IV

MANAGEMENT OF THORACIC AND ABDOMINAL AORTIC DISEASE

Debranching Procedures for Thoracoabdominal Aortic Aneurysms

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The repair of extensive thoracoabdominal aortic aneurysms remains a formidable challenge to vascular surgeons. Despite significant advances in surgical technique and perioperative critical care, the traditional open repair, even in the best centers in the world, is still associated with a high morbidity and mortality.

Thoracic stent-grafting is limited to the descending thoracic aorta by either the arch vessels proximally or the visceral and renal vessels distally. However, by first revascularising and/or debranching these vessels, one can subsequently complete aneurysm exclusion by thoracoabdominal aortic endo-grafting. The less invasive nature of these hybrids represents a viable treatment alternative to those patients that may have previously been declined an open procedure due to advanced age or comorbidities.

As endovascular techniques and technology are constantly improving and evolving, the full impact of fenestrated stents and branched grafts on TAAA repair is yet to be realized. However, in the absence of an elegant wholly endovascular approach, hybrid surgery will remain a robust and adaptable method of treating this complex and life-threatening disease process, particularly in high-risk individuals.

Thoracoabdominal aortic aneurysms (TAAA) are defined by the involvement of the origins of the coeliac, superior mesenteric, and renal arteries. Crawford's classification is universally accepted[1] (Figure 13–1), although Safi subsequently added a fifth class of TAAA in his version of the classification system[2] (Figure 13–2).

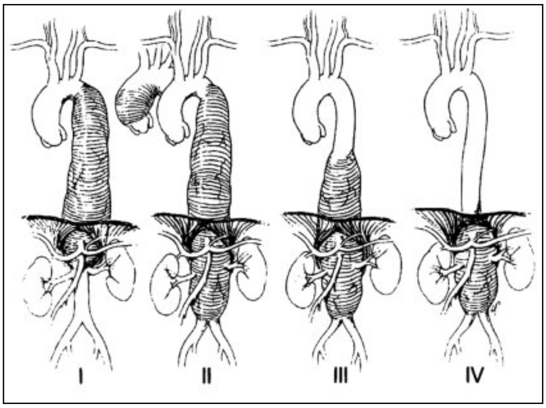

Figure 13–1. Crawford's classification system of thoracoabdominal aortic aneurysms.

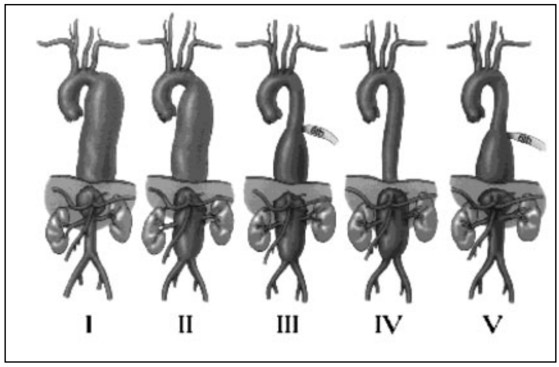

Figure 13–2. Safi's classification system of thoracoabdominal aortic aneurysms.

The open repair of TAAA has a high mortality and morbidity when treated by open techniques.[3,4] These risks have persisted despite advances in operative technique (including cardiopulmonary or left heart bypass, hypothermic cardiopulmonary arrest, selective visceral perfusion, spinal cord protection) and higher standards of perioperative care.

EVOLUTION OF THE HYBRID REPAIR

In 1991, Parodi et al. described the deployment of the first endovascular stent-graft (EVSG) in an infrarenal abdominal aortic aneurysm.[5] By 1994, as a direct evolutionary step, Dake et al. then used an EVSG for isolated descending thoracic aortic aneurysms.[6] This use of EVSG for aortic aneurysms limited to the thoracic segment showed significant early promise. However, their use for extensive TAAA was necessarily limited by the presence of the arch vessels proximally and the visceral and renal vessels distally.

In 1999, Quinones-Baldrich et al. were the first to report a combined endovascular and open surgical approach for a type IV TAAA.[7] Previous abdominal aortic surgery and concomitant visceral artery aneurysms precluded an open repair. Retrograde visceral bypasses from a limb of a preexisting bifurcated aortic tube graft were performed followed by TAAA stent-grafting. By revascularising the visceral and renal branches first, total endovascular aneurysm exclusion was achieved by completion endo-grafting.

