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Clinical research

Endovascular stent-graft treatment of aortic dissection: determinants of post-interventional outcome

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Complication

Aims To investigate the results of endovascular stent-graft placement for the treatment of patients with type B aortic dissection (B-AD).
Methods and results A total of 38 patients (62 $\pm$ 10 years, 32 male) with acute ($n = 10$) and chronic ($n = 28$) type B-AD were treated with endovascular stent-grafts. The implantation procedure was successful in all patients. Peri-procedural non-fatal complications occurred in four (11%) patients. Overall, 4/38 (11%) patients died during the in-hospital period. Patients undergoing stent-graft placement for acute AD had a significantly higher in-hospital mortality than patients with chronic AD (40 vs. 0%, $P = 0.001$). During a median follow-up of 18 (1–57) months, there were six additional deaths. Overall survival rates were 97.4 $\pm$ 2.6% at 30 days, 80.4 $\pm$ 6.7% at 1 year, 73.2 $\pm$ 7.8% at 2 years, and 54.9 $\pm$ 16.9% at 4 years. Patients with a poor clinical health status (ASA class $>$ 3) had a significantly reduced life expectancy compared with patients with only moderate co-morbidities (ASA class $\leq$ 3) (1-year survival rate 28.6 $\pm$ 17.1 vs. 92.6 $\pm$ 6.7%, $P = 0.0001$). Multivariable analysis revealed that a poor clinical health status (ASA $>$ 3) pre-operatively (HR = 29.5, 95% CI 1.5–581.9, $P = 0.026$) and increased age (HR = 1.1, 95% CI 0.9–1.2, $P = 0.084$) were independent determinants of post-interventional mortality.
Conclusion Endovascular stent-graft treatment is a safe alternative for patients with AD. The pre-operative clinical health status of the patient is the most important determinant of post-interventional outcome. Careful patient selection is thus of particular importance.

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Introduction

For the management of patients with aortic dissection (AD), consensus exists regarding the need for emergency surgery in patients with proximal AD, but the optimal therapeutic strategy for patients with exclusive involvement of the descending aorta (type B-AD) is still a matter of debate.[1] Given the high morbidity and mortality of direct surgical resection of the descending thoracic aorta, most institutions favour a complication-specific approach with medical treatment being the primary therapy, while reserving surgery for evolving complications [e.g. unrelenting pain, progressive false lumen (FL) expansion, visceral or limb ischaemia, or (imminent) rupture].[2,3]

Medical treatment aims at tight blood pressure control with a target blood pressure of $<$135/90 mmHg, which has recently been recommended for patients with chronic AD.[2] However, even with optimal medical and surgical therapy, the acute and long-term prognosis of type B-AD remains poor.[4] Survival rates at 5 years range between 32 and 60%.[4–6] Besides uncontrolled hypertension and advanced age,[6] persistent perfusion of the FL via a patent proximal entry tear has been identified as the main predictor of adverse outcome during the long-term course.[4,5]

Endovascular stent-graft treatment of AD aims at covering the proximal entry tear in the thoracic aorta, thus obliterating flow into the FL. Although data from randomized trials are lacking, endovascular repair is generally considered to be highly successful technically and safe.[7–11] The less invasive nature of endovascular repair may be tempting to expand the treatment indication even to elderly patients with reduced general health status, who would not be suitable for open repair. However, patient-related or procedural determinants of the post-interventional outcome that would aid better patient selection are so far unknown.

The present study details our experience with endovascular stent-graft placement performed in 38 patients with acute and chronic AD over a 5-year period.

Methods

Between July 1999 and April 2004, 38 patients with type B-AD underwent endovascular stent-graft placement. AD was considered to be acute within the first 14 days from onset.[2] After 14 days, AD was considered to be chronic.[2] Patients' clinical health status was evaluated according to the classification of the American Society of Anesthesiologists (ASA).[12]

Indications for treatment were: (contained) aortic rupture (e.g. haemothorax), unrelenting pain, refractory hypertension, or branch vessel ischaemia; a maximum diameter of $\geq$40 mm (acute AD) or $\geq$50 mm (chronic AD) of the descending thoracic aorta or documented aortic enlargement of $\geq$1.0 mm/year; and a patent FL with an accessible proximal entry tear. Written informed consent for vascular access and stent-graft placement was obtained from every patient.

Pre-interventional imaging

All patients who were haemodynamically stable routinely underwent a pre-interventional vascular staging that included the use of contrast-enhanced computed tomography (CT) or magnetic resonance imaging (MRI), transoesophageal echocardiography (TEE), and aortography as well as coronary angiography. In patients with haemodynamic compromise, diagnosis of AD and localization of the primary entry site were determined using standard criteria by TEE and/or CT, immediately before urgent stent-graft placement.

