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Endovascular Treatment of the Descending Thoracic Aorta

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Objectives: *to report our initial experience with endovascular stent graft repair of a variety of thoracic aortic pathology.*
Design: *retrospective single center study.*
Material and methods: *between February 2000 and January 2002, endovascular stent graft repair was performed in 26 patients: traumatic aortic isthmus rupture (n = 3), Type B dissection (n = 11) and descending thoracic aortic aneurysm (n = 12). The deployed stent graft systems were AneuRx-Medtronic (n = 1), Talent-Medtronic (n = 13) and Excluder-Gore (n = 12).*
Results: *successful deployment of the stent grafts in the intended position was achieved in all patients. No hospital mortality neither paraplegia were observed. Late, non procedure related, death occurred in four patients (15%). Access artery complications with rupture of the iliac artery occurred in two patients and were managed by iliac-femoral bypass. The left subclavian artery was overstented in seven patients (27%). Only the first patient received a carotido-subclavian bypass. The mean maximal aortic diameter decreased significantly in patients treated for descending thoracic aneurysm. Only one patient had an endoleak type II after 6 months without enlargement of the aneurysm. Complete thrombosis of the thoracic false lumen occurred in all but one patient treated for Type B dissection 6 months postoperatively. Two patients underwent a consecutive stent graft placement, due to a large re-entry tear distal to the first stent graft.*
Conclusions: *endovascular stent graft repair for Type B dissection, descending thoracic aneurysm and aortic isthmus rupture is a promising less-invasive alternative to surgical repair. Further studies are mandatory to determine its long-term efficacy.*

Key Words: Stent graft; Endovascular; Descending thoracic aorta; Aortic dissection; Thoracic aortic aneurysm; Aortic isthmus rupture.

Introduction

Thoracic aortic aneurysms and dissections are life-threatening conditions and pose a significant challenge to the surgeon. The incidence of thoracic aortic aneurysms is approximately 6 per 100 000 persons per year.[1] Surgical repair with prosthetic graft is the traditional therapy and is associated with operative mortalities of 5–20%.[2] It is also associated with substantial morbidity such as postoperative paraplegia, renal failure and need for prolonged ventilatory support.[2,3]

Aortic dissections affect around 1–2 per 100 000 of the population per year.[4] Stanford Type A dissection constitutes an emergent surgical intervention. In contrast, medical therapy is the treatment of choice for uncomplicated Type B dissection.[5,6] Hospital mortality rate for patients with uncomplicated Type B dissection is equivalent whether treated medically or surgically and varies between 9 and 20%.[6] Medical therapy, however, implicates less morbidity and less costs. Surgical treatment is reserved for patients with intractable pain or with complications of the dissection, such as aortic dilatation, rupture and malperfusion syndrome.[7]

Endovascular stent graft (ESG) placement has emerged as a less invasive alternative for repair of the descending thoracic aorta.[8–16] The purpose of this study is to describe retrospectively our initial experience with ESG in the treatment of thoracic aneurysm, Type B dissection and traumatic aortic isthmus rupture.

Material and Methods

Between February 2000 and January 2002, 26 patients underwent ESG repair of the descending thoracic aorta at our institution. Three patients were treated for a traumatic aortic isthmus rupture, 11 for a complicated Type B dissection and 12 for a thoracic

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Table 1. Patient characteristics ($n = 26$).

Characteristic	Number	%
Age (yr)		
Mean	64	
Range	30–84	
Sex		
Male/Female	8/18	31/69
Comorbidity		
Cigarette smoking	13	50
Arterial hypertension	18	69
Coronary artery disease	5	19
Congestive heart failure	4	15
Peripheral vascular disease	11	42
COPD	5	19
NIDDM	1	4
Hypercholesterolemia	7	27
Renal failure*		
Mild	6	23
Severe, no dialysis	1	4
Severe, with dialysis	1	4
History of cerebrovascular disease	3	12
Systemic disorders†	5	19

COPD: chronic obstructive pulmonary disease; NIDDM: non insuline dependent diabetes mellitus.
*Mild renal failure defined as serum creatinine level 1.3–2.3 mg/dL (115–203 μmol/L) and severe renal failure as serum creatinine level >2.3 mg/dL (212 μmol/L).
†Systemic disorders: Marfan's syndrome ($n = 1$), M. Wegener ($n = 1$), amyloidosis ($n = 1$) and polymyalgia rheumatica ($n = 2$).

atherosclerotic aneurysm. Patient characteristics are listed in Table 1.

