Stent grafting for aneurysmal degeneration of chronic descending thoracic aortic dissections

Derek P. Nathan, MD,a Edward Y. Woo, MD,b Ronald M. Fairman, MD,b Grace J. Wang, MD,b Alberto Pochettino, MD,c Nimesh D. Desai, MD,c Joseph E. Bavaria, MD,e and Benjamin M. Jackson, MD,b Philadelphia, Pa

Objective: The objective of this study was to examine the results of thoracic endovascular aneurysm repair (TEVAR) for chronic descending thoracic aortic (DTA) dissections with aneurysmal degeneration.

Methods: Over 70 months at a single institution, 27 patients underwent TEVAR for aneurysms related to chronic (>6 weeks) DTA dissections.

Results: Mean patient age was 67.5 ± 9.6 years; 18 were men. Primary indications for repair were aneurysm size (n = 20), rapid aneurysmal growth (n = 5), saccular aneurysm (n = 1), and rupture (n = 1). Preoperative false lumen status was patent in 18 patients, partially thrombosed in 8 patients, and unknown in the patient whose aneurysm ruptured. The proximal entry tear was covered in all 27 patients. Fourteen patients required coverage of the left subclavian artery, of which 9 patients underwent prophylactic revascularization. On completion angiogram, no patient had antegrade perfusion of the aneurysmal false lumen. There were three procedural complications: 2 patients sustained paraparesis (one resolved and one improved), and 1 patient had an access injury requiring stent graft placement. Thirty-day mortality was 3.7% (1 of 27); the one death was in the patient whose aneurysm ruptured. Of the 26 surviving patients, 23 (88.5%) had thrombosis of the aneurysmal false lumen. Twenty-two patients (84.6%) had stability or decrease in maximal aneurysm diameter on last radiographic follow-up at 18 ± 20 months. Three-year Kaplan-Meier survival was 90.3% ± 6.5% in the 26 patients who survived to hospital discharge, with a mean follow-up of 27.3 ± 22.1 months. In patients with preoperatively partially thrombosed false lumens (n = 8), 3-year survival was 100%.

Conclusions: TEVAR for aneurysms due to chronic dissections of the DTA can be performed safely and effectively at midterm follow-up according to this single-institution study. Stent graft therapy may be of particular benefit in patients presenting with partially thrombosed false lumens. (J Vasc Surg 2012;55:963-7.)
Table I. Indications for TEVAR at the Hospital of the University of Pennsylvania

<table>
<thead>
<tr>
<th>Indication</th>
<th>N (%)</th>
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<tbody>
<tr>
<td>Bland aneurysmal disease</td>
<td>281 (54.8)</td>
</tr>
<tr>
<td>Complicated acute aortic syndrome</td>
<td></td>
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<tr>
<td>(aortic dissection, intramural hematoma, or penetrating atherosclerotic ulcer)</td>
<td>87 (17.0)</td>
</tr>
<tr>
<td>Prophylactic antegrade placement during type A dissection repair</td>
<td>53 (10.3)</td>
</tr>
<tr>
<td>Traumatic aortic dissection</td>
<td>31 (6.0)</td>
</tr>
<tr>
<td>Chronic type B dissection with aneurysmal degeneration</td>
<td>27 (5.3)</td>
</tr>
<tr>
<td>Other</td>
<td>34 (6.6)</td>
</tr>
</tbody>
</table>

TEVAR, Thoracic endovascular aneurysm repair.

search Ethics Committee, and the need for informed consent from the patients was waived.

Procedures. Intravascular ultrasound scan was used selectively (n = 10) to verify true lumen access, as was cerebrospinal fluid drainage (n = 12), which was used based on the planned extent of aortic coverage and previous aortic surgery. Monitoring of spinal cord function with somatosensory-evoked potentials and cerebral perfusion with electroencephalogram were used in all elective cases, and in nonelective cases when available. The Gore TAG endografts (W. L. Gore and Associates, Flagstaff, Ariz) were used in 21 patients, the Zenith TX2 endografts (Cook Medical Incorporated, Bloomington, Ind) were used in three patients, and the Medtronic Talent endografts (Medtronic, Santa Rosa, Calif) were used in three patients. Device sizing was performed according to the primary goal of sealing the primary entry tear; the aorta is generally undissected proximal to this tear, so device sizing was done according to the appropriate device instructions for use.