Stent-graft prosthesis

In all patients, a self-expandable endoprosthesis with circumferential nitinol stent springs arranged in a zig-zag formation sandwiched between thin layers of a polyester graft membrane (Talent, Medtronic Vascular, Santa Rosa, CA, USA) was used. The stent-grafts were available in standard configurations or tailored for the individual patient. Generally, the endoprostheses were sized 4 mm larger than measurements taken from the contrast-enhanced CT scans to ensure secure anchoring of the endoprostheses. Stent-graft length was mainly dependent on the pre-formatted length available which initially measured 100 mm and was later extended to 150 mm. In all patients, the stent-grafts had a bare spring at the proximal end to allow improved side branch access.

Stent-graft procedure

Stent-graft placement was performed in the cardiac catheterization laboratory by a team of interventional cardiologists, cardiothoracic surgeons, and anaesthesiologists. It was the designated strategy to seal only the proximal major entry tear at that time. If more entries were present, these were excluded in a second endovascular procedure performed after a time interval of at least 2 months.

All patients were under general anaesthesia receiving mechanical ventilation. The operative field was prepared under strict sterile conditions. Ceftriaxone (2 g) was administered intravenously prior to the procedure. Direct access through the iliac artery was necessary in three (8%) patients due to insufficient luminal diameters of both femoral arteries; in all other patients the femoral artery was used for access after surgical exposure. After exposition of the femoral artery and open insertion of a standard 6-French arterial sheath, 5000 IU of heparin were administered. A biplane angiogram was obtained using a graduated 6-French pigtail catheter with metallic markers to determine the optimal stent-graft landing zones and the relation to side branches (i.e. left subclavian artery). Additionally, a 6-French pigtail catheter was advanced from the left radial artery to allow intra-procedural angiography. The stent-graft delivery system was advanced over an ultrastiff 0.035 in guidewire (Meier Back-Up, Boston Scientific, Oakland, CA, USA). The stent-grafts were positioned in the thoracic aorta under fluoroscopic guidance. Additional guidance by TEE or intravascular ultrasound (IVUS) was used in 17 (45%) and 18 (47%) patients, respectively. Before the stent-graft was deployed, systolic blood pressure was lowered to $\sim$50 mmHg using intravenous sodium nitroprusside to prevent inadvertent downstream displacement of the stent-graft during delivery. In cases of underexpansion, balloon moulding was used only in the initial cases. It should be noted that it was not the aim to push the dissecting lamella back to the aortic wall by the stent-graft, but only to obliterate flow into the FL. In the later series, balloon dilatation was completely avoided if stent expansion was acceptable based on the angiographic/fluoroscopic result to avoid disruption of the dissecting membrane. Immediate procedural success was evaluated using biplane angiography

and TEE. No additional heparin or antiplatelet medications were administered following completion of the procedure.

Follow-up

All patients were subjected to a strict follow-up protocol. Clinical examination and imaging of the aorta by contrast-enhanced CT or MRI and TEE were performed prior to discharge, and after 3, 6, and 12 months, and then annually.

Definitions and statistical analysis

Procedural success was defined by the technically successful deployment of the endoprosthesis at the intended target location. All statistical analyses were performed using the SPSS software package (version 11.0, SPSS, Chicago, IL, USA). Continuous variables are presented as mean ± 1SD (range) or median (range), and categorical variables using frequencies and percentages. Comparisons were made with the two-sided χ^2 test or Fisher's exact test for categorical variables and two-sided Student's *t*-test for continuous variables. A *P*-value <0.05 was considered statistically significant. The Kaplan–Meier non-parametric method was used to generate estimates of survival and freedom from aortic re-intervention, and compared using the log-rank test. For the survival analysis, day 1 was defined as the first day after stent-graft placement. To identify independent risk factors for adverse outcome, a multivariable Cox regression model was used that included five variables that were found to be have a significant influence by exploratory univariate analysis of 23 pre-operative and peri-operative parameters (see Appendix). For the univariate analysis, a *P*-value <0.05 was considered statistically significant.

Results

Patient demographics

Baseline characteristics of the patients are given in *Table 1*. There were 32 male and six female patients at an age of 62 ± 10 (36–83) years. Ten patients with acute AD underwent urgent stent-graft procedures within 2 (0–7) days of onset of symptoms. Twenty-eight patients had chronic AD [time from first diagnosis: 4.5 (1–93) months] and were treated electively. In all patients (acute and chronic), the FL was patent without evidence of thrombus formation.

