Early and Long-term Outcome after Thoracic Endovascular Aortic Repair (TEVAR) for Acute Complicated Type B Aortic Dissection

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- complicated;
Aortic dissection-acute;
Endovascular repair;
TEVAR;
Re-intervention;
Survival

Abstract
Objectives: The study aimed to investigate early and long-term outcome of thoracic endovascular aortic repair (TEVAR) for acute complicated type B dissection.
Design: This was a retrospective, single-centre, consecutive case series.
Materials and Methods: During the period 1999–2009, TEVAR was carried out in 50 patients with non-traumatic acute complicated type B dissection, and in another 10 patients with acute complications, including rupture, end-organ ischaemia and acute dilatation during the primary hospitalisation, but >14 days after onset of symptoms. Thus, in total, 60 patients were included; 22 with a DeBakey type IIIa dissection and 38 with a type IIIb; median age was 67 years. Early (30-day) and long-term (5-year) survival, re-intervention rate and complications were recorded until 1 July 2010.
Results: Within 30 days, two (3%) deaths, one (2%) paraplegia and three (5%) strokes were observed. Five-year survival was 87% and freedom from re-intervention at 5 years was 65%.
Conclusions: In patients with acute complicated type B aortic dissection, TEVAR can be performed with excellent early and long-term survival, whereas morbidity and long-term durability must be further elucidated.

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Acute aortic dissection is a potentially deleterious and highly challenging condition. The classification of aortic dissection is based on location of the entry tear and time from onset. The Stanford classification distinguishes between type A and B; a type A dissection includes the ascending aorta, and type B originates in the descending aorta.1 The DeBakey classification is a further subdivision, dividing descending aortic dissections into class IIIa, which terminates above the
diaphragm, and class IIIb, which also involves the abdominal aorta. The acute phase is defined as the first 2 weeks after onset because mortality rates are highest during that time.\(^1\) The International Registry of Acute Aortic Dissection (IRAD) has demonstrated that roughly one in three dissections is of type B.\(^2,3\) In acute type A dissection, surgery is the undisputed treatment, whereas in acute type B dissection, surgery carries high risks of spinal injury, renal failure and postoperative mortality.\(^4-7\)

In uncomplicated, non-traumatic type B dissection, medical management including aggressive anti-hypertensive medication and alleviation of pain is recommended.\(^1,8\) Surgical or interventional treatment is limited to patients with complicated type B dissection, involving impending rupture, rapid dilatation, malperfusion or uncontrollable pain. Since the early reports on the use of stent grafts in treating aneurysms and dissections of the thoracic aorta,\(^9-11\) several reports have shown the beneficial effects of thoracic endovascular aortic repair (TEVAR) in acute complicated type B dissection,\(^12-14\) but there still is no consensus on when to use this method. In addition to covering the primary intimal tear and stabilising the true lumen, correction of end-organ malperfusion must also be undertaken unless branch vessel obstruction is relieved by TEVAR, and the patients need to be carefully followed up.

The aim of the present study was to investigate the early and long-term results of our initial 10-year TEVAR experience of treating patients with complicated acute type B dissections, with focus on survival, re-intervention rate and complications. A secondary aim was to analyse whether outcome differed between DeBakey class IIIa and IIIb patients.

**Materials and Methods**

During a 10-year period from the first patient in December 1999 until 31 December 2009, a total of 186 patients underwent TEVAR. In all, 50 patients were treated for non-traumatic acute complicated type B dissection. In addition, 10 patients treated for an acute complication occurring during hospitalisation for the primary aortic dissection event but >14 days after onset of symptoms were included in the study group. Thus, in all, 60 patients were followed up. No patient underwent TEVAR for uncomplicated type B dissection.

