Initial experience in the treatment of thoracic aortic aneurysmal disease with a thoracic aortic endograft at Baylor University Medical Center

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A retrospective review of 27 patients who underwent endovascular repair of thoracic aneurysms and of other thoracic aortic pathology with the thoracic aortic endograft (Gore Medical, Flagstaff, AZ) from June 2005 to July 2007 was performed. The mean follow-up period was 13.5 months (range, 2–25 months). Indications for thoracic endografting included descending thoracic aneurysms (n = 18), thoracoabdominal aneurysms (n = 3), traumatic aortic injuries (n = 3), penetrating aortic ulcers (n = 2), and contained rupture of a type B dissection (n = 1). One patient died during the procedure, for an overall mortality rate of 3.7%. The average length of stay was 8.1 days, with an average stay in the intensive care unit of 4.2 days. If patients with traumatic aortic injuries were excluded, the average overall and intensive care unit length of stay were 5.6 and 1.8 days, respectively. There was one incident of spinal cord ischemia (3.7%). There were five type I or type III endoleaks, three of which required revision (11.1%). In conclusion, thoracic endografting is a safe and viable option for the repair of descending thoracic aneurysms and other aortic pathologies. We have found it to be less invasive, even in conjunction with preoperative debranching procedures, with a shorter recovery time, decreased perioperative morbidity and blood loss, and decreased perioperative mortality compared with standard open repair.

Endovascular repair of thoracic aortic pathology has demonstrated lower morbidity and mortality than open surgery in this group of patients who typically have multiple comorbidities (1, 2). Open surgery on the thoracic aorta presents several challenges, including the morbidities often associated with cardiopulmonary bypass or circulatory arrest, spinal cord ischemia, renal insufficiency, postoperative pneumonia, and the morbidity of a thoracotomy incision. In recent years, the method of endovascular deployment and the stent-graft design have continued to improve. As a result, the number of problems from access-site complications and endoleaks has continued to decrease.

The TAG endograft was approved by the Food and Drug Administration to treat aneurysms of the descending thoracic aorta and has traditionally been used for that purpose (3). We have used the TAG device since 2005 for this indication and for several off-label indications, including traumatic aortic injury, penetrating aortic ulcers, and thoracoabdominal aneurysms. Several of the aneurysms have originated proximal to the left subclavian artery. This report summarizes our experience with the TAG thoracic endograft and its use in various types of pathology in the thoracic aorta. We also describe alternative access routes for complex aneurysms of the aortic arch. Morbidity, mortality, length of stay, and technical challenges are reviewed.

PATIENTS AND METHODS

Data from patients undergoing thoracic endografting from June 2005 to July 2007 were reviewed, using operative notes, medical records during hospitalization, and clinic notes during follow-up. The institutional review board at Baylor University Medical Center approved this retrospective study.

Patients considered for thoracic aortic stent grafts were evaluated preoperatively as a team approach by a vascular surgeon, a thoracic surgeon, and an anesthesiologist, and their suitability and appropriateness for intervention were determined. The aortic graft was sized by computed tomographic angiography (CTA) with three-dimensional reconstruction and in some cases by intravascular ultrasound.

Once suitability for intervention was determined, the procedures were performed in a dedicated endovascular suite or in an operative suite with angiographic capability using a C-arm in emergency cases. Preoperative spinal drains were placed in patients with the following risk factors for spinal cord ischemia: planned coverage of spinal levels T8–L1, prior aortic aneurysm repair, or planned coverage of the descending thoracic aorta over 20 cm. Spinal drains were managed to keep the cerebrospinal fluid pressure <10 cm of water. Heparin was given during the procedures to maintain an activated clotting time >250 seconds.

Exposure for deployment of the graft was via femoral cutdown, iliac or aortic conduit, or median sternotomy in the case of transverse arch aneurysm. The spinal drains were left in place for 24 to 48 hours postoperatively and were usually removed

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Table 1. Patient demographics and medical comorbidities

Variable	Mean ± SD (N = 27 patients)
Age (years)	72 ± 13
Men	17 (63%)
Coronary artery disease	15 (56%)
Chronic obstructive pulmonary disease	12 (44%)
Diabetes	3 (11%)
Hypertension	11 (41%)
Heart failure	3 (11%)
Prior abdominal aortic aneurysm repair	4 (15%)
Urgent operation	3 (11%)
Elective operation	24 (89%)
Preoperative subclavian transposition or bypass	7 (26%)
Average aneurysm size (cm)	5.6 ± 1.4