Table 1 Patient characteristics

	All patients ($n = 38$)
Age, years	62.2 ± 10.8 (36–83)
Gender (♂/♀)	32/6
Body mass index, kg/m^2	26.2 ± 5.1 (16–38)
ASA-class	3.5 ± 0.4 (3–5)
C-reactive protein, mg/dL	4.2 ± 5.6 (0.1–17.4)
Contained rupture	6 (16)
Oral anticoagulation	10 (26)
Hypertension	36 (95)
Chronic obstructive pulmonary disease	7 (18)
Impaired renal function	13 (34)
Previous stroke	2 (5)
Diabetes	6 (16)
Hypercholesterolaemia	25 (66)
Smoking history	14 (37)
CAD	14 (37)
Previous aortic surgery	8 (21)

Data are mean ± 1SD (range), or frequency (percentage).
CAD, coronary artery disease.

Procedural results

Procedural success was obtained in all (100%) patients, without the need for open surgical conversion. Additional percutaneous transluminal coronary angioplasty was successfully performed in four patients and coronary artery bypass grafting (CABG) in one patient during the same session. Procedural data are given in *Table 2*. In 13 (34%) patients, the stent-grafts had to be placed across the origin of the left subclavian artery to cover the adjacent entry tear, resulting in diminished inflow in seven (18%) and occlusion in six (16%) patients.

Injury to the access vessel required Dacron interposition graft reconstruction of the femoral artery in two (5%) patients. In one patient, disruption of the dissecting membrane occurred after balloon moulding of the stent-graft, which required placement of a second stent-graft. A localized subintimal dissection in the aortic arch, which was related to guidewire manipulation, occurred in one (3%) patient, but he did not experience any sequelae, and the dissection resolved without further treatment. There were no neurological complications (e.g. stroke or paraplegia) or acute deaths.

In-hospital outcome

All but five patients were extubated on the day of the stent-graft procedure. Severe blood pressure elevations were observed during the immediate post-interventional course in 32 (84%) patients. The median stay in the intensive care unit (ICU) was 3 days (1–78) (*Table 2*). Two (5%) patients with ruptured AD required surgical drainage for pre-existing haemothoraces.

Table 2 Procedural data

	All patients ($n = 38$)
Technical success	38 (100)
Access vessel	
right/left femoral artery	26/9 (68/24)
iliac artery	3 (8)
Stent-grafts/patient	1.2 ± 0.5 (1–3)
Stent-graft diameter, mm	37 (30–46)
Stent-graft length, mm	100 (100–160)
Procedure time, min	155 ± 72 (45–380)
Fluoroscopy time, min	14.5 ± 8.4 (3.5–41.1)
Contrast media, mL	364 ± 185 (97–750)
ICU stay, days	3 (1–78)
Hospital stay, days	13 (4–77)

Date are frequency (percentage), mean ± 1SD (range), or median (range).

Another patient developed pericardial tamponade following simultaneously performed CABG, requiring pericardiocentesis. One patient developed recurrent haemoptyses due to bronchial bleeding, and recovered *ad integrum* under conservative management.

One of the 38 patients died within 30 days of stent-graft placement, yielding a 30-day mortality rate of 3%. Another three patients died [51 (38–77) days] before discharge (overall in-hospital mortality rate 11%). All four patients had undergone urgent stent-graft procedures for acute AD. The entry tear was successfully covered. After a complicated course on the ICU with need for prolonged ventilation, two patients developed acute respiratory distress syndrome secondary to severe pneumonia. The remaining two patients succumbed in septic multi-organ failure. There were no aorta-related deaths during the in-hospital period.

Mid-term and long-term outcome

During a median follow-up of 18 (1–57) months, major complications occurred in seven (21%) of the 34 surviving patients. The complication-free survival was 80.7 $\pm$ 7.1% at 1 year, 75.0 $\pm$ 8.6% at 2 years, and remained at 75.0 $\pm$ 8.6% at 4 years (*Figure 1*). One (3%) patient developed a minor stroke without permanent neurological deficit 4 weeks after endovascular repair of chronic AD. One (3%) asymptomatic patient showed a mobile intraluminal thrombus attached to the stent-graft during a routine follow-up visit. Under anticoagulation, the thrombus had become completely wall adherent, and there has been no event of peripheral embolization, so far. Oral anticoagulation is continued and the patient is followed by TEE every 6 months. Three (9%) patients treated for chronic AD sustained fatal aortic rupture. One (3%) patient developed an aorto-oesophageal fistula related to the stent-graft, which resulted in fatal upper gastrointestinal bleeding. Finally, out of the 13 patients with (partial) coverage of the left subclavian artery, one (3%) patient developed mild subclavian steal syndrome, which did not require surgical correction.