Spiral computed tomographic (CT) scanning and angiography of the aorta were performed before the scheduled procedure in each but two patients with a ruptured Type B dissection.

Three different commercially manufactured stent graft systems were used. The AneuRx ESG system (Peripheral Technologies, Santa Rosa, CA, U.S.A.) was only used in the first patient treated. The Talent ESG system (World Medical Corp, Sunrise, FL, U.S.A.) was used in 13 patients and the Excluder (W.L. Gore & Associates, Flagstaff, AZ, U.S.A.) in 12 patients. Each endoprosthesis consists of a self-expanding nitinol stent, covered externally by a Dacron graft or internally by a PTFE graft (Excluder). Technical details of the different ESG systems and their deployment have been described previously.[9,13,16] Recently, the Excluder system was removed from the market for thoracic use because of reported stent fractures. All stent grafts were 10–15% oversized in diameter compared with the diameter of the nonaffected aorta proximal and distal to the entry tear or aneurysm inlet.

All procedures were performed in the operating room under general anaesthesia. Vascular access was obtained through the femoral artery after surgical cut down. For access, the site with the least tortuous iliac artery and the widest lumen was chosen for ESG introduction. A 5-F measuring pigtail catheter (Cook Australia Pty Ltd, Queens land, Australia) was advanced into the ascending aorta over a 0.035-inch-diameter stiff guide wire (Terumo Corporation, Tokyo, Japan). This pigtail catheter was used to exchange the Terumo guide wire for a 0.035-inch-diameter Back-up Meier (Boston Scientific Corp., Natick, MA, U.S.A.). After intravenous administration of 5000 IU of heparin sodium, the 20- to 24-F Talent stent graft system itself or a 22- to 24-F Keller-Timmermans introduction kit (William Cook Europe, Bjaeverskov, DK) in case of the Excluder system was passed over the Back-up Meier. Angiography via contralateral percutaneous femoral artery approach with the previously used measuring pigtail catheter was performed before and after ESG deployment. Balloon moulding further expanded the stent graft. In addition to angiography, transesophageal colour Doppler imaging was always performed. After removal of the placement system, the arteriotomy was closed in the usual manner.

Follow-up spiral CT was performed prior to discharge, at 3–6 months intervals for 2 years, and annually thereafter. Each patient underwent a follow-up CT at least 6 months postoperatively, except the four patients who died. The median follow-up time was 8 months (range, 1–18 months). The procedure was technically successful when the primary entry tear of the aortic dissection or the inlet of the (pseudo)aneurysm was completely excluded from the circulation and no perigraft leakage was detected on completion angiography or follow-up CT. In patients with Type B dissection, we assessed the extent of thrombosis in the thoracic and abdominal false lumen, and measured the diameter of the true and false lumen at the level of maximal dilatation. Obliteration and thrombosis of the aneurysm sac or pseudoaneurysm as well as reduction of the maximal aortic diameter were examined in patients with traumatic aortic rupture and atherosclerotic aneurysm.

Statistics

Results are expressed as medians and ranges. The data concerning aortic measurements before and after stent graft procedure are expressed as means ± SD and are compared with use of the Wilcoxon matched pairs test. p values of less than 0.05 are considered statistically significant.

Results

Atherosclerotic aneurysm

Five of the 12 patients treated for an atherosclerotic aneurysm were symptomatic. One of them had paralysis of the left vocal cord, due to extrinsic pressure of the aneurysm on the left recurrent nerve. The other four symptomatic patients complained of persistent interscapular pain: The localisation of the thoracic aneurysms is listed in Table 2. The mean aneurysmal diameter was 63 mm (range, 42–84 mm). Only one of the 12 patients had an aneurysm <55 mm in diameter and was treated immediately because of a rupturing thoracic aneurysm with intramural haematoma.

Successful exclusion of the thoracic aneurysms was achieved in all 12 patients. The size of the stent grafts as well as their number are listed in Table 3. For aneurysm exclusion, several stent grafts were necessary in 10 patients (83%). The mean postoperative diameter decreased significantly ($p = 0.01$) (Table 4).

Endoleak type II was detected in three patients on CT scan before discharge. Complete thrombosis of the aneurysm sac with disappearance of the endoleak occurred in two of them 6 months after ESG placement. One patient still has endoleak type II without enlargement of the aneurysm.

