Endovascular Stent Graft Repair of Aortic Dissection Type B Extending to the Aortic Arch

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KEYWORDS
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type A;
Aortic arch;
Endovascular stent graft repair

Abstract  Objective: To analyse our experience with endovascular stent graft repair of descending aorta dissections that require supraaortic branch vessel revascularisation.
Design: Retrospective study.
Methods: From 2001 to 2009, 22 consecutive patients with the above dissections were retrospectively analysed. Inclusion requirement: aortic landing zone proximal to the left subclavian artery of less than 15 mm. Hybrid, scalloped or fenestrated endovascular stent grafts were selected based on dissection characteristics. Annual follow-up visits (median 27.1 months) included computed tomography angiography. End points include progressive pathology, complications and survival rates.
Results: Surgery was successful in all except for one operative complication. Two patients died within 30 days after surgery, one to cerebral infarction and the other to myocardial infarction. No postoperative complications occurred in the remaining patients. Thrombosis formed in the aortic false lumen of the graft exclusion segment in all patients. The maximum diameter of this segment decreased in 18 patients and was stable in two. In 19 patients, blood flow remained in the false lumen distal to the exclusion area not covered by stent. Patency was seen at mid- and long-term follow-up, without proximal endoleak, graft displacement or deaths.
Conclusion: Endovascular stent graft methods show promise in endovascular stent graft repair of proximal descending aortic dissections involving the distal arch.

Introduction
Stanford type A dissections involve primarily dissections with an entry in the ascending arch, but also include dissections of the descending aorta with retrograde extension into the aortic arch. For patients with acute Stanford type A dissections, surgical intervention is the treatment of choice.1–3

In contrast to open surgical repair, stent graft repair requires suitable proximal and distal ‘landing zones’ for stent graft fixation.4–6 A minimum of 15 mm of normal aortic wall is needed for adequate sealing of the stent graft.7,8

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Dissections of the descending aorta often also extend into the arch, with arch tears occurring in up to 30% of patients with dissection.\(^4,8,9\) Stent graft treatment of dissections of the descending aorta that involve the aortic arch must address the problem of ensuring adequate proximal fixation of the stent graft without blocking the blood supply to the collateral vessels branching off from the arch. Several choices have been proposed for endovascular repair when arch dissection and aneurysm are involved, including the use of branched stent grafts, fenestrated stent grafts and hybrid procedures.\(^{10–12}\) In the current study, we aimed to analyse our single-centre experience with endovascular stent graft repair of dissections of the descending aorta that extend into the aortic arch and need branch vessel revascularisation, addressing arch dissections that begin less than 15 mm from the left subclavian artery (LSA).

**Materials and Methods**

**Patients**

From October 2001 to March 2009, a cohort of 22 consecutive patients with dissections of the descending aorta extending to the aortic arch received endovascular graft repair, and the related medical and surgical data were retrospectively analysed. Before surgery, all these patients had been given the options of conventional surgery or stent grafting and had voluntarily chosen stent grafting. The study was approved by the Internal Review Board. Informed consent for the procedure used was obtained from all those participating.

All the patients included in the study had dissections involving the aortic arch, including either dissections beginning at the aortic arch and extending to proximal descending aortic or descending aortic dissections with retrograde dissection involving the arch, and all were less than 15 mm from the opening of the LSA. The aetiologies of the dissections were unclear, but no congenital disease was involved. During the study period, there were 25 patients with descending dissections with arch involvement that did not meet the inclusion criteria and were not included. Ten received medical treatment and the other 15 received open surgery. We also had 418 patients with descending aorta dissections without extension to the arch, and these patients were not included in the study.

**Preoperative evaluation, imaging and classification of dissections**

Coexisting morbidity was evaluated in all patients by preoperative check-ups and prior medical history.