Statistical analysis. Primary outcome variables were midterm outcomes and procedural outcomes. Procedural outcomes included 30-day mortality and major complications. Midterm outcomes included 3-year survival and status of the aneurysmal false lumen on last radiographic follow-up. Aneurysm sac enlargement (>5 mm), regression (>5 mm), and stability (no significant change in sac diameter) were defined according to the Society for Vascular Surgery reporting standards. Typically, patients underwent computed tomographic angiography at 1 month, 6 months, and 1 year postprocedure, and then annually. Disease-related (dissection extent above or below diaphragm, interval between dissection, diagnosis, and treatment, history of ascending aortic dissection repair, preoperative false lumen status, and number of visceral and renal vessels perfused by the true lumen) and treatment-related (left subclavian artery coverage and extent of aortic coverage) variables were assessed for their influence on the primary outcomes using Pearson χ² test, t test, and Mann-Whitney U test, as appropriate. Patient follow-up information was collected through the interrogation of medical records, the Social Security Database Index, and telephone interviews. Long-term survival was determined with the Kaplan-Meier life-table methods. Log rank tests were used to compare life-table curves for categorical variables. Cox proportional hazards were also used to evaluate the effects of continuous variables on long-term mortality. Statistical analyses were performed with SPSS software (SPSS, Chicago, Ill). Data are presented in mean ± SD.

RESULTS

Patient and dissection characteristics. The mean age of the patients was 67.5 ± 9.6 years. The interval from diagnosis of aortic dissection to TEVAR was 47.0 ± 44.2 months. Nine patients (33.3%) had previous type A dissection repairs; of those, three patients (11.1%) had previous total arch replacements. Patient demographics are presented in Table II.

Table II. Patient demographics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N (%)</th>
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<tbody>
<tr>
<td>Mean age</td>
<td>67.5 ± 9.6 yrs</td>
</tr>
<tr>
<td>Men</td>
<td>18 (66.7%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>27 (100%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>3 (11.1%)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>4 (14.8%)</td>
</tr>
<tr>
<td>COPD</td>
<td>7 (25.9%)</td>
</tr>
<tr>
<td>Chronic renal insufficiency</td>
<td>5 (11.1%)</td>
</tr>
</tbody>
</table>

COPD, Chronic obstructive pulmonary disease.

<insert data from Table II here>

The mean maximum DTA aneurysm diameter was 6.1 ± 1.1 cm. The preoperative false lumen status of the patients was patent in 18 patients and partially thrombosed in eight patients (Fig 1). The false lumen status of the patient with the rupture was unknown.

Ten patients (37.0%) had DeBakey extent IIIa dissections. Of the 17 patients with extent IIIb dissections, seven had all four renal and visceral vessels perfused by the true lumen, seven had three vessels perfused by the true lumen, and three had two vessels perfused by the true lumen. The left renal artery was the vessel most commonly supplied by the false lumen (n = 7).

Operative details. Three patients (11.1%) required access of the right common iliac artery through a retroperitoneal incision due to inadequate size of the common femoral arteries. Fourteen patients (51.9%) required coverage of the left subclavian artery in order to cover the entry tear or achieve a proximal seal and nine patients underwent prophylactic revascularization with left carotid-subclavian bypass. The celiac axis was partially covered in one patient in order to cover a distal fenestration just proximal to the visceral segment, and completely covered in one patient in order to obtain a seal distal to the aneurysmal true lumen.

The mean extent of thoracic aortic coverage was 22.1 ± 4.3 cm. Seventeen patients (63.0%) had stent graft coverage from the left subclavian artery to the celiac axis; and 10 patients (25.9%) had coverage from the left subclavian artery to the mid-descending thoracic aorta. All 27 patients had coverage of the proximal entry tear; no patient had...
antegrade perfusion of the false lumen on completion intraprocedural angiogram. Two patients underwent nonelective repair due to rupture (n = 1) and symptomatic aneurysm (n = 1), respectively. One patient required intraprocedural femoral-femoral bypass because the left iliac artery arose from the false lumen and all fenestrations were covered in the descending thoracic aorta.

**Procedural outcomes.** Thirty-day mortality was 3.7% (one of 27). In-hospital mortality was the same. The single death occurred in the ruptured patient; therefore, 30-day mortality in nonruptured patients was 0% (0 of 26). There were three major complications (11.1%). Two patients developed paraparesis (motor weakness in the lower extremities): one of whom had complete recovery of neurologic function, and the other who improved but did not recover completely. There was one access injury of an iliac artery, which required stent graft placement. No patient sustained stroke, paraplegia (complete loss of motor strength), renal failure requiring new dialysis, or retrograde acute type A aortic dissection after stent graft implantation. Mean postoperative length of stay was 6.9 ± 3.0 days. No factor predicted 30-day mortality or major complication.