Intended overstenting of the left subclavian artery occurred in three patients in order to exclude the aneurysm completely.

Type B dissection

Eleven patients were treated for Type B dissection. Five patients had an acute dissection (<14 days of onset) and 6 were chronic (>14 days). Reason for intervention as well as primary tear location are listed in Table 5. The dissection ended at the level of the diaphragm in two patients, extended into the abdominal aorta in five patients and distally into the iliac arteries in four patients.

Successful covering of the primary tear occurred in all 11 patients. Deployment of 1 ESG was sufficient in five patients (45%) to cover the primary entry tear. In the other six patients (55%), two ESG's had to be deployed. This was necessary in four patients to cover the primary tear completely and in one patient to cover a re-entry site just distal to the first ESG. The last patient, who needed two ESG's, had a very tortuous descending aorta, which was impossible to pass with the ESG. By deploying a first ESG at this tortuous level and by exerting traction on both ends of a stiff guide wire, inserted into the right brachial artery and picked up in the groin, we could reduce the tortuosity of the descending aorta. Only thereafter a second ESG could be inserted to seal the primary tear.

CT images before discharge revealed complete thrombosis of the thoracic false lumen in five patients, partial thrombosis also in five patients and no thrombosis in one patient. Completion aortogram in this latter patient as well as in one patient with partial thrombosis of the thoracic false lumen, whom maximal thoracic aortic diameter was dilated further, depicted abundant backflow through a large re-entry tear just distal to the first stent graft. Both patients needed reintervention with additional ESG placement in order to cover this large re-entry tear.

Two of the 11 patients treated for Type B dissection died 4 months postoperatively (cfr infra). Of the remainder nine patients, complete thrombosis of the thoracic false lumen was evident in eight on CT-scan 6 months postoperatively. The patient, with partial thrombosis of the thoracic false lumen, still has only partial thrombosis at this level 18 months postoperatively, but without dilatation.

Although finally eight of the nine patients exhibited complete thrombosis of the thoracic false lumen, their abdominal false lumen remained patent without thrombus formation. Only one patient developed further dilatation of the abdominal false lumen with an increase of his high abdominal aortic diameter from 40 to 46 mm 6 months after ESG placement. Because of this dilatation and also because of atypical abdominal complains, a classical exclusion replacement of the thoraco-abdominal aorta was performed with left assist device and with reimplantation of the celiac trunk, the mesenteric superior artery and the renal arteries.

Generally, the mean value of the maximal diameter of the descending thoracic aorta and also the false lumen, decreased significantly in all 11 patients treated for Type B dissection (Table 4). One patient with a chronic and 2 patients with an acute Type B dissection (Fig. 1) had complete disappearance of the thoracic false lumen after 3, 6 and 12 months respectively.

Overstenting of the left subclavian artery occurred in four patients because of a primary tear at this level.

Table 2. Thoracic aortic aneurysm localization ($n = 12$).

Aorta	Number
Arch + proximal descending aorta	2
Proximal descending aorta	5
Distal descending aorta	1
Entire descending aorta	4

Table 3. Size and number of stent grafts for ESG treatment.

Variable	Traumatic isthmus injury ($n = 3$)	Thoracic aneurysm ($n = 12$)	Type B dissection ($n = 11$)
Length of ESG (mm)			
Median	100	100	100
Range	100	90–200	60–200
Diameter of ESG (mm)			
Median	28	42	36
Range	26–31	34–46	32–42
Number of ESG			
Median	1	2	2
Range	1	1–5	1–2

Traumatic aortic isthmus rupture

Three patients were treated for a concealed isthmus rupture and were all victim of a car accident. One patient was referred 10 days after trauma. She was intubated and haemodynamically stable. Multiple other injuries were present. Two other patients were treated with ESG because of chronic aneurysmal dilatation of a concealed isthmus rupture 12 years after trauma. In both patients, diagnosis of pseudoaneurysm was detected accidentally on chest X-rays.

One stent graft was sufficient to seal the injury site completely in these three patients. Retraction of the thrombus occurred in the two chronic patients, while complete resolution of the periaortic haematoma was seen 6 months postoperatively in the patient treated for acute isthmus rupture. The decrease of the mean aortic isthmus diameter after ESG placement in the three patients was not significant ($p = 0.1$), probably due to the small number of patients.

Procedure time and hospital stay

The median procedure time was 82 min (range, 50–205 mm). Sixteen patients (62%) were transferred immediately to the ward without staying in the intensive care unit. The median hospital stay was 6 days (range, 3–20 days).