Rimmer et al. in 2003, at St Mary's, used a similar technique of retrograde visceral/renal revascularisation with completion endo-grafting for a 49-year-old gentleman with a 9 cm aneurysm of native aorta occurring between a previous infrarenal abdominal and an upper descending thoracic aortic aneurysm repair.[8] Three years later, Black et al. from St Mary's reported the largest published series of these repairs describing a total of 29 attempted visceral hybrid procedures.[9] Our unit performs this technique in preference to an open repair for Crawford Type I, II, and III TAAA, while an open approach with medial visceral rotation is used for Crawford Type IV aneurysms. These repairs are particularly attractive and deemed less invasive as they avoid the need for a thoracotomy, single-lung ventilation, aortic cross-clamp, left or full heart bypass, as well as the extensive tissue dissection all associated with an open repair.

ST MARY'S VISCERAL HYBRID REPAIR

Technique

The patient is placed in a supine position under general and epidural anaesthesia. Cerebrospinal fluid drainage is always used. We routinely use cell salvage techniques with rapid infusers available. Arterial and central venous lines, urethral catheterization, and transoesophageal echocardiography are all mandatory perioperative invasive monitoring.

A midline laparotomy allows for adequate exposure of the abdominal aorta, the origins of the renal arteries, the coeliac axis, and the superior mesenteric artery (SMA). The in-flow site for retrograde visceral bypass grafting is determined by the distal extent of aneurysmal disease and previous abdominal surgery. If a previous infrarenal repair has been undertaken, the bypass grafts are anastomosed in an end-to-side fashion to the existing graft. If an infrarenal repair is possible, this is completed first and bypass grafts are subsequently sutured as before. If the infrarenal aorta is normal, an arteriotomy is performed and the bypass grafts anastomosed in an end-to-side fashion to the native aorta. If the aneurysmal disease extends to the bifurcation, one external iliac artery can provides the in-flow to the bypass grafts.

Two inverted (14 by 7mm or 16 by 8mm) Dacron® trouser-grafts can function as the conduits. Otherwise, a single trouser-graft is used with additional side-limbs sutured in an end-to-side manner. This four-limbed "spaghetti graft" is fashioned in a bespoke fashion during the procedure.

The renal arteries are sequentially anastomosed in an end-to-side fashion. The two remaining graft limbs are routed along the base of the small bowel mesentery to the coeliac axis and SMA in an end-to-side fashion. If Doppler signals are satisfactory in the bypass grafts (with the origins of the native vessel clamped), they are subsequently suture-ligated to prevent retrograde flow into the aneurysm sac (type II endoleak).

Following successful visceral and renal bypass, a suitable access site is chosen for endovascular stent deployment. A dedicated conduit attached to the common iliac artery or the abdominal aorta is common, but native vessels are also used provided they are of suitable caliber. An angiogram catheter is introduced on the contralateral side and the stents are deployed in a sequential fashion from the left subclavian artery through the thoracic aorta to the landing zone. Completion angiography after adjunctive procedures (extension cuff, giant Palmaz stent, balloon molding) then confirm exclusion of the aneurysm. Figure 13–3 shows a Type III TAAA and Figure 13–4 depicts a Type III TAAA repaired with visceral hybrid procedure.

Other Experiences of Hybrid Repairs of TAAA

Several centers around the world have published individual cases/small series (<5) of hybrid approaches to TAAA.[7,8,10-25] The results of these cases are

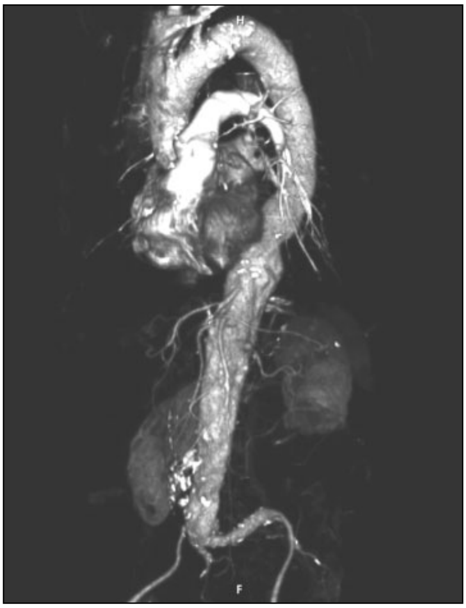

Figure 13–3. Type III TAAA

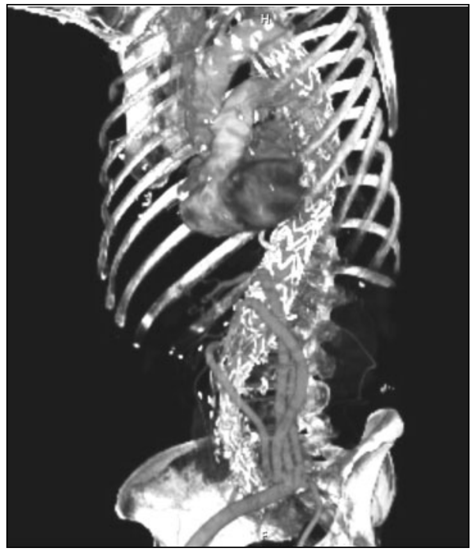

Figure 13–4. Type III TAAA repaired with visceral hybrid procedure

encouraging, considering the complicated nature of the TAAA disease process as well as the patients' comorbidities. Of the 30 patients in this combined series, spinal cord ischaemia appeared to be rare or went unreported. Other postoperative complications were greatly reduced and intensive care stay was less than that of open TAAA surgery. Of note, no standard operative technique was employed and there was much variation in the EVSG used.