**Midterm outcomes.** Three-year survival in the 26 patients who survived to hospital discharge was 90.3% ± 6.5% (Fig 2). No patient was lost to follow-up, and mean duration of follow-up was 27.3 ± 22.1 months. There were three late deaths due to unknown causes. No factor predicted decreased 5-year survival.

All 26 patients who survived to hospital discharge had follow-up imaging, the mean duration of which was 18 ± 20 months. Of these 26 patients, 23 (88.5%) had thrombosis of the aneurysmal false lumen. Of the 23 patients who eventually had false lumen thrombosis, two patients had persistent perfusion of the aneurysmal false lumen through the left subclavian artery and were successfully treated with coil embolization. The three patients (three of 26) who failed to thrombose the aneurysmal false lumens had retrograde perfusion of the false lumen; one of these patients also suffered aneurysmal enlargement.

Twenty-two of the 26 patients (84.6%) who survived to hospital discharge had shrinkage or stability of the aneurysmal false lumen: 14 exhibited stability and 8 demonstrated shrinkage. Of the four patients who had growth of their aneurysms, one had radiographic evidence of aneurysmal false lumen perfusion. No factor predicted aneurysmal false lumen thrombosis or aneurysm growth. Follow-up outcomes by preoperative false lumen status are presented in Table III.

**DISCUSSION**

This experience with the treatment of chronic type B dissections with aneurysmal degeneration using TEVAR reflects an evolution in the operative therapy of the disease. The overall 90% 3-year survival in patients leaving the operating room compares well both to patients treated medically for type B dissection and to the results of open repair for aneurysmal type B dissections.

The intermediate outcomes achieved with TEVAR of chronic type B dissections with aneurysmal degeneration compare favorably with the results of medical management. Tsai et al12 examined 201 patients with acute type B aortic dissections who survived to hospital discharge and found a 5-year mortality rate of 24.9%; in particular, patients with partially thrombosed false lumens fared the worst with a 5-year mortality of 31.6%. Further subanalysis of the 146 patients who did not receive surgery or endovascular ther-
Table III. Outcomes following TEVAR for aneurysmal degeneration of chronic descending thoracic aortic dissections by preoperative false lumen status (n = 26)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Patient (n = 26)</th>
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<tbody>
<tr>
<td></td>
<td>Extent IIIa (n = 6)</td>
</tr>
<tr>
<td>Aneurysm sac thrombosis</td>
<td>6 (100%)</td>
</tr>
<tr>
<td>Aneurysm sac stability or shrinkage</td>
<td>4 (66.7%)</td>
</tr>
<tr>
<td>3-yr survival</td>
<td>75%</td>
</tr>
</tbody>
</table>

*TEVAR, Thoracic endovascular aneurysm repair.*

apy in that study still revealed that partial thrombosis of the false lumen was a significant predictor of postdischarge mortality. Given the sobering outcomes of patients with chronic type B dissections, the Investigation of Stent Grafts in Aortic Dissection (INSTEAD) trial\textsuperscript{13} randomized patients with uncomplicated chronic type B dissections to optimal medical management or elective stent graft placement plus optimal medical management. Two-year survival in the optimal medical therapy group was 95.6%, and in the stent graft group it was 88.9%.

Before the introduction of thoracic stent graft devices, the only option for repair was open thoracoabdominal surgery of extent I or II thoracoabdominal aortic aneurysms. The morbidity and mortality rates in these open surgeries are not insignificant. In a large series of 104 patients with chronic distal aortic dissection who underwent surgical repair, Zoli et al\textsuperscript{7} reported spinal cord injury and stroke rates of 5%, and 30-day and 1-year mortality rates of 10% and 22%, respectively. In another series of 148 patients with DTA aneurysms, in whom half had aneurysms due to chronic DTA dissections, the spinal cord ischemia rate was 3% and the 30-day mortality rate was 9%.\textsuperscript{8}

Although there are few series of TEVAR for aneurysmal degeneration of chronic type B dissections reported in the literature, intermediate outcomes demonstrate favorable results. Parsa et al\textsuperscript{5} assessed TEVAR for the management of aneurysms related to chronic type B dissection in 51 patients and reported no strokes, permanent spinal cord injuries, or in-hospital deaths; 5-year survival in this study was 78%. Meanwhile, Rodriguez et al\textsuperscript{11} examined the use of stent grafts to treat 106 patients with acute and chronic DTA dissections at the Arizona Heart Institute and reported a spinal cord injury rate of 4% and a 30-day mortality rate of 8%. The Arizona authors found that chronic dissections limited to the thoracic aorta were more likely to undergo false lumen thrombosis. Last, Czerney et al\textsuperscript{15} examined the results of TEVAR in 14 patients with aneurysms involving the descending aorta originating from chronic type B dissections: two patients (14%) had type 1 proximal endoleaks at early follow-up; however, the authors did not provide rigorous survival statistics.

A Chinese group recently reported on 84 patients undergoing TEVAR for chronic type B dissection,\textsuperscript{16} but they did not report the indication for repair in their cohort, and their practice is “to treat all patients with chronic type B dissection with a patent false lumen.” That practice is in stark contrast to ours, which is to treat only symptomatic or aneurysmal type B dissections. With regard to reintervention in particular, Manning et al\textsuperscript{17} reported that six of 10 patients having undergone TEVAR for chronic type B dissection with false lumen aneurysms required reoperation (most often distal extension of stent grafts) at a mean follow-up (all patients) of 56 months. Our experience compares favorably to that one: two patients (7.4%) required subsequent adjunctive endovascular procedures to treat type 2 endoleaks (both from patent left subclavian arteries).

The approach to aneurysmal degeneration of chronic type B dissections in this series includes coverage of the proximal entry tear and of all distal fenestrations within the descending thoracic aorta. More distal fenestrations were not addressed, and the results of this series justify observation of the patent false lumen in cases of continued nonaneurysmal false lumen perfusion. In cases of planned left subclavian coverage, patients underwent prior carotid-to-subclavian bypass and then coil embolization of the proximal left subclavian at the time of TEVAR.\textsuperscript{18}

Based on the current experience and prior clinical and investigational studies, the authors feel that coverage of the proximal entry tear is mandatory and often sufficient in cases of chronic type B dissection with aneurysmal degeneration in order to achieve thrombosis of the aneurysmal false lumen. This agrees with the results and recommendations of Rodriguez et al\textsuperscript{11} in their study of TEVAR for acute and chronic type B dissection. In the current series, coverage of the proximal entry tear required coverage of the left subclavian 51.9% of the time.

Parsa et al\textsuperscript{5} evaluated the retrograde pressurization of the false lumen via distal fenestrations after stent graft placement by placing pressure measurement systems in the false lumen at the time of surgery, and found that the ratio of false lumen aneurysm sac pressure to systemic arterial pressure decreased, suggesting that persistent retrograde false lumen perfusion is clinically insignificant. Meanwhile, Karmonik et al\textsuperscript{19} performed computational fluid dynamics using magnetic resonance images of a patient with an extent III DeBakey dissection, and found that the false lumen pressure decreased essentially to zero with coverage...
of the proximal entry tear only. Finally, Tsai et al.20 examined the impact of tear location on false lumen pressure in an ex vivo model of chronic type B aortic dissections with an entry and exit tear, and reported that proximal entry tear coverage resulted in a significant decrease in false lumen pressurization.

While the INSTEAD trial13 failed to detect a benefit to prophylactic TEVAR in chronic type B aortic dissection, the current results, along with those of Parsa et al5 and Rodriguez et al.,11 provide compelling support for the use of TEVAR to treat aneurysmal degeneration of chronic type B dissections to prevent rupture. Given that four of 26 patients in this cohort suffered enlargement of their aneurysm sacs, and that three of 26 patients had continued perfusion of their aneurysmal false lumens, serial imaging at regular intervals is essential in the follow-up of patients with aneurysms treated with TEVAR.

CONCLUSIONS

TEVAR for aneurysms due to chronic dissections of the DTA can be performed safely and effectively, as assessed at midterm follow-up. Our approach involves mandatory coverage of the proximal entry tear. Although this is a small single-institution study, patients presenting with partially thrombosed false lumens may benefit disproportionately from endovascular repair, given their increased dissection-related mortality relative to other anatomies.

AUTHOR CONTRIBUTIONS

Conception and design: DN, RF, BJ
Analysis and interpretation: DN, EW, RF, GW, AP, ND, JB, BJ
Data collection: DN
Writing the article: DN, EW, BJ
Critical revision of the article: RF, GW, AP, ND, JB, BJ
Statistical analysis: DN, BJ
Obtained funding: Not applicable
Overall responsibility: BJ

REFERENCES


Submitted Aug 18, 2011; accepted Nov 1, 2011.