Complications and morbidity

Three procedure related complications occurred (Table 6). Rupture of the iliac artery after withdrawal of the device happened in 2 patients. Urgent iliac-femoral bypass was performed in both cases. One patient developed an ischemic right leg during the procedure. Embolectomy with dilatation of the right femoral artery was performed immediately after ESG deployment. Hospital mortality was 0%. None of our patients developed paraparesis or paraplegia. Early postoperative morbidity occurred in five patients (Table 6).

Four patients (15%) died late (>30 days) postoperatively. None of them seemed to be procedure related. Two patients with a symptomatic thoracic aneurysm died respectively 3 and 11 months postoperatively. Renal failure with dialysis and deterioration of the general condition was the cause of death in one patient and the second patient died because of disseminated intravascular coagulation of unknown reason. Two patients with an acute Type B dissection died both 4 months postoperatively. One patient died because of pneumonia and the second one due to rupture of an ascending aortic aneurysm. This latter patient was treated with ESG for a ruptured Type B dissection and was known with an ascending aortic dilatation of 55 mm, which was treated conservatively because of her bad general condition.

Table 4. Comparison of the diameter of the aorta, true and false lumen on CT-scan pre-and postoperatively ($n = 26$).

Type of lesion	Preoperative diameter* (mm ± SD)	Latest follow-up diameter (mm ± SD)	p value
Thoracic aneurysm ($n = 12$)			
Aorta	63 ± 11	57 ± 12	0.01
Traumatic isthmus rupture ($n = 3$)			
Aorta	45 ± 9	38 ± 11	0.1
Type B dissection ($n = 11$)			
Aorta	51 ± 14	46 ± 13	0.01
True lumen	23 ± 3	31 ± 3	0.003
False lumen	28 ± 13	15 ± 14	0.003

*The diameters of the aorta, true and false lumen were expressed as mean values of the maximal diameter and were measured at the same levels before and after ESG placement.

Table 5. Treatment indication for Type B dissection.

Type B dissection ($n = 11$)	Acute ($n = 5$)	Chronic ($n = 6$)
Indication		
Persistent pain	5	1
Diameter (>55 mm)	1	5
Rupture	2	–
Primary tear localization		
Left subclavian artery	2	2
Isthmus	1	-
Lower descending aorta	2	4

Discussion

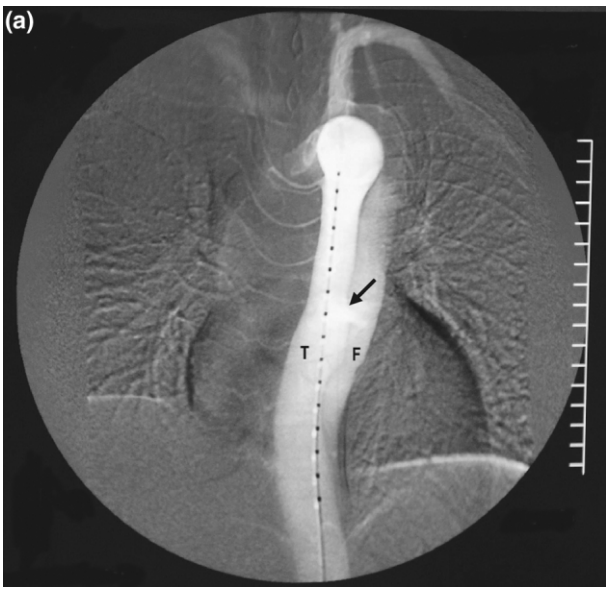
Thoracic aortic dissections and aneurysms, together with traumatic injuries remain a fascinating problem for the surgeon. Early surgical mortality rate still ranges from 5 to 20%[3] and exceeds 50% in high-risk patients with end-organ ischemia.[17] Recently, many groups introduced endoluminal aortic reconstruction with stent graft deployment and they reported reduced morbidity and mortality, ranging from 0 to 16%.[8–15]