Table 2. Procedural data on thoracic endografts

Variable	All patients (n = 27)	DTA (n = 18)	TAA (n = 3)	TAI (n = 3)	PAU (n =2)	AD (n = 1)
Mortality: 30 day or in-hospital (n)	1	0	1	0	0	0
Median length of stay (days)	6	5	7	30	7.5	6
Median intensive care unit stay (days)	1	1	4	16	1	1
Mean estimated blood loss (cc)	817	422	1800	417	200	300
Mean fluids (cc)	1935	2211	3267	1100	1850	1300
Patients with cerebrospinal fluid drain (n)	15	11	3	0	0	1

DTA indicates descending thoracic aneurysm; TAA, thoracoabdominal aneurysm; TAI, traumatic aortic injury; PAU, penetrating aortic ulcer; AD, aortic dissection (rupture of a type B dissection).

upon transfer to the floor from the intensive care unit (ICU). Postoperative blood pressure management was maintained to keep the mean arterial pressure >80 mm Hg. If the patient developed any signs of lower-extremity neurologic dysfunction, the cerebrospinal fluid was immediately drained until symptoms resolved.

Postoperative chest x-rays were obtained daily until discharge, with a postoperative CTA performed prior to discharge if clinically indicated based on intraoperative findings. A four-view chest x-ray was obtained before discharge to assess graft stability and to use for comparison during later follow-up. Clinical follow-up occurred at 1, 3, 6, 12, and 18 months postoperatively and then yearly thereafter; CTAs were obtained to assess for endoleak at all follow-up visits except the 3-month visit.

RESULTS

Since June 2005, we have placed 27 thoracic endografts: 18 for descending thoracic aneurysm (67%), 3 for thoracoabdominal aneurysm (11%), 3 for traumatic aortic injury (11%), 2 for penetrating aortic ulcers (7%), and 1 for contained rupture of a type B dissection (4%). Two of the descending thoracic aneurysms originated at an aberrant right subclavian artery. The average length of stay (LOS) was 8.1 days, with an average ICU stay of 4.2 days. Excluding patients treated for traumatic aortic injury, the average hospital and ICU LOS were 5.6 and 1.8 days, respectively. The mean follow-up period for our patients was 13.5 months (range, 2–25 months). *Table 1* summarizes the patient demographics.

Procedural success was defined as deployment of a thoracic endograft and exclusion of the thoracic pathology. Initial procedural success was achieved in 26 of 27 patients (96%) and after revision during the same hospitalization in one patient, in all 27 patients (100%). A total of 47 grafts were deployed, with a mean of 1.7 grafts per patient.

Overall, five patients (19%) developed endoleaks postoperatively: four were type I (i.e., blood flow due to an inadequate seal at one or more of the graft endpoints), and one was type III (i.e., blood flow due to graft defect, porosity, or failure). Four of the endoleaks occurred in descending thoracic aneurysms, while one occurred in a young trauma patient with an aortic injury. This young patient underwent repair of a traumatic aortic injury and was noted on postoperative evaluation to have a narrowing of the proximal aortic endograft with a type I leak requiring a second endograft to be placed more proximally. Two additional patients required endovascular revision, and the endoleaks have subsequently resolved. One of the type I endoleaks present at the completion of a descending thoracic aneurysm was not present on follow-up CTA at 1 month and did not require treatment. One other small type I leak is currently being observed; the aneurysmal size has not increased in this patient.

Routine femoral exposure was possible in 11 patients (41%), and retroperitoneal iliac exposure was used in 13 patients (48%). One iliac conduit was used. In one patient, access was achieved via median sternotomy and antegrade deployment using a side-branch conduit off of a 14 × 7–mm bifurcated Dacron graft. A third conduit limb was created using a separate 10-mm graft. This was a transverse arch aneurysm, and complete supra-aortic debranching was utilized. One 10-mm Dacron aortic conduit was used in a patient with an infrarenal aortic occlusion. This conduit then became one part of an aortobifemoral bypass at the completion of the procedure. Procedural details are summarized in *Table 2*.