Eight (24%) of the surviving 34 patients required a second stent-graft procedure. The freedom from re-intervention rate was 88.0 $\pm$ 6.5% at 1 year, 66.5 $\pm$ 10.8% at 2 years, and remained at 66.5 $\pm$ 10.8% at 4 years (*Figure 2*). Six patients had additional entry sites, whereas two patients had developed aneurysms of the descending aorta proximal to the previously implanted stent-graft. In one patient, repeat stent-graft placement was unsuccessful due to device failure requiring emergency surgical conversion. The patient succumbed 3 weeks post-operatively after successful surgery, but a complicated course in the ICU.

Overall, six of the 34 patients surviving the in-hospital period died during the follow-up period. The overall survival rates were 97.4 $\pm$ 2.6% at 30 days, 80.4 $\pm$ 6.7% at 1 year, 73.2 $\pm$ 7.8% at 2 years, and 54.9 $\pm$ 16.9% at 4 years (*Figure 3*). Patients with poor clinical health status (ASA class $>$ 3) had a significantly reduced life

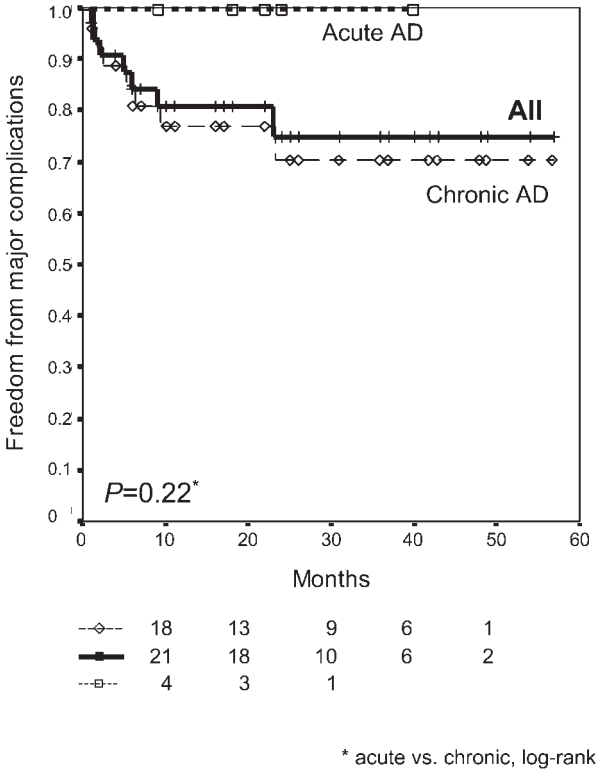

Figure 1 Kaplan–Meier estimates of complication-free survival (black square, all patients; open diamond, patients with chronic AD; open square, patients with acute AD).

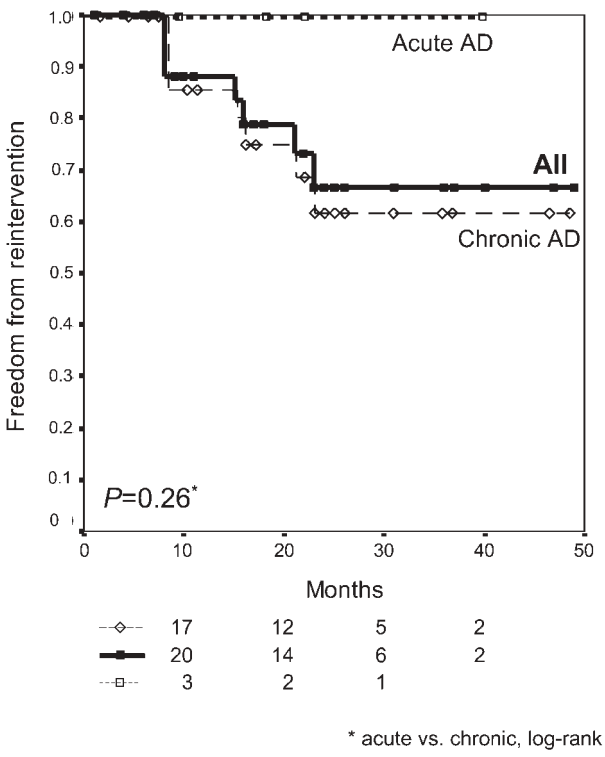

Figure 2 Kaplan–Meier estimates of freedom from aortic reintervention (black square, all patients; open diamond, patients with chronic AD; open square, patients with acute AD).

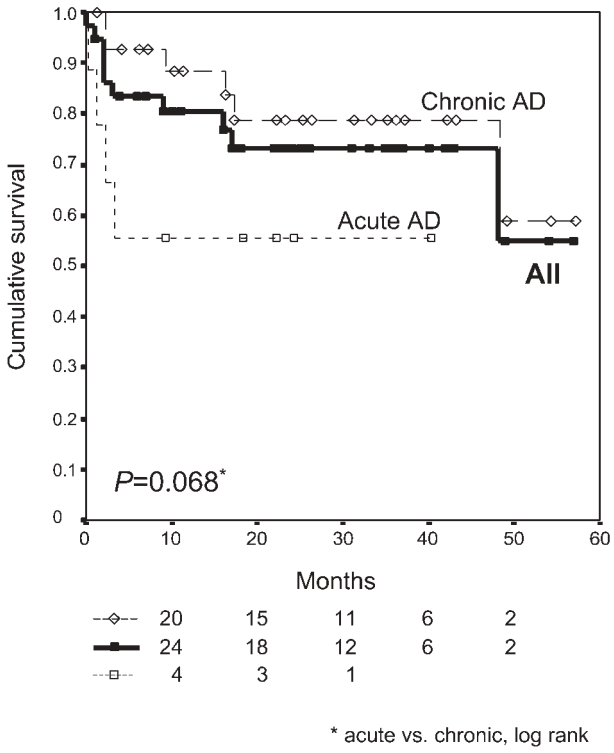

Figure 3 Kaplan–Meier survival estimates (black square, all patients; open diamond, patients with chronic AD; open square, patients with acute AD).

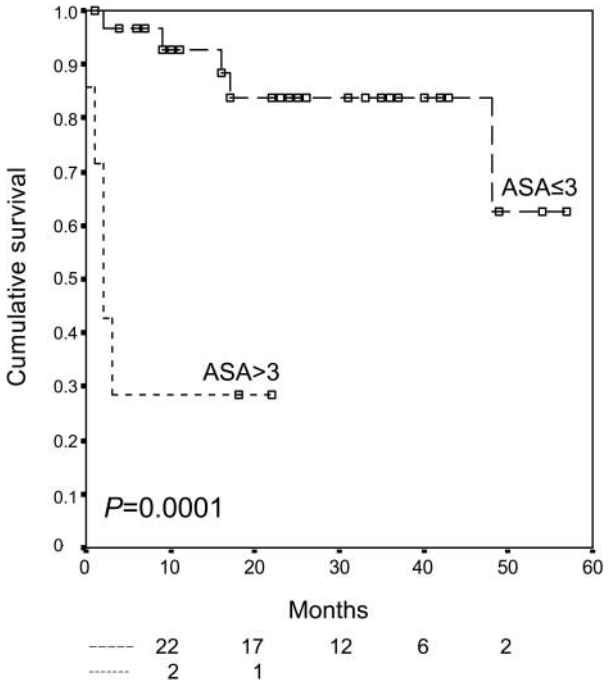

Figure 4 Kaplan–Meier estimates of survival in patients with poor clinical health status (ASA > 3) compared with patients with moderate systemic disease (ASA ≤ 3).

expectancy compared with patients with only moderate systemic disease (ASA class ≤3) ($P = 0.0001$, *Figure 4*). The survival rate at 1 year was only 28.6 ± 17.1% in this group compared with 92.6 ± 6.7% in ASA class ≤ 3 patients (*Figure 4*).

Acute versus chronic AD

Patients with acute AD had a significantly worse general health status than patients with chronic AD (ASA class 3.5 ± 0.5 vs. 2.2 ± 0.5, $P < 0.001$). In-hospital complications were not different between the two groups (*Table 3*). The 30-day mortality was also not different between the groups (10% for acute AD vs. 0% for chronic). However, overall in-hospital mortality was significantly higher in patients with acute AD ($P = 0.001$, *Table 3*). In addition, there was a trend towards better survival of patients with chronic AD compared with patients with acute AD ($P = 0.068$, *Figure 3*), although late complications occurred more frequently, albeit statistically not significantly, in patients with chronic AD (*Figure 1*). The rate of re-intervention also tended to be higher in patients with chronic AD.

Imaging follow-up

In 29 of the 34 surviving patients with a follow-up >6 months, all stent-grafts were patent without evidence of migration, twisting, or fracture. Increase in true lumen (TL) diameter was observed in all patients.

Table 3 Comparison of in-hospital complications and mortality during follow-up between patients with acute and chronic AD

	Acute AD ($n = 10$)	Chronic AD ($n = 28$)	P
In-hospital complications	3 (30)	5 (21)	0.411
procedure-related	0	4 (14)	0.566
neurological	0	0	—
Overall mortality			
at 30 days, %	10.0 ± 9.5	0	0.09[a]
at 1 year, %	44.4 ± 16.7	13.6 ± 7.3	0.067[a]
at 2 years, %	44.4 ± 16.7	21.2 ± 16.7	0.068[a]
at 4 years, %	44.4 ± 16.7	40.9 ± 18.2	0.068[a]

[a]Log-rank test.
Data are frequency (percentage), or mean ± 1SD.

Complete FL thrombosis of the descending thoracic aorta was observed in 21/29 (72%) patients and partial thrombosis in five (17%) (*Figure 5*). In three (10%) patients, there was no evidence of thrombus formation within the thoracic FL. Complete thrombosis of the abdominal FL was observed in three (10%) patients and partial thrombosis in five (17%).

Multivariable analysis

Multivariable analysis revealed that a poor pre-operative clinical health status (ASA class > 3; HR = 29.5, 95% CI 1.5–581.9, $P = 0.026$) and increased age (HR = 1.1, 95%

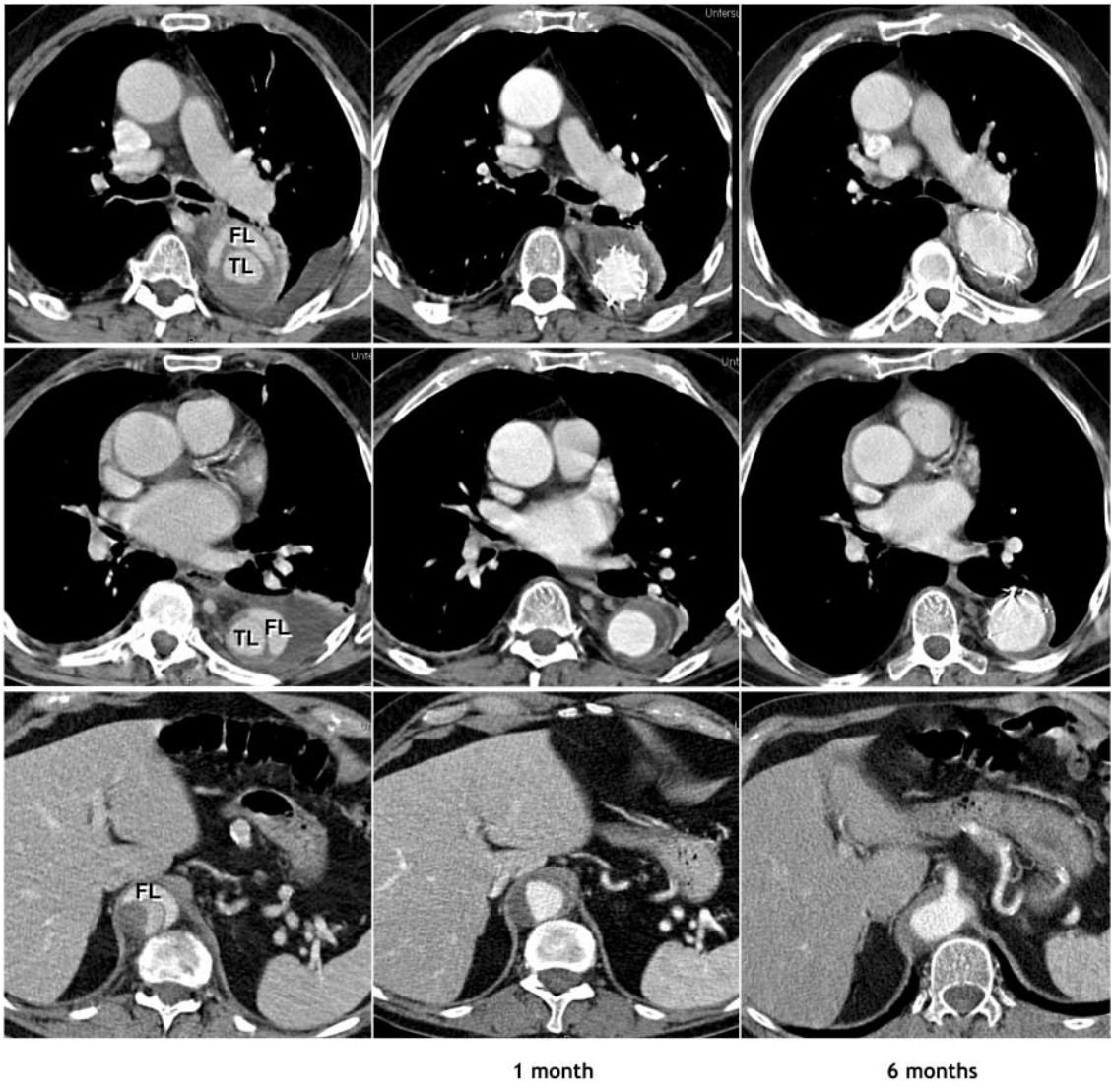

Figure 5 Pre-interventional contrast-enhanced CT and comparable CT scans 1 month and 6 months following thoracic endovascular stent-graft placement demonstrating complete obliteration and resolution of the FL and enlargement of the TL of the entire thoracic aorta down to the level of the abdominal aorta (aortic remodelling).