The remaining 126 patients underwent TEVAR for the following indications: chronic type B dissection with dilatation (n = 22), traumatic aortic transection (n = 15), aortic arch/descending aortic aneurysm (n = 62), thoracoabdominal aneurysm (n = 13), acute type A dissection with distal malperfusion (n = 5), chronic type A dissection (n = 3), coarctation (n = 3), mycotic aneurysm (n = 2) and aortobronchial fistulae (n = 1).

Among the 60 patients included, 22 had a DeBakey IIIa dissection and 38 a IIIb dissection. Median age was 67 years; 33% were women. Median time to treatment from onset of symptoms was 1.5 days. In the 10 patients treated after more than 14 days, median time was 22 days (range, 15–38 days).

All patients were evaluated by a team of cardiothoracic and vascular surgeons, interventional radiologists and anaesthesiologists. Preprocedural imaging was performed with contrast-enhanced computed tomography (CT). Arterial access was established through surgical exposure or percutaneously, and the stent grafts were deployed over a stiff wire.\(^9\) A fixed angiographic system was used for the procedure, and transesophageal echocardiography was used to distinguish the true lumen from the false, and to identify the entries.

A proximal sealing zone of at least 15 mm was required, and whenever necessary, the origins of the left subclavian artery (LSA) and/or the left common carotid artery (CCA) were covered. Debranching of the CCA was then performed preprocedurally by an extra-anatomical bypass, while selective post-procedural revascularisation of the LSA was undertaken.

Cerebrospinal fluid drainage was used selectively when the patient was considered to be at increased risk of spinal cord ischaemia (i.e., most of the descending aorta was to be excluded (>20 cm) or a history of previous abdominal aortic repair) or when symptoms of spinal cord ischaemia occurred. After insertion of the drainage catheter, the patient was placed in the supine position, and the zero level of the pressure chamber set at the level of the lumbar spine, accomplishing passive, continuous drainage. The drainage was kept for 72 h. In case of progressive neurological symptoms, active drainage was applied. After deployment of the stent graft, the mean arterial blood pressure was kept above 80 mmHg.

Since the introduction of TEVAR, it has been our first-line therapy in patients with acute complicated type B dissection. Whenever TEVAR did not relieve malperfusion, additional branch artery stenting was performed. Two patients, not in the study group, underwent endovascular fenestration. No patient underwent branch artery stenting alone, and no patient underwent open surgical repair.

**Follow-up**

All patients were prospectively registered. A unique 10-digit personal identity number (PIN) is allocated to Swedish citizens and permanent residents. In July 2010, all these patients were followed up with respect to survival by computerised cross-linkage to two national registers: the Swedish Cause of Death Register and the Population Register. The latter is updated every week, and there is a maximum delay of 3 weeks from death to registration. By use of these combined registers, all patients could be assigned a date of death or identified as being alive on 30 June 2010. Three patients were neither Swedish citizens nor residents; two were from the nearby Finnish island of Åland, and could be followed up through their local hospital, whereas one British citizen came back for a visit 15 months after the procedure, but was then lost to follow-up.

The patients were followed with CT angiography before discharge or at 1 month, after 3–6 months, after 12 months, and thereafter annually. In case of endoleak or expansion, patients underwent angiography, followed by secondary procedures whenever necessary.

**Statistical methods**

Continuous variables were summarised with medians and ranges, and categorical variables with frequencies.
Categorical data were analysed by Fischer’s exact test; for age comparisons, the Mann–Whitney test was used. The Kaplan–Meier method was applied to calculate life-table estimates for death and re-intervention. Statistical Package for Social Sciences (SPSS) for Windows 16.0 was used for data processing and statistical analyses.

Results

Baseline characteristics are given in Table 1. Patients with DeBakey IIIa dissection were older than patients with type IIb. A high prevalence of hypertension and a large proportion of smokers was observed in both groups. The indications for TEVAR are shown in Table 2. Multiple indications were present in 19 (32%) patients, six of whom were among the 10, who were treated >14 days after onset of symptoms. The predominant indication in IIIa patients was rupture/haematoma/pleural effusion. Distal malperfusion was barely seen in type IIIa dissections, whereas one or more vascular beds were affected in 22 (58%) of the 38 patients with IIIb dissections.