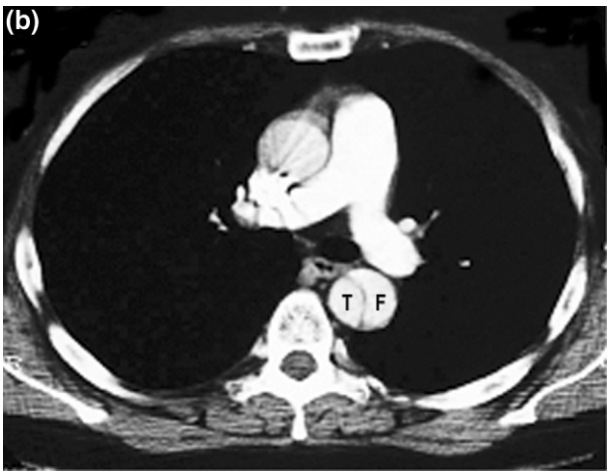
Safe ESG placement requires distal arterial access of sufficient size with limited tortuosity and sufficient proximal and distal neck. In our experience, rupture of the iliac artery occurred in two patients (8%), once with the Talent and once with the Excluder device. The first sign of iliac rupture after withdrawal of the device was bradycardia, due to peritoneal reaction with vagal reflex. Urgent iliac-femoral bypass was performed in both cases. Smaller devices may prevent this complication in the future.[9] Furthermore, we agree with Cambria and colleagues that the potential for such complications constitutes a compelling argument for continued use of general anaesthesia in a fully equipped operating room.[12] For adequate fixation and safe ESG deployment, a normal aorta of at least 1 cm in length is necessary

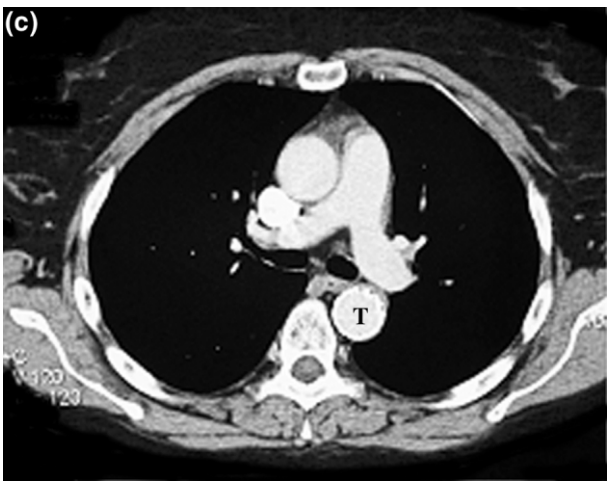
In addition to intraprocedural contrast angiography, we want to highlight the importancy of colour Doppler transesophageal echocardiography. TEE is very useful for exact visualization of the origin of the

Table 6. Per- and postoperative morbidity ($n = 26$).

Type of complication	n (%)
Procedure related complications	3 (11%)
Iliac artery rupture	2
Peripheral emboli	1
Early postoperative morbidity	5 (19%)
Acute cholecystitis	1
Pneumonia	1
Groin pseudoaneurysm	1
Transient renal failure	1
Transient aphasia	1







dissection and aneurysm, which can be difficult with angiography alone. Furthermore TEE provides useful information for exact positioning of the ESG and detects accurately perigraft leakage as well as the patency of the false lumen in case of Type B dissection.[18–20]

Intended overstenting of the left subclavian artery with ESG placement just distal to the left common carotid artery occurred in seven patients (27%). Only the first patient received a carotido-subclavian shunt prior to ESG deployment. In the following six patients, we did not perform a carotido-subclavian shunt and none of them developed vertebrobasilar or left arm ischemia. Coverage of the left subclavian artery has been reported to be apparently safe[21] and our own experience with seven cases supports this view. We also agree with the statement by Dake[22] that a prophylactic transposition of the subclavian artery must not be forced. If vertebrobasilar or arm ischemia occurs, secondary revascularization with carotido-subclavian shunt or transposition can be performed.

Endovascularly excluded thoracic aortic aneurysms decrease in size similar to that found in abdominal aneurysms. Sac shrinkage of about 10% yearly was detected by Greenberg *et al*.[23] Resch *et al*.[24] documented mean aneurysm shrinkage of about 4 mm at 12 months follow-up. We noted a mean aneurysmal sac shrinkage of 6 mm in the 12 patients treated for atherosclerotic aneurysms.