CI 0.9–1.2, $P = 0.084$) were significant independent determinants of mortality.

Discussion

The present study indicates that endovascular stent-graft repair of AD can be achieved with high technical success rates and low rates of severe acute complications. In this regard, our study confirms the results of previous studies reporting technical success rates $>90\%$.[7–11] Moreover, our results indicate that the mid-term outcome following endovascular repair is mainly dependent on the pre-operative clinical health status of the patient, comprising age and co-morbidities, rather than on the less traumatic treatment concept.[13] In the present study, the 1-year survival rate of patients with poor clinical health status pre-operatively was sobering, whereas patients with only a minor or moderately reduced general health status (ASA class ≤ 3) had a very satisfactory outcome following stent-graft treatment with a 1-year survival rate $>90\%$. Similarly, Demers and co-workers[14] recently reported that patients undergoing endovascular stent-graft treatment of thoracic aortic aneurysms who were considered not to be suitable open surgical candidates had a significantly worse mid- and long-term outcome compared with good surgical candidates (5-year survival rate 31 vs. 78%, $P < 0.001$). Our results, together with those of Demers *et al.*,[14] demonstrate that the pre-operative clinical health status has crucial impact on the post-operative outcome of endovascular stent-graft treatment. Careful patient selection is thus of particular importance, but may be difficult in patients with AD since these are usually elderly with a variety of co-morbidities which portend an inherent risk.[13]

The rationale of endovascular stent-graft treatment of AD (i.e. obliteration of flow into the FL) is based on the clinical observation that patients with spontaneous thrombosis of the FL have an improved long-term prognosis.[4] Conversely, persistent perfusion of the FL has been identified as a major predictor of adverse long-term outcome.[5] Spontaneous thrombosis of the FL is, however, only rarely observed ($\leq$4% of patients).[4] In the present study, complete FL thrombosis of the descending thoracic aorta as a result of stent-graft placement was observed in 72% of the patients. This is consistent with the results of previous studies reporting FL thrombosis rates of between 58 and 100%.[7–11] FL thrombosis of the abdominal aorta was, however, achieved in only 10% of our patients. Similarly, Lambrechts *et al.*[15] observed FL thrombosis of the thoracic aorta in the majority of their patients, while the abdominal FL remained patent, without evidence of thrombus formation, in all of them. Persistent perfusion of the abdominal FL can be explained by the presence of multiple natural fenestrations at the level of the visceral arteries. The therapeutic consequence of persistent perfusion of the abdominal FL is so far unclear. Stent-graft placement to cover the abdominal entry sites is thwarted by the uptake of the visceral arteries. Interestingly, Lambrechts *et al.*[15] reported that only one patient in their series developed further dilatation of the abdominal aorta during follow-up.

At present, the optimal timing of endovascular repair in patients with AD is controversial. We observed a trend towards a better outcome in patients with chronic AD undergoing endovascular repair. In particular, in-hospital mortality was significantly higher in patients with acute AD compared with patients with chronic AD. It is important to note that the mortality in all of these patients was related to non-aortic, albeit procedure-related complications which resulted in a complicated post-operative course while the dissection was successfully treated. Our findings are supported by Kato *et al.*[16] who observed significantly increased early and late complication and mortality rates in patients with acute AD undergoing endovascular repair compared with patients with chronic dissection. This may suggest that endovascular repair should be delayed in patients with acute AD. Kato *et al.*[16] speculated that morphological changes of the initially fragile dissecting membrane to a more fibrotic and seemingly stable membrane in the chronic phase are critical for endovascular repair, particularly as these authors used relatively rigid first-generation stent-graft prostheses. Our results, however, suggest that the more stable clinical status of the patients in the chronic phase of AD (as outlined above) is the most important determinant of better survival following endovascular repair. In patients with poor general health status who have to be treated acutely (e.g. due to rupture), the early post-operative period appears to be most critical. Weaning from mechanical ventilation, which is, so far, required for the stent-graft procedure may be a particular clinical problem in these patients. Prolonged ventilation is associated with severe secondary problems, as was the case in all our patients dying during the in-hospital period. Thus, further technical developments and miniaturization of the stent-graft devices which allow a percutaneous placement without the need for general anaesthesia and mechanical ventilation will help to reduce secondary post-operative complications by limiting the invasiveness of the procedure.

The upper time limit for treating patients with chronic AD with stent-grafts remains speculative. Interestingly, it appears that patients with acute AD have a greater potential for stent-graft-induced remodelling of the aorta. Shimono *et al.*[11] reported that complete obliteration and resolution of the FL following endovascular stent-graft treatment was more frequently achieved in patients with acute AD compared with patients with chronic AD (70 vs. 38.5%). At least, our results suggest that even patients with a long-standing history of AD can be treated endovascularly with satisfactory clinical outcome. However, patients with chronic AD require close follow-up after stent-graft placement as, in our experience, late complications were more frequently encountered in these patients. Furthermore, re-interventions may be required more frequently than in patients undergoing stent-grafting for acute AD.