The median length of aorta covered by the stent graft was 20 cm (range, 10–33 cm). In 46 (77%) patients, one stent graft was used, in 12 patients two stent grafts and in two patients three stent grafts were used. The Gore TAG® endoprosthesis (WL Gore & Associates, Inc, Flagstaff, AZ, USA) was used in 54 (90%) patients, and in one combined with a Relay® thoracic stent graft (Bolton Medical, Inc, Sunrise, FL, USA). The Relay® stent graft was used in one more patient. The Talent® thoracic stent graft was used in four, and the Valiant® thoracic stent graft (Medtronic, Inc, Minneapolis, MN, USA) in one patient. The stent graft arch landing zone was Z1 in three patients, Z2 in 30, Z3 in 26 and Z4 in one patient.15

End-organ complications and concomitant procedures

Stenting of the true lumen of end-organ arteries was performed in 13 patients. In one patient, the coeliac trunk was stented (to prevent migration of the thoracic stent graft), four patients got stents in the superior mesenteric artery for bowel ischaemia, five patients got renal artery stents for renal malperfusion and five patients got iliac artery stents, bilaterally in two. Two patients got both renal and iliac artery stents (Table 2).

Renal malperfusion was seen in 17 patients. Ten patients resolved their renal perfusion after TEVAR, and five after an additional renal artery stent (four left renal artery and one right). Two patients needed temporary renal replacement therapy; neither one of them had had a renal artery stent primarily. One of these patients also developed an abdominal compartment syndrome, secondary to an intestinal reperfusion syndrome, requiring decompression laparotomy. The abdomen could be closed on day 13 after a combination of mesh and vacuum-assisted wound closure.

Table 1 Baseline characteristics of patients treated with TEVAR.

<table>
<thead>
<tr>
<th></th>
<th>Type B dissection DeBakey IIIa (n = 22)</th>
<th>Type B dissection DeBakey IIIb (n = 38)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>10 (45%)</td>
<td>10 (26%)</td>
<td>0.16</td>
</tr>
<tr>
<td>Median age (range)</td>
<td>73 (55–84)</td>
<td>63 (34–82)</td>
<td>0.002</td>
</tr>
<tr>
<td>Hypertension</td>
<td>10 (45%)</td>
<td>23 (61%)</td>
<td>0.28</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1 (5%)</td>
<td>0</td>
<td>0.36</td>
</tr>
<tr>
<td>Ischaemic heart disease</td>
<td>7 (32%)</td>
<td>5 (13%)</td>
<td>0.10</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>6 (27%)</td>
<td>6 (16%)</td>
<td>0.31</td>
</tr>
<tr>
<td>Smoking</td>
<td>10 (45%)</td>
<td>15 (39%)</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Table 2 Indication for TEVAR and concomitant procedures in patients with type B dissection in relation to DeBakey subtype. Multiple indications may be present. Number of patients in each category are given.

<table>
<thead>
<tr>
<th></th>
<th>DeBakey IIIa (n = 22)</th>
<th>DeBakey IIIb (n = 38)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visceral malperfusion</td>
<td>1</td>
<td>11</td>
<td>0.04</td>
</tr>
<tr>
<td>Coeliac trunk stent</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>SMA stent</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Renal malperfusion</td>
<td>2</td>
<td>15</td>
<td>0.02</td>
</tr>
<tr>
<td>Renal artery stent</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Leg ischaemia</td>
<td>0</td>
<td>9</td>
<td>0.02</td>
</tr>
<tr>
<td>Iliac artery stent</td>
<td>1^</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Rupture/Haematoma/Pleural effusion</td>
<td>19</td>
<td>15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Acute dilatation</td>
<td>6</td>
<td>4</td>
<td>0.15</td>
</tr>
<tr>
<td>Intractable pain</td>
<td>1</td>
<td>3</td>
<td>1.00</td>
</tr>
</tbody>
</table>

SMA = Superior Mesenteric Artery.