Resch et al. have reported their series of 13 staged hybrid repair of TAAA.[26] They all underwent retrograde visceral bypasses (11 ilio-visceral and two infrarenal aortic-visceral) as a first procedure prior to completion with EVSG. They report a 30-day mortality of 23% (3/13) for all patients. Their mean follow-up in the 10 surviving patients was 23 months (1–45), during which time a further two deaths were related to the hybrid repair. 2 patients unfortunately suffered paraplegia and two other patients had transient parapetic events.

Most recently, Zhou et al.[27] published their series of 31 high-risk patients undergoing hybrid approaches to TAAA. Although there were a variety of hybrid approaches used for these TAAA, 18 of these patients had aneurysms involving the visceral vessels: Crawford type I (three), III (eight) and IV (seven). They reported 15 patients required iliac-to-coeliac artery bypasses, 15 required iliac-to-SMA bypasses, and 10 required iliac-to-renal artery bypass grafting. There was no incidence of stroke or paraplegia reported in their series.

Donas et al.[28] recently analysed published data in their systematic review of "hybrid open-endovascular repairs of TAAA". Their study eligibility criteria were as follows:

1. TAAA was diagnosed on the basis of the Crawford classification, modified by Safi.
2. Hybrid open endovascular repair (visceral bypass followed by endovascular stent-graft implantation) was the intended repair strategy and was completed in all patients.
3. There had been a minimum follow-up period of four months.
4. Diagnosis of complex TAAA had been made according to computed tomographic scans of the thorax, abdomen, and pelvis.
5. At least one of the basic outcome criteria (neurological, renal, respiratory morbidity, visceral vessel patency, and endoprosthesis-related complications, as well as the primary technical success rate and the total mortality rates, were stated.
6. Articles were excluded if TAAA repair was only by surgical or endovascular approaches alone.

Table 13–1 presents Donas et al.'s systematic review.[28]

Of the 13 studies identified and included in their statistical analysis, the nubmer of patients reported totalled 58: M:F 37:21 (64.4:35.6%). The mean age of the patients was 68.8 years (range 35–80, median 69.6, 95%CI [72.8, 64.9]). There were 15 Crawford type I TAAA, 21 type II, 11 type III, six type IV, and five type V. The mean follow-up period was 14.3 +/- 8.4 months (range 4–36, median 12, 95%CI [18.7, 9.9]). The mean aneurysm diameter was 7.15 cm (range 5–12, median 7.5, 95%CI [7.87, 6.69]).

Table 13–1. Donas et al.'s Systematic Review[28]

Authors	Year	Location	Follow-up	Number of Patients	30-day Mortality
Black et al[9]	2006	London/UK	8	26	6
Flye et al[18]	2004	St.Louis, Mo/USA	14.6	3	0
Donas et al[29]	2007	Cologne/Germany	21	8	1
Chiesa et al[30]	2004	Milan/Italy	12	1	0
Macierewicz et al[10]	2000	Nottingham/UK	22	1	0
Quinones-Baldrich et al[7]	1999	LA, Calif/USA	6	1	0
Lawrence-Brown et al[31]	2000	Perth/Australia	36	2	0
Kotsis et al[16]	2003	Ulm/Germany	14	4	1
Agostinelli et al[12]	2002	Parma/Italy	6	1	0
Iguro et al[15]	2003	Kagoshima/Japan	12	1	0
Saccani et al[13]	2002	Parma/Italy	4	3	1
Khoury et al[32]	2002	Detroit/USA	21	1	0
Gawenda et al[33]	2006	Cologne/Germany	12	6	0

In this series, no patients developed paraplegia or other procedure-related neurological deficits due to spinal cord injury or ischaemia. Thirty-day elective and urgent mortality was 10.7% (6/55). Three patients with a ruptured TAAA who underwent a hybrid procedure died. The overall early and long-term mortality for completed procedures was 15.5% (9/58).

Advantages

The authors perceive several advantages of the visceral hybrid approach over standard, open techniques:

- No thoracotomy
  - Fewