominal aortic stent-grafts have been reported. Although the literature on thoracic stent deficits is still scarce, device failures due to fabric tears and/or stent fractures can be expected here as well. Fatigue fractures of the stent frame are known to occur in both the Talent and Gore thoracic graft – a reason for W.L. Gore and Associates to seize production of this stent-graft. Despite this potential uncertainty about the mechanical properties, it seems important that the endovascular technology remains available for treating patients with thoracic aortic pathology. Long-term results are especially relevant in the relatively young (trauma) patients.

In conclusion, endovascular treatment of aneurysms and traumatic ruptures of the thoracic aorta after adequate patient selection is a feasible procedure with an acceptable mortality and morbidity. In our patients we achieved excellent short- and mid-term results. The ability to treat otherwise inoperable patients with a thoracic stent-graft is a definite benefit over conventional treatment. The risk of neurological complications appears to be equal to that of conventional treatment. However, lack of long-term results and randomized studies ask for caution. A multidisciplinary approach in specialized medical centers is necessary.

References
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