^ Periprocedural rupture, not primary ischaemia.
The second patient also had to undergo right hemicolectomy for bowel ischaemia, and so did another three patients. Two of them had had superior mesenteric artery stents.

Two patients had an iliac stent graft due to rupture. In three cases, lower extremity ischaemia necessitated iliac artery stenting, unilaterally in one, bilaterally in one and one patient underwent concomitant abdominal aortobifemoral stenting. The latter also had a femorofemoral crossover bypass, but eventually underwent unilateral below-knee amputation.

**Neurologic complications and concomitant procedures**

Cervical debranching was carried out in four patients prior to TEVAR. Three patients underwent right-to-left carotid crossover bypass and two of them concomitant carotid–subclavian bypass to allow stent-graft placement in the arch; one of these patients had a retrograde dissection. The fourth patient had a carotid–subclavian bypass done prior to TEVAR because of the presence of a mammary artery–coronary bypass graft. None of these patients had neurologic complications.

Nine patients had cerebrospinal fluid drainage catheters inserted prior to TEVAR. None of them had neurologic or local complications.

A total of seven patients (12%) sustained neurologic complications; they were all evaluated by a neurologist. Four patients (7%) had post-procedural spinal ischaemic symptoms. Two had predominantly unilateral symptoms (monoplegia), and two had paraplegia. All four got spinal drainage catheters after onset of symptoms. Three patients recovered, and one remained paraplegic (2%). Three of the seven patients showed signs of cerebral lesions. One had post-procedural right hemiparesis, with a CT-verified left-sided lacunar infarct; he recovered partially. Another patient with right hemiparesis had a CT-verified right-sided lesion, making the interpretation unclear. The third patient had a left hemiparesis, with a CT-verified right-sided cerebellar infarction, and the patient recovered.

Two patients had neurologic symptoms on admission. One had paraplegia with mainly left-leg symptoms, with concomitant leg ischaemia. After TEVAR and stenting of the left external iliac artery, he recovered motor function, but had a remaining impairment of sensibility. The second patient had partial right hemiplegia, with a remaining impairment of sensibility. The second patient also had to undergo right hemicolectomy for bowel ischaemia, and so did another three patients. Two of them had had superior mesenteric artery stents.

Early and late mortality

There were two early deaths. One died from an intracerebral bleeding on the second day and one from multiple organ failure on day 17 after TEVAR for rupture. Thus, 30-day mortality was 3%.

Median follow-up time was 3.7 years (interquartile range, 2.3–5.0 years). Actuarial survival among all patients was 90% ± 4% at 3 years, and 87% ± 5% at 5 years. There was no survival difference between the two DeBakey subgroups (log rank, $p = 0.61$). Survival curves for patients with DeBakey type IIIa and IIIb dissections, respectively, are depicted in Fig. 1.

**Re-intervention**

A total of 19 patients (32%) underwent one or more re-interventions; five had type IIIa dissection, and 14 type IIIb. In all, nine patients underwent re-TEVAR. In two patients, both with type II endoleak, it was done as a secondary re-intervention after first attempting to remedy the endoleak. The indication for re-TEVAR was dilatation in all nine. In three patients, re-TEVAR was combined with cervical debranching, and in two patients with stenting of the left renal artery. One patient developed a chronic dissection with dilatation of the remaining thoraco-abdominal aorta, and underwent a visceral debranching operation, combined with stent grafting of both the thoracic and abdominal aorta. Finally, one patient underwent re-TEVAR without additional procedures.