The left subclavian artery was purposely covered in eight patients; six of these had subclavian revascularization via carotid-subclavian bypass (n = 4) or subclavian transposition (n = 2) prior to endograft placement. Perfusion of the posterior circulation with a patent right vertebral artery was confirmed by

Table 3. Perioperative complications

Morbidity	N (%)
Major	
Spinal cord ischemia	1 (4%)
Access complications	2 (7%)
Pulmonary embolism	1 (4%)
Ischemic colitis	1 (4%)
Minor	
Pulmonary effusions	2 (7%)
Atrial fibrillation	1 (4%)
Postoperative ileus	1 (4%)
Wound dehiscence	1 (4%)
Wound hematoma	2 (7%)

catheter-based angiography preoperatively in all patients. There was one incident of postoperative left-upper-extremity ischemia as evidenced by monophasic finger pressures and clinical symptoms of claudication. This patient refused carotid-subclavian bypass and has continued to do well with symptoms of claudication only. There was no evidence of posterior circulatory stroke after coverage of the left subclavian artery in any patient.

Postoperative and intraoperative complications occurred in 11 patients (41%), with two major complications occurring in a single patient. Five complications were classified as major and seven as minor *(Table 3).* There was one episode of spinal cord ischemia and ischemic colitis in a thoracoabdominal aneurysm patient. This patient had a prior remote infrarenal aortic aneurysm repair, complete visceral debranching, and intraoperative/postoperative hypotension from significant intraoperative blood loss due to avulsion of the left renal artery during debranching. He eventually died of multisystem organ failure and was the only patient who died within 30 days of the procedure. Two left common iliac artery dissections were treated at the time of surgery (one with endovascular stenting and one with operative bypass). The remaining patients with complications as outlined in Table 3 were treated medically, with no further surgical procedures required.

DISCUSSION

Thoracic endograft placement has proven to be a safe and effective treatment for thoracic aortic pathology (4). Our experience includes a fairly diverse amount of pathology, including traumatic aortic injuries, penetrating aortic ulcers, and an aneurysm of the transverse arch. We have found that a systematic approach to preoperative evaluation and perioperative care has assisted in reducing the morbidity of the procedure compared with standard open surgical repair. The overall morbidity rate in our patients was 41% in the immediate postoperative period, with one episode of spinal cord ischemia. This number includes both major and minor complications such as wound hematomas and pulmonary effusions.

Our mortality rate of 4% and our morbidity rate compare more than favorably with the most recent series of open thoracoabdominal aneurysm repair (5). Estrera et al reported a mortality rate of 7.3% in a series of 300 patients with and without the use of distal aortic perfusion. Their neurologic event rate (spinal cord ischemia) was 6.5% in patients repaired without distal aortic perfusion and cerebrospinal fluid drainage and 1.3% in patients repaired with the above adjuncts.

Risk factors for spinal cord ischemia identified in our patient population included the presence of prior abdominal aortic aneurysm repair and coverage of the entire descending thoracic aorta (6). The one patient in our series with postoperative paraplegia had multiple risk factors for spinal ischemia, including a prior abdominal aortic aneurysm repair and a large area of thoracic aortic coverage. Although immediately postoperatively the patient was moving all extremities, when postoperative hypotension ensued secondary to ischemic colitis the patient became paraplegic. We do not routinely perform spinal cord drainage unless risk factors are present or the area of coverage involves spinal levels T8 to L1. Though spinal cord protection protocols differ, we usually remove the drains upon transfer from the ICU. Spinal cord ischemia rates vary in endovascular thoracoabdominal aneurysm repair, from 0 to 2.9%, with many episodes completely resolving after spinal cord drainage and blood pressure augmentation (7).

In contrast to many other series, our need for iliac conduit was minimal. Historically, iliac conduits have been used in up to 15% of patients (1, 3). If the femoral vessel was deemed too small in diameter, we either directly exposed the iliac artery and gained access via direct puncture or chose access routes by direct puncture of the infrarenal aorta. We used an iliac conduit in only one patient. There were two complications after iliac exposure: one arterial disruption from the large sheath and one dissection. The arterial disruption was repaired at the end of the procedure with an iliofemoral bypass, and the dissection was repaired with iliac stent placement. We had no complications from femoral exposure.

In two cases, we used alternative access routes. An aortic conduit was used in a man with a thoracic aneurysm and an occluded aorta so that an aortobifemoral bypass could be performed at the completion of the thoracic stent graft deployment. Our other patient had a transverse arch aneurysm that was repaired using antegrade deployment. We used a 10-mm aortic side-branch conduit off of an aorto-innominate/aortocarotid bypass graft. The 10-mm conduit was ligated at the completion of the procedure. This patient required a preoperative left subclavian transposition and complete supraortic debranching as described above. We chose this alternative method due to the high morbidity of standard arch repair in this patient.