Although the incidence of neurological complications is low (1–3%)[17] compared with conventional surgery (up to 21%),[18] paraplegia and stroke remain the major concern of endovascular repair. In the present study, there were no acute neurological complications. A single patient developed a minor stroke 4 weeks after the stent-graft procedure. At present, it is not completely understood which effect of endovascular repair results in the development of paraplegia; however, coverage of numerous potentially critical intercostal arteries by the stent-graft is commonly believed to determine increased risk of paraplegia.[17,18] Particularly, simultaneous abdominal and thoracic aortic repair with loss of lumbar and intercostal arteries appears to pose an increased risk of spinal cord damage caused by insufficient collateral circulation.[19] To avoid this devastating complication, it was our designated strategy to seal only the main proximal entry initially, and not to cover the entire descending thoracic aorta. If more entry sites were present, these were addressed in a secondary endovascular procedure performed after a time interval of at least 2 months in a staged approach. This explains the relatively high number of adjunctive endovascular procedures in the present study.

With growing experience in endovascular stent-graft treatment, the spectrum of mid-term and long-term complications has broadened to include potentially disastrous events, other than paraplegia or stroke, that require lifelong diligent surveillance.[20] In our series, two out of the 34 patients who survived the in-hospital period developed such unanticipated complications during long-term follow-up (one aorto-oesophageal fistula, one mobile thrombus within the stent-graft lumen). Another noteworthy finding in this study was the relatively high incidence of late aortic rupture, which occurred in 9% of our patients. This—in addition to the risk of unanticipated complications—re-emphasizes the importance of lifelong clinical and imaging surveillance and the need for tight

blood pressure control following endovascular stent-graft treatment.

Limitations

Our study is limited by the relatively small number of patients treated; however, AD has a low incidence. In the present study, we reported our mid-term experience with a median follow-up of 18 months. Long-term follow-up studies are necessary to assess the durability and effectiveness of endovascular repair. Furthermore, we presented the imaging follow-up of only 29 of the 34 surviving patients, which may introduce selection bias; however, we believe that a sufficient follow-up time is crucial to evaluate morphological changes of the aorta after stent-graft placement, and thus only patients with an imaging follow-up of >6 months were included. It is an inherent limitation of our approach that the natural course of the disease in our patients, particularly with acute AD, remains unknown. All acute AD patients were symptomatic and/or had complications and therefore underwent stent-graft placement. We cannot rule out that patients would have died even without stent-graft treatment, and thus our results may also reflect a biological selection of survivors. So far, the indication for endovascular stent-graft treatment of patients with uncomplicated AD remains unclear, until randomized studies are available that compare this new approach with optimal medical therapy alone.

Clinical implications

The present study demonstrates that endovascular stent-graft treatment of patients with AD using second-generation stent-graft prostheses can be achieved with high technical success rates and low rates of severe acute complications. In our experience, the pre-operative clinical health status of the patient was the most important determinant of post-operative outcome. Careful patient selection is thus of particular importance. Severely ill patients who are considered not to be suitable candidates for open surgery might also not be suitable candidates for endovascular repair. Conversely, AD patients with only moderate co-morbidities have a very satisfactory mid-term outcome following endovascular stent-graft treatment of AD. During follow-up, lifelong diligent surveillance with serial imaging of the aorta is mandatory due to the risk of unanticipated complications and the risk of late aortic rupture.

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Appendix

Pre-operative and operative variables examined as potential independent risk factors for overall death in the multivariable analysis.

	χ^2	P
Demographic		
Age	—	0.028
Gender	0.34	0.559
Acute versus chronic dissection	1.31	0.252
Oral anticoagulation	1.6	0.206
Beta-blocker therapy	2.13	0.144
Body mass index	—	0.457
Comorbidities		
ASA class	12.3	0.002
Aortic rupture	2.06	0.151
Presence of shock	5.46	0.019
Hypertension	0.75	0.385
Chronic obstructive lung disease	0.12	0.731
Impaired renal function	1.50	0.220
Diabetes	0.34	0.559
Previous cerebrovascular accident	0.75	0.385
Coronary artery disease	0.06	0.809
C-reactive protein level	—	0.242
Operative variables		
Procedure duration	—	0.467
Amount of contrast media used	—	0.290
Number of stents implanted	—	0.273
Use of intra-operative TEE guidance	0.12	0.726
Coverage of subclavian artery	0.34	0.842
Post-operative variables		
Need for prolonged ventilation	8.56	0.003
Need for dialysis	12.52	<0.001

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