All patients underwent preoperative computed tomography angiography (CTA) to determine the extent of the dissection, location of the proximal tear and diameter of the blood vessel (Fig. 1A and B). In two patients, when the location of the rupture was not clear, transoesophageal echocardiography was used preoperatively and intraoperatively to determine the location and size of the proximal tear. The distances from the LSA of the proximal border of the tear and the distal end of the normal aorta were measured using 64-row CTA with 0.5-mm-thick scanning slices. The distance from proximal tear and distal end of the normal aorta in the proximal landing area to the beginning of the LSA was measured along the aortic wall because it is the aortic wall that the stent graft adheres to during the landing procedure. The Aquarius workstation (TeraRecon) was used for three-dimensional (3D) imaging measurements. Panels A and B of Fig. 2 show these measurements for dissections distal to and proximal to the LSA.

The proximal landing zones were classified as described by Fillinger et al.\(^{13}\) and were as follows: zone 0 (Z0), the proximal edge of the covered endograft is distal to the innominate artery; zone 1 (Z1), the proximal edge of the covered endograft is distal to the innominate artery but proximal to the left common carotid artery (LCCA); and zone 2 (Z2), the proximal edge of the covered endograft is distal to the LCCA, but proximal to the subclavian artery, were used: graft scalloping (Fig. 3); graft fenestration (Fig. 4) with stent branch placement (bare stent or stent graft) into the fenestration; chimney graft (a technique in which a portion of the proximal edge of the stent graft is depressed enough to allow a stent to a side branch to be inserted between the stent graft and the wall of the aorta)\(^{14}\); and, in most patients, bypasses of various types between the branches (Fig. 5). The period between the dissection itself and stent implantation was less than 2 weeks for acute dissection and 2 months to 5 years for chronic dissection.

All endovascular surgeries were carried out under general anaesthesia and digital subtraction angiography (DSA), and employed both right- and left-sided common femoral access, except in two patients with thin external iliac and femoral arteries requiring conduits for device delivery. The indications to treat acute cases were rupture or formation of an aneurysm, and because such patients must be treated immediately, scalloping or fenestration of the stent graft was performed at the operating table.
Endovascular exclusion grafts

Graft diameter for endovascular exclusion was 10–15% greater than the diameter of the normal aorta at the proximal end of the dissection. The diameter of the stented aortic segment was 24–34 mm at the proximal end of the aortic segment and 18–30 mm at the distal end of this segment. Graft length was between 100 and 202 mm.

Postoperative follow-up

All patients were followed up prior to discharge from the hospital and at 6 and 12 months after endovascular exclusion. Subsequently, patients were followed up once per year until April 2009 (median: 27.1 months), including CTA examination at each follow-up visit.

Statistical analysis

Descriptions of continuous variables are presented as median (interquartile ranges), while categorical data are represented by number (n) and percentage (%). Life table analysis was used to estimate survival rates. Statistical analyses were performed using SPSS 15.0 statistics software (SPSS Inc., Chicago, IL, USA).

Results

Patient demographics

Twenty-two consecutive patients were recruited for this study (Table 1). Chronic dissections were present in 17 cases, all with aneurysm formation in the false lumen; in 14 of these patients, the maximum diameter of the aneurysm was ≥50 mm. Acute dissections were present in five patients: two with signs of rupture (diagnosed by CT screening) and three with aneurysm formation.

Co-morbidities are shown in Table 1. One patient had undergone prior surgery on the proximal aorta (from ascending aorta to starting segment of the aortic dissection).

During the same time period as the study, 10 patients in our hospital with descending dissections and aortic arch involvement were treated conservatively. Two of these
patients died, presumably due to rupture of the dissection. The other eight were alive at the time of follow-up.

Dissection, types of surgery and survival

Table 2 shows proximal attachment zones, anatomical attachment zones, types of graft, distances from main tear and proximal landing area to the LSA, endovascular surgery approach and method for aortic arch protection for each patient.

Endovascular stent graft procedures included 17 hybrid grafts, two fenestrated grafts, two scalloped grafts and one...
Nine patients received Talent stent grafts (Medtronic, Eden Prairie, MN, USA), seven received Relay Thoracic stent grafts (Bolton & Co., Pasadena, CA, USA), three received Zenith grafts (Cook Medical, Bloomington, IN, USA) and three received Valiant stent grafts (Medtronic, Eden Prairie, MN, USA). Graft scalloping was performed in one patient using the Talent graft and in one using the Relay graft. Graft fenestration was performed using the Valiant graft.

In 16 patients (72.7%), a reverse tear was present at the beginning of the proximal tear. In the remaining six patients, the beginning of the dissection was the beginning of the proximal tear. In patients with zone ‘Z1’ dissections, the dissections began in the aortic arch, or were descending aorta dissections with retrograde dissection involving the arch. In the zone ‘Z0’ patient, the dissection was a descending aorta dissection, but the distance between the three branches was so short that the estimated stent coverage would close off all three branch arteries, that is, the innominate artery, the LCCA and the LSA. Therefore, an ascending aorta–innominate artery–LCCA–LSA bypass was used for this patient. Patients with descending aorta dissections required LSA exclusion. Of the zone ‘Z2’ dissections, patients 1 and 3 had left subclavian artery (SCA) coverage without revascularisation. Graft scalloping of the fabric-covered portion of the proximal end of the graft was used in two patients. CT was used after placement in these patients to confirm the orientation of the scallop.

Surgery was performed successfully in all patients except for one operative complication. In 19 patients, blood flow remained in the false lumen distal to exclusion area. No spinal drainage was used in any patient. Vascular bypasses showed patency at mid- and long-term follow-up, with no proximal endoleak, graft displacement or deaths.

Follow-up

The median duration of follow-up was 2.71 (7.5–51.3) months. Survival rates are summarised in Table 1. Patient No. 1 received endovascular graft exclusion, and the graft inadvertently covered the LSA during surgery, resulting in immediate postoperative stroke. We performed LECA–LVA surgery 6 h later (Table 2), and the patient died 12 days after surgery.
<table>
<thead>
<tr>
<th>ID</th>
<th>D1 (mm)</th>
<th>D2 (mm)</th>
<th>Landing Zone</th>
<th>Indication</th>
<th>First procedure</th>
<th>Type of graft</th>
<th>Second procedure</th>
<th>Duration between two procedures</th>
<th>Survival</th>
<th>Follow-up (days)</th>
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<td>1</td>
<td>7</td>
<td>2</td>
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<td>Chronic AD, enlarging &gt;5 mm per half year</td>
<td>ESGR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>hybrid</td>
<td>LECA&lt;sup&gt;b&lt;/sup&gt;-LVA&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6 hours</td>
<td>Death (cerebral infarction)</td>
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<td>Same day</td>
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<td>-20</td>
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<td>ESGR</td>
<td>4 months</td>
<td>Death (myocardial infarction)</td>
<td>7</td>
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<td>14 days</td>
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<td>Z2</td>
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<td>ESGR (graft scalloping)</td>
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<td>-13</td>
<td>Z1</td>
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<td>RCCA&lt;sup&gt;g&lt;/sup&gt;—LCCA—LSA</td>
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<td>Same day</td>
<td>Survival</td>
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<td>Survival</td>
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<td>ESGR</td>
<td>14 days</td>
<td>Survival</td>
<td>591</td>
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<td>10 days</td>
<td>Survival</td>
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<td>ESGR (graft fenestration, left subclavian artery stent graft)</td>
<td>fenestrated grafts</td>
<td>ESGR</td>
<td>Survival</td>
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<td>14 days</td>
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<td>fenestrated grafts</td>
<td>Survival</td>
<td>57</td>
<td></td>
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</table>

<sup>a</sup> Endovascular Stent Grafting of Aortic Dissection 461

(continued on next page)
later. Patient No. 4 experienced myocardial infarction and heart failure after the second procedure and died 7 days after surgery. Stenosis of the initiation of the LSA was found in one patient later; at 6 months after graft scalloping endovascular graft exclusion was performed, but no ischaemic symptoms were observed. The remaining patients had no postoperative complications (Table 2). Thrombosis formed in the aortic false lumen of the graft exclusion segment in all 20 surviving patients. The maximum diameter of the aortic exclusion segment decreased in 18 patients and was stable in two patients. The median decrease in maximum aortic diameter was 14 (9, 21.5) mm (Fig. 1C and D).

Discussion

Eighteen of the 22 patients were treated with hybrid techniques. Patients with Z2 dissections were treated with LCCA—left vertebral artery (five patients), LCCA—LSA (three patients) or left external carotid—LSA (three patients) bypasses. No left upper limb ischaemia or vertebral leakage was seen in these patients. For Z1 patients, simultaneous exclusion of the LCCA and LSA was desirable. These patients were given right common carotid—LCCA—LSA (four patients) or right common carotid—LCCA (one patient) bypasses. The single Z0 patient received an ascending aorta—innominate artery—LCCA—LSA bypass.

The techniques used and also the development of the technique were determined by dissection characteristics. At first, we used LCCA—left vertebral artery bypass, because LCCA anatomy is simple and the risk of ischaemia is relatively low. But we found that the left vertebral artery was too far from the left vertebral artery, the anatomy of the left vertebral artery was complicated and this bypass technique could not improve blood flow to the LSA. Therefore, in later cases, we switched to an LCCA—LSA bypass. In other cases, we initially used bilateral external carotid artery bypass in order to avoid interfering with blood flow in the common carotid artery, but found blood flow through the external carotids to be too small, so we then changed to bilateral common carotid bypass.

LSA bypass was used in 17 patients in order to prevent cerebral ischaemia-induced infarction and subsequent paraplegia, and in one patient to repair ischaemia caused by unintentional intra-operative obstruction of the LSA. Other methods used to prevent obstruction of the LSA were the scalloping, fenestration and chimney techniques. In the two patients in whom the proximal tear and dissection were in the lesser curvature of the arch, graft scalloping was performed at the fabric-covered portion of the proximal end of the graft. In these cases, the distance from apex to the LSA was 8–9 mm and the distance from the area with fabric coverage (without scalloping) to the dissection apex was >15 mm. Fenestration was suitable for dissections with a longer landing zone, and in the two patients in whom fenestration was used, the dissection apex was closer to the LSA. The chimney technique, used in a single patient, although it has no need for precise positioning like the scalloping and fenestration techniques, has a risk of endoleak at the proximal region.
A minimum length of 15 mm for the landing zone (20 mm at the aortic corner) is required to ensure stable fixation of the stent at the targeted position and to have an exclusion length long enough to prevent type I endoleak. In our experience, the presence of a 15-mm potential attachment area at the proximal end of the aortic dissection is a key indication that ESGR may be used.

The INvestigation of STEnt Grafts in Aortic Dissection (INSTEAD) trial (2009) showed no benefit of aggressive stent grafting in chronic dissection and recommended using our approach only in acute complicated type B dissection. However, the INSTEAD patients, unlike our patients, had only early chronic and uncomplicated dissections.

Reported results of post-interventional outcomes in patients with aortic dissection type B who were treated with stent graft placement have been inconsistent. In the series of Kato et al., early and late complication rates were 33% and 36% in patients with acute dissection and 4% and 0% in patients with chronic dissection. Our complication rate of 9% (2/22) compares favourably with those of these previous studies. A limitation of the study, however, is that the study population was heterogeneous and the numbers too small to allow stratified analysis.

In conclusion, this preliminary study confirms that graft scalloping, graft fenestration and hybrid techniques show promise for endovascular stent graft repair of proximal descending aortic dissections involving the distal aortic arch. Our results contribute new evidence supporting the safety and efficacy of hybrid surgeries for treating aortic dissections that require revascularisation.

Conflict of Interest

None declared.

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