Saleh et al reported on 15 patients with transverse arch aneurysms who underwent supraortic debranching and thoracic endograft placement (8). In that series, the procedure was performed in two stages, with the first stage being supraortic debranching and the second being the deployment of the endograft via an iliac or femoral exposure. We chose to complete our procedure in one stage using a trifurcated graft, one limb of which was used for antegrade deployment of the endograft. We also used ascending aortic banding using a circumferential wrap of Dacron in order to improve the stability of the landing zone and prevent future expansion. Antona et al described this technique in 2007 (9).

Our endoleak rate of 19% compares favorably with that of other authors (1–3). Five endoleaks were noted, four type I and one type III. Three of these (two type I and one type III) eventually required revision. Although we recommend repair of a type I endoleak if detected, we occasionally observe small type I endoleaks on a case-by-case basis. One patient in our series has a type I endoleak that is currently under surveillance with a stable aneurysm size. One of our trauma patients had a major type I leak several days after implantation that required a second graft to be deployed inside the first. This patient was a young trauma patient who developed functional coarctation postoperatively due to his small aortic size and the curvature of his aorta. We have since agreed with other authors and try to manage aortic tears in young patients with abdominal aortic cuffs, due to their enhanced flexibility. Hopefully, as technology continues to progress, a device will become available for these patients with smaller-diameter thoracic aortas rather than having to rely on using multiple "stacked" cuffs.

Thoracoabdominal aneurysms continue to be the most difficult aneurysms to treat, whether open or endovascular routes are chosen. Operative mortality still approaches 20% in recent reports (10). Visceral debranching and subsequent endograft placement have resulted in decreased mortality rates, with a recent mortality rate reported as zero in one series (11). We utilized visceral debranching in one patient who had a large type III thoracoabdominal aneurysm. Unfortunately, the patient had significant intraoperative blood loss due to renal artery avulsion. This patient developed multiorgan failure after surgery despite successful graft deployment. This was our only death. Two of the patients with type III thoracoabdominal aneurysms required only repair of their descending thoracic aorta and did not require visceral debranching. We feel that the hybrid treatment of these complex aneurysms will continue to improve and that the visceral debranching technique avoids the morbidity of high-aortic cross-clamping and two-cavity incisions. In a series of 29 patients, Black and colleagues reported a mortality rate of 6% in elective and urgent patients and no postoperative paraplegia (12).

Coverage of the left subclavian artery is not an infrequent requirement for an optimal proximal landing zone in proximal thoracic aortic endografting. There are several ways to manage coverage of the left subclavian, including coverage without revascularization, preoperative revascularization via subclavian artery transposition, or carotid-subclavian bypass. Peterson and colleagues warned against coverage without revascularization, as they had a 63% complication rate in patients who did not undergo revascularization (13). Four of the eight patients who experienced complications had strokes, one leading to subsequent death. They stressed the importance of confirming the patency of the right vertebral artery before blind coverage of the left subclavian artery and revascularization in patients who required coverage of a large number of intercostals. Revascularization is done in this case to provide collaterals via the ipsilateral vertebral artery to the artery of Adamkiewicz. In our series, we did not revascularize two subclavian arteries, and one of these patients presented later with left-upper-extremity ischemia with symptoms of claudication but refused revascularization. Though intentional coverage of the left subclavian is proposed by some authors (14), we continue to advocate revascularization when possible via transposition or bypass, especially if a long thoracic segment is planned for coverage. We prefer transposition due to the superior patency and the absence of prosthetic if possible.

CONCLUSION

Our initial experience with thoracic endografting at Baylor University Medical Center includes a broad selection of patients with thoracic aortic pathology. Our morbidity and mortality rates seem to be consistent with other series, and our lessons learned have centered on access difficulties and the management of difficult proximal landing zones as well as proper patient selection and planning. In addition, this treatment method has offered our patients a less painful postoperative course compared with open surgical repair as well as a shorter ICU/hospital stay and a faster recovery to normal daily activity. We believe that left subclavian artery revascularization is ideal before elective cases and that advances will continue to be made in visceral and supraortic debranching, expanding the treatment options for thoracoabdominal and transverse arch aneurysms. Protocol-driven postoperative care, extensive endovascular experience, and thorough preoperative imaging and planning with a multidisciplinary approach continue to improve the outcome of these challenging patients. In contrast with open aortic repair, endografting requires long-term follow-up with appropriate radiologic imaging to ensure the long-term durability of this new treatment option for thoracic aortic disease.

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