Our treatment strategy for complicated Type B dissection is exclusion of the primary entry tear in order to induce thrombosis and retraction of the thoracic false lumen. Stent graft placement creates a remodelling of the aorta by expansion of the true lumen and thrombosis and retraction of the false lumen, which mimics the natural healing process of the aorta.[11] In our group, complete thrombosis of the thoracic false lumen occurred in eight of nine patients 6 months postoperatively. The patient with partial thrombosis of the thoracic false lumen still has only partial thrombosis without dilatation 18 months postoperatively. Indeed, even if only partial false lumen thrombosis is achieved, it still can be advantageous by protecting the false lumen from enlarging over time since systemic blood pressure is no longer directly transmitted from the aorta through a large primary tear.[25] In view of these results we believe that, also for chronic Type B dissection, covering of the primary tear alone without covering of the entire dilated thoracic aorta, is sufficient to induce thrombosis of the thoracic false lumen.

Furthermore, one may question whether this therapy should be offered in all patients with an acute Type B dissection, even when uncomplicated. Approximately 20% of patients, treated medically for a Type B dissection, indeed, develop aneurysmal dilatation of the thoracic false lumen during the first 5 years after diagnosis. Although we cannot draw any concrete conclusions from the short-term follow-up of this small number of patients, it may be reasonable to speculate that ESG treatment in all patients with an acute type B dissection may limit this complication.[10,26,27]

While complete thrombosis of the thoracic false lumen occurred in eight of nine patients treated for Type B dissection, the abdominal false lumen remained patent in all patients with infrarenal extension of the false lumen. Re-entry sites, usually near the exit site of major splanchnic branch vessels, are responsible for these natural fenestrations (Fig. 2).[10,28] Natural fenestrations are holes in the septum of the dissection when it has been ripped off the branch vessels and they account for the continued perfusion of the false lumen when the primary entry tear has been sealed with a stent graft. Only one of these patients developed further dilatation of the abdominal false lumen. Six months after ESG placement, this patient underwent a classical exclusion replacement of his high abdominal aorta.

We did not encounter spinal cord ischemia, although the distal thoracic aorta was stented in five patients. In addition, two patients underwent previous open AAA repair, a circumstance that increases the risk of paraplegia in the Stanford experience.[29] Greenberg *et al*., on the other hand, correlated more extensive lengths of ESG as increasing spinal cord ischemia complications, which they observed in 12% of their patients.[23] This latter figure must be considered a maximum for spinal cord complications, because most reports are in the 0 to 3% range.

Monitoring evoked spinal cord potentials during temporary interruption of the intercostal arteries by test deployment of a collapsable stent graft,[30] may aid in identifying patients at risk for spinal cord ischemia, in whom conversion to open repair[31] or prophylactic cerebrospinal fluids drainage may be performed.[32] Multiple circumstances are in favour for the ESG technique compared with classical thoracic aorta surgery in preventing spinal cord ischemia. The total procedure time is much shorter with only a small amount of blood loss. There is no need for circulatory

Fig. 1. Acute Type B dissection before and after stent graft repair. Preoperative thoracic aortogram (a) and contrast-enhanced CT (b) with visualization of the primary entry tear (arrow), true (T) and false (F) lumen. Postoperative CT (c) after 6 months shows the true lumen with complete obliteration of the false lumen.

