Percutaneous Endovascular Repair of Aneurysm After Previous Coarctation Surgery

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Background—Formation of aortic aneurysm late after surgical repair of coarctation carries a significant risk of rupture and lethal outcome, and repeat surgery is associated with a 14% in-hospital mortality rate and morbidity from paraplegia, injury to the central nervous system, or from bleeding. The potential of nonsurgical endovascular repair by the use of stent-grafts in lieu of repeat surgery for postcoarctation aneurysm is unknown.

Methods and Results—The concept of postsurgical endovascular stent-graft placement was evaluated with respect to feasibility and safety in 6 consecutive patients with late aneurysm formation after coarctation repair. All patients had aneurysm formation late after patch aortoplasty; placement of an elephant trunk during surgical repair of secondary type I dissection preceded formation of a local aneurysm in 2 cases. Patient age was 49±12 years, ranging from 31 to 68 years. Transluminal placement of customized stent-grafts was successful, with no 30-day or 1-year intervention-related mortality or morbidity. Follow-up survey of 11 to 47 months revealed optimal reconstruction of the thoracic aorta; 1 patient died 11 months after endovascular repair from cancer.

Conclusions—Nonsurgical aortic reconstruction of postsurgical thoracic aneurysms forming late after coarctation repair is safe and feasible; interventional stent-graft placement has the potential to avoid repeat surgery of postsurgical aortic aneurysm. (Circulation. 2003;108:2967-2970.)

Key Words: coarctation ■ aneurysm ■ grafting ■ stents ■ aorta

Severe adult-type coarctation accounts for 4% of congenital cardiovascular malformation and is usually corrected by surgical repair. Despite primary success, 9% of patients have local aneurysms late after coarctation surgery, with inherent risk of rupture and lethal outcome.1 Postsurgical aneurysm formation is observed with subclavian flap aortoplasty in 17%, after patch aortoplasty in 14%, after interposition graft repair in 6%, and occasionally with end-to-end anastomosis in the presence of persistent systemic hypertension or after the use of Dacron sutures2; postsurgical aortic aneurysm may present as false, true, or dissecting.3 Balloon-expandable endovascular stents have been used successfully as primary treatment for coarctation and recoarctation.4,5 The concept of endovascular stent-grafts for secondary repair of postsurgical aneurysm, however, has not been tested. This alternative was subsequently used to avoid repeat surgery for postcoarctation aneurysm in 6 consecutive cases.

Methods

Patient Characteristics

Patient characteristics are listed in the Table. All patients underwent previous surgical repair for aortic coarctation, with excellent primary results; the 6 index patients represent 8% of the total number of 75 patients operated on for coarctation by use of either patch aortoplasty or surgical variants over 2 decades; 17±4 years after initial repair, local aortic aneurysm of 63 ±10-mm diameter had developed at the site of patch aortoplasty. All patients had undergone patch aortoplasty; in 2 cases, an elephant trunk was inserted as an adjunct to manage new-onset type I dissection after previous patch aortoplasty. Both patients had a patch repair of adult-type coarctation and had acute type I aortic dissection of an ectatic ascending aorta (with a bicuspid aortic valve) 4 and 6 years later. Both underwent aortic root reconstruction with interposition grafting and adjunctive intraoperative placement of an elephant trunk sutured to the distal aortic arch. Despite this precaution, a local aneurysm developed at the site of coarctation repair despite the inlining coaxial distal end of the elephant trunk.

When offered a second (patients 1 through 4) and third (patient 5 and 6) surgical repair or customized endovascular treatment with optimal surgical conversion, all patients opted for an endovascular procedure as an alternative to repeat surgery and signed a written informed consent form approved by the institutional ethics committee.

Endovascular Stent-Graft

The stent-graft prosthesis (Talent, MedtronicAVE) is based on a self-expanding circumferential nitinol stent covered with a Dacron shell; each stent is customized with respect to width, length, and configuration of each end (bare stent segment or covered ends for optimal apposition) and delivered from a 22F to 24F polytetrafluoroethylene (Teflon) housing; the nitinol rings are interconnected by a longitudinal wire to ensure stability and prevent
twisting. Morphometric measurements from 3-dimensional MR scans served as blueprint for each customized configuration (Figure 1A and Figure 2A).

**Imaging Protocol**

All patients underwent spin–echo (anatomical) MRI and 3-dimensional magnetic resonance angiography (MRA) with individual bolus tracking of gadolinium–diethylenetriamine pentaacetic acid (gadolinium-DTPA; Magnevist, Schering). Gadolinium-DTPA produces contrast-induced T1-shortening effects and eliminates saturation problems from slow flow or turbulence-induced signal voids. A body-array coil was used for signal transmission and reception. With the use of an ultrafast gradient on a 1.5-T magnet (Magnetom Vision, Siemens Medical Systems), acquisition was performed in breathhold technique. A FLASH (fast low-angle shot) 3-dimensional sequence was used to create maximal-intensity projections; echo and repetition times were as short as 1.9 and 4.0 ms, respectively. With a field of view of 390 to 450 mm, a 512×512 matrix provided an in-plane resolution of 1.1×1.6 mm². Slice thickness varied from 2 to 4 mm; a flip angle of 30 degrees was selected. Imaging of 64 interpolated contiguous slices with half-k-space data acquisition in the phase-encoding direction took 20 to 28 seconds. With subvolume multiplanar reconstruction, MR scans and angiograms were evaluated for morphometric measurements for manufacturing the individualized endovascular prosthesis before stent implantation and for follow-up comparison.

**Implantation Technique**

Stent-graft placement was performed in a cardiac catheterization laboratory rigged for surgical conversion with patients under general anesthesia and ventilation. The procedure was begun by injecting 5000 U of heparin and introducing a 6F pigtail catheter (Cordis) through the left brachial artery for landmarking the subclavian artery and intraprocedural aortography. The femoral or distal iliac artery was surgically exposed to accommodate a protected 0.035-inch guide wire. With wire position confirmed by fluoroscopy and transesophageal ultrasound, the stent-graft sheath was introduced at blood pressure titrated to 50 mm Hg by intravenous sodium nitroprusside before unloading the stent-graft; with correct positioning of the endoprosthesis, cessation of flow and exclusion of the aneurysmal sac was documented by both color Doppler ultrasound and contrast aortography before removal of sheath and guide wire. The access site was closed by vascular microsurgery.

**Results**

**Procedural Success**

Transfemoral stent-graft deployment was uneventful and successful in all patients. Complete exclusion of the aneurysm and absence of endoleak was documented by transesophageal echocardiography and aortography. No patient required adjunctive procedures or a second stent. Initiation of thrombosis was seen in all patients, and none required blood transfusion or inotropic support; yet, 120±20 mL of contrast material was necessary and fluoroscopic examination lasted 9±3 minutes (range, 5 to 16 minutes). Recovery allowed ambulating at day 2 and discharge within 5 days.

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**Figure 1.** MRA before (A) and 16 months after stent-graft exclusion of aneurysm (B) late after surgical correction of aortic coarctation. Left subclavian artery is occluded without symptoms; aneurysm is completely thrombosed and shrunk.

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**Characteristics of Patients**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Gender/Age at Surgical Repair</th>
<th>Detailed Surgical Interventions</th>
<th>Follow-Up Interval After Surgery</th>
<th>Dimension of Aneurysm</th>
<th>Age at SG Implantation</th>
<th>Follow-Up Interval After SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F/13y</td>
<td>Patch aortoplasty</td>
<td>31 y</td>
<td>68 mm</td>
<td>44 y</td>
<td>47 mo</td>
</tr>
<tr>
<td>2</td>
<td>M/7 y</td>
<td>Patch aortoplasty</td>
<td>24 y</td>
<td>66 mm</td>
<td>31 y</td>
<td>16 mo</td>
</tr>
<tr>
<td>3</td>
<td>F/20y</td>
<td>Patch aortoplasty</td>
<td>27 y</td>
<td>65 mm</td>
<td>47 y</td>
<td>19 mo</td>
</tr>
<tr>
<td>4</td>
<td>M/42y</td>
<td>Patch aortoplasty</td>
<td>20 y</td>
<td>60 mm</td>
<td>62 y</td>
<td>11 mo</td>
</tr>
<tr>
<td>5</td>
<td>F/16y</td>
<td>Patch aortoplasty, root reconstr and ET for type I AD</td>
<td>24 y</td>
<td>60 mm</td>
<td>40 y</td>
<td>31 mo</td>
</tr>
<tr>
<td>6</td>
<td>F/52y</td>
<td>Patch aortoplasty, root reconstr and ET for type I AD</td>
<td>16 y</td>
<td>62 mm</td>
<td>68 y</td>
<td>11 mo</td>
</tr>
</tbody>
</table>

ET indicates elephant trunk; AD, aortic dissection; and SG, customized stent-graft.
Recurrent coarctation used to be the only late complication associated with surgical procedures are not uncommon, with aneurysm formation, stenosis, or occlusion of bypass grafts.10 However, relapse after coarctation repair and complications related to surgical procedures are not uncommon, with aneurysm formation, stenosis, or occlusion of bypass grafts. Recurrent coarctation used to be the only late complication amenable to interventional treatment in lieu of surgical graft interposition or end-to-end anastomosis; postsurgical aneurysm may quality next for interventional repair.

Secondary surgical repair of postsurgical complications in complex forms of coarctation has been associated with high mortality and morbidity; yet, optimal treatment is far from settled and in favor for palliative rather than corrective surgical repair because of considerable risk. Our encouraging results in 6 consecutive patients undergoing endovascular repair for post–patch-graft aortoplasty aneurysm suggest potential for a new nonsurgical option.3,11 The problem of postsurgical aneurysm formation has also been recognized after bypass grafting for long aortic coarctation and even after subclavian flap aortoplasty.12 Reoperation after previous patch-graft aortoplasty carries a 14% mortality rate and significant morbidity, including paralysis of the nerves recurrents and bleeding complications3,17; similarly, Kieffer et al18 found that open surgery for thoracic aneurysm in association with aberrant subclavian arteries is associated with a 23.5% mortality rate and a 13% paraplegia rate. Yet, conservative treatment of aneurysm after surgical coarctation repair remains unpredictable and is associated with a 100% rate of rupture within 15 years in the single-center experience of Knyshev et al.3

Our preliminary series demonstrates promising potential of endovascular stent-graft treatment in 6 patients with late aneurysm formation after complex surgical repair of coarctation (Figure 2, A and B). Transfemoral stent-graft deployment was safe and completed within 54±19 minutes in a multidisciplinary effort of an interventional cardiologist, a vascular surgeon for open femoral access, and anesthesiologist and led to favorable infrainterventional and postinterventional outcomes.9 Preservation of the integrity of the aorta by endovascular access rather than surgical resection has previously proven to protect spinal arteries and avoid neurological events.6

Considering the immediate vicinity of the aneurysm to the left subclavian artery, complete occlusion was necessary in 3 cases, followed by a postprocedural drop in ipsilateral systolic brachial pressure to 55 mm Hg, without any signs of malperfusion. Even at follow-up over 16 to 47 months,

**Figure 2.** MRA before (A) and 13 months after (B) stent-graft exclusion of aortic aneurysm forming late at the distal end of elephant trunk previously implanted as an adjunct to surgery for type I dissection some years after preceding initial coarctation surgery (patient 5). This patient had acute type I aortic dissection from an ectatic ascending aorta 6 years after initial patch aortoplasty for adult-type coarctation and underwent aortic root reconstruction with interposition grafting and adjunctive intraoperative placement of an elephant trunk sutured to the distal aortic arch. Local aneurysm developed at the site of coarctation repair despite the inlining coaxial distal end of the elephant trunk.

**Immediate and Long-Term Outcomes**

Both intraprocedural and postprocedural outcomes were uneventful. Monitoring transesophageal ultrasound revealed intensifying echodensity (thrombosis) within minutes of aneurysm exclusion and no persisting endoleak. Transient postimplantation syndrome with mild leukocytosis, elevated levels of C-reactive protein, and moderately elevated body temperature occurred in all patients; maximal C-reactive protein level was 148 mg/L, and leukocyte count was 11±9×10⁶/cm³ on day 3 but normalized thereafter. Spin-echo MRI and MR angiography at discharge, 3-month, and 1-year follow-up documented normal patency of stent-grafts and complete fibrotic remodeling of the aorta with retraction of the aneurysm (shrinkage). Neither migration nor twisting of the stent-graft nor any leakage was noted. To ensure full exclusion of the postsurgical aneurysm, the grafted part of three endoprosthesis was placed over the origin of the left subclavian artery and led to a 55% reduction in distal arterial pressure; interestingly, no patient had pain or notable symptoms of dysfunction or fatigue (Figure 1, A and B). Distal left arm arterial pressure was unchanged in 3 patients. Individual follow-up is summarized in the Table; 1 patient died 11 months after stent-graft implantation from colorectal cancer, whereas all others enjoy an active, unrestricted life.

**Discussion**

Adult-type coarctation usually requires surgical resection of the abnormal aortic segment either by end-to-end anastomosis, subclavian flap aortoplasty, or patch graft aortoplasty, using synthetic material or autologous arterial wall.7–9 However, relapse after coarctation repair and complications related to surgical procedures are not uncommon, with aneurysm formation, stenosis, or occlusion of bypass grafts.10–12 Recurrent coarctation used to be the only late complication amenable to interventional treatment in lieu of surgical graft interposition or end-to-end anastomosis; postsurgical aneurysm may quality next for interventional repair.
neither symptoms nor functional deficits nor differences in temperature were noted, lending credence to the notion that secondary transposition of the left subclavian artery is rarely necessary.20 Although conceptually promising, treatment by custom-made stent-grafts requires the support of long-term follow-up data. On the other hand, over several years of follow-up after stent-graft placement for the treatment of both thoracic and abdominal aneurysms, late adverse effects were infrequent, justifying the use of stent-grafts in younger patients after coarctation surgery.6,19,20

Finally, the custom design of each stent-graft currently limits the concept to patients undergoing elective procedures. In addition, sophisticated imaging techniques are required for planning and executing such delicate procedures. Given these prerequisites, placement of customized stent-grafts may be a promising nonsurgical strategy offered in specialized centers to avoid complicated secondary or tertiary aortic surgery.

References
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