Of 28 patients who had their LSA covered without prior revascularisation, one developed arm claudication, one rest pain and one subclavian steal syndrome. All three patients underwent carotid–subclavian bypass, in one it was combined with percutaneous placement of an Amplatzer plug in the proximal LSA. Another patient, who had undergone carotico-carotid and carotid–subclavian bypass primarily, developed arm claudication due to stenosis of the right carotid artery–graft anastomosis and underwent surgical revision.

Of the remaining six patients needing re-intervention, two had percutaneous coverage of the LSA, whereby the endoleak ceased, two patients underwent stent grafting of one renal artery to cover re-entry sites, in one of these patients it was combined with EVAR for an aneurysm and yet another patient underwent EVAR for subsequent dilatation. Finally, in one patient, the stent graft had collapsed in association with operative repair of a later type A dissection. It was managed by placing Palmaz stents in the proximal part of the stent graft.

Median time to first re-intervention in the 19 patients was 0.5 year (range, 1 day to 3.1 years). Actuarial freedom from re-intervention among all patients was 68% ± 6% at 3 years and 65% ± 7% at 5 years. There was no difference
repair. After TEVAR, lower incidences of spinal and dissection, and 2- and 3-year survivals of 60% after endovascular repair in complicated acute type B patients was 11%. Single-centre studies and a meta-analysis have reported early mortality rates of 10% in endovascularly treated patients. Early mortality in TEVAR charged alive with acute type B dissection was around 25%. Thus, survival in this study compares favourably with previously published results.

In spite of refined surgical technique with neuroprotective measures, the incidence of perioperative neurologic complications remains at 5–15% after open repair. After TEVAR, lower incidences of spinal and cerebral complications have been reported than after surgery. The use of the combination of endovascular flap fenestration and branch artery stenting in patients presenting with malperfusion is an alternative means to restore end-organ perfusion used by some centres, with a reported incidence of neurologic complications at the same magnitude as after TEVAR. However, fenestration cannot be used to treat rupture or dilatation.

![Figure 2](image_url)

The incidence of neurologic events, 7 out of 60 patients (12%), was fairly high. Another two patients had severe neurologic impairment on admission. However, three of four patients with spinal ischaemia and one of the patients with a new cerebral ischaemic lesion recovered completely. The incidence of permanent neurologic damage was similar to other reports. All patients, who developed spinal symptoms, received a cerebrospinal fluid drain shortly after onset, and were monitored in the intensive care unit. We cannot tell whether or not they might have recovered without drainage, but none of the patients who received a drain prior to TEVAR had any neurologic symptoms. Spinal drain is now used more frequently in our TEVAR patients.

Approximately one-third of the patients needed re-intervention, half of them had re-TEVAR and half had adjunctive procedures. Previous reports have addressed potential mechanisms of remodelling and expansion after TEVAR for acute complicated type B dissection. The recent development of more flexible stent grafts may help prevent some cases of proximal type I endoleak. We have modified our technique in that we now routinely deploy the stent graft at the level of the LSA, even in case of a more distal primary intimal tear.

In this report, we included 10 patients with complicated type B dissections, who were still hospitalised after the primary event. They were treated because of acute complications, with multiple complications present in six of them, indicating that these patients differed from other chronic dissection patients, who are commonly treated for progressive dilatation. As the original 2-week definition was based on a mixed type A and type B cohort with many patients left untreated, we believe that this arbitrary time limit could be questioned; it may take longer than 2 weeks for a dissection to stabilise.

We conclude that TEVAR in patients with complicated acute type B dissection was associated with few permanent neurologic complications and excellent long-term survival. TEVAR was often sufficient to relieve malperfusion, but immediate concomitant procedures were sometimes necessary, as well as later re-interventions. These patients require careful post-procedural surveillance, both in the early and late stages. Until results of further studies are reported, endovascular therapy of the thoracic aorta should be confined to large centres with post-procedural follow-up, as well as scientific evaluation of the results.

### Conflict of Interest

None.

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### References

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