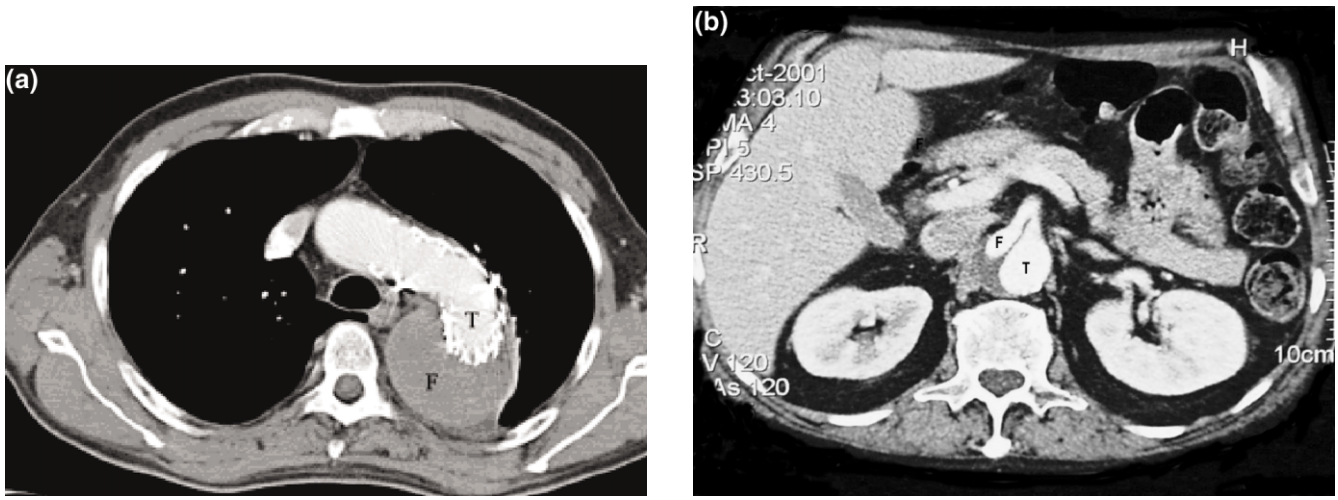


Fig. 2. Natural fenestration after successful covering of a primary entry tear of a chronic Type B dissection. Contrast-enhanced CT at the proximal thoracic aortic level (a) with complete thrombosis of the false lumen (F). CT at the level of the celiac artery (b) shows opacification of the true (T) as well as the false (F) lumen, due to natural fenestration.

arrest and cross clamping of the aorta, with associated ischemia and potential reperfusion injury.[11] The sudden deployment of the stent graft probably does not produce a steal phenomenon in the perfusion of the spinal cord.[9] Furthermore, ESG procedure is associated with less postoperative respiratory failure and less prolonged hypotension, which reduces the risk of delayed paraplegia.[11]

Finally, we can remark that stent graft procedures are substantially cost saving, as compared with classical thoracic surgery, because of reduced need for intensive care and shorter hospital stay.[11] Moreover, patients recover much faster.

In conclusion, our results demonstrate that endovascular stent graft placement for Type B dissection, thoracic aortic aneurysm and trauma is a save alternative to surgical repair. Further studies are mandatory to determine the long-term efficacy and durability of this innovative technique.

References

1 Bickerstaff LK, Pairolero PC, Hollier LH *et al.* Thoracic aortic aneurysms: A population-based study. *Surgery* 1982; **92**: 1103–1108.

2 Moreno-Cabral CE, Miller DC, Mitchell RS *et al.* Degenerative and atherosclerotic aneurysms of the thoracic aorta: Determinants of early and late surgical outcome. *J Thorac Cardiovasc Surg* 1984; **88**: 1020–1032.

3 Svensson LG, Crawford ES, Hess KR, Coselli JS, Safi HJ. Variables predictive of outcome in 832 patients undergoing repairs of the descending thoracic aorta. *Chest* 1993; **104**: 1248–1253.

4 Svensson LG, Crawford ES. Aortic dissection and aortic aneurysm surgery: Clinical observations, experimental investigations, and statistical analyses. Part II. *Curr Probl Surg* 1992; **29**: 915–1057.

5 Elefteriades JA, Hartleroad J, Gusberg RJ *et al.* Long-term experience with descending aortic dissection: The complication-specific approach. *Ann Thorac Surg* 1992; **53**: 11–21.

6 Glower DD, Fann JI, Speier RH *et al.* Comparison of medical and surgical therapy for uncomplicated descending aortic dissection. *Circulation* 1990; **82**: IV-39–IV-46.

7 Fann JI, Miller DC. Aortic dissection. *Ann Vasc Surg* 1995; **9**: 311–323.

8 Mitchell RS. Endovascular stent-graft repair of thoracic aortic aneurysms. *Semin Thorac Cardiovasc Surg* 1997; **9**: 257–268.

9 Grabenwöger M, Hutschala D, Ehrlich MP *et al.* Thoracic aortic aneurysms: Treatment with endovascular self-expandable stent grafts. *Ann Thorac Surg* 2000; **69**: 441–445.

10 Dare MD, Kato N, Mitchell RS *et al.* Endovascular stent-graft placement for the treatment of acute aortic dissection. *N Engl J Med* 1999; **340**: 1546–1552.

11 Nienaber CA, Fattori R, Lund G *et al.* Non surgical reconstruction of thoracic aortic dissection by stent-graft placement. *N Engl J Med* 1999; **340**: 1539–1545.

12 Cambria RF, Brewster DC, Lauterbach SR *et al.* Evolving experience with thoracic aortic stent graft repair. *J Vasc Surg* 2002; **35**: 1129–1136.

13 Thompson CS, Gaxotte VD, Rodriguez JA *et al.* Endoluminal stent grafting of the thoracic aorta: Initial experience with the Gore Excluder. *J Vasc Surg* 2002; **6**: 1163–1170.

14 Criado FJ, Clark NS, Barnatan MF. Stent graft repair in the aortic arch and descending thoracic aorta: A 4-year experience. *J Vasc Surg* 2002; **36**: 1121–1128.

15 Taylor PR, Gaines PA, McGuinness CL *et al.* Thoracic aortic stent-grafts—Early experience from two centres using commercially available devices. *Eur J Vasc Endovasc Surg* 2001; **22**: 70–76.

16 White R, Donayre C, Walot I *et al.* Endovascular exclusion of descending thoracic aortic aneurysms and chronic dissections: initial clinical results with the AneuRx device. *J Vasc Surg* 2001; **33**: 927–934.

17 Miller DC, Mitchell RS, Oyer PE, Stinson EB, Jamieson SW, Shumway NE. Independent determinants of operative mortality for patients with aortic dissection. *Circulation* 1984; **70**: I-153–I-164.

18 Fattori R, Caldarera I, Rapezzi C *et al.* Primary endoleakage in endovascular treatment of the thoracic aorta: Importance of intraoperative transesophageal echocardiography. *J Thorac Cardiovasc Surg* 2000; **120**: 490–495.

19 Orihashi K, Matsuura Y, Sueda I *et al.* Echocardiography—assisted surgery in transaortic endovascular stent grafting: Role

of transesophageal echocardiography. *J Thorac Cardiovasc Surg* 2000; **120**: 672–678.
20 Rousseau H, Otal P, Kos X *et al.* Endovascular treatment of thoracic dissection. *Acta Chir Belg* 2002; **102**: 299–306.
21 Gorich J, Asquan Y, Seifarth H *et al.* Initial experience with intentional stent graft coverage of the subclavian artery during endovascular thoracic aortic repairs. *J Endovasc Ther* 2002; **9**: II39–II43.
22 Dake MD. Endovascular stent-graft management of thoracic aortic diseases. *Eur J Radiol* 2001; **39**: 42–49.
23 Greenberg R, Resch I, Nyman U *et al.* Endovascular repair of descending thoracic aortic aneurysm: an early experience with intermediate-term follow-up. *J Vasc Surg* 2000; **31**: 147–156.
24 Resch T, Koul B, Dias N, Lindblad B, Ivancev K. Changes in aneurysm morphology and stent-graft configuration after endovascular repair of aneurysms of the descending thoracic aorta. *J Thorac Cardiovasc Surg* 2001; **122**: 47–52.
25 Hutschala D, Fleck T, Czerny M *et al.* Endoluminal stent-graft placement in patients with acute aortic dissection Type B. *Eur J Cardiothorac Surg* 2002; **21**: 964–969.
26 Palma JH, Marcondes de Souza JA, Rodrigues Alves CM *et al.* Self-expandable aortic stent-grafts for treatment of descending aortic dissections. *Ann Thorac Surg* 2002; **73**: 1138–1142.
27 Nienaber CA, Ince H, Petzsch M *et al.* Endovascular treatment of thoracic aortic dissection and its variants. *Acta Chir Belg* 2002; **102**: 292–298.
28 Won JY, Lee DY, Shim WH *et al.* Elective endovascular treatment of descending thoracic aortic aneurysms and chronic dissections with stent-grafts. *J Vasc Interv Radiol* 2001; **12**: 575–582.
29 Mitchell RE, Miller DC, Dare MD, Semba CP, Moore KA, Sakai T. Thoracic aortic aneurysm repair with an endovascular stent graft: "the first generation". *Ann Thorac Surg* 1999; **67**: 1971–1974.
30 Ishimaru S, Kawaguchi S, Koizumi N, Obitsu Y, Ishikawa M. Preliminary report on prediction of spinal cord ischemia in endovascular stent graft repair of thoracic aortic aneurysm by retrievable stent graft. *J Thorac Cardovasc Surg* 1998; **115**: 811–818.
31 Reichart M, Balm R, Meilof J *et al.* Ischemic transverse myelopathy after endovascular repair of a thoracic aortic aneurysm. *J Endovasc Ther* 2001; **8**: 321–327.
32 Tiesenhausen K, Amann W, Koch C *et al.* Cerebrospinal fluid drainage to reverse paraplegia after endovascular thoracic aortic aneurysm repair. *J Endovasc Ther* 2000; **7**: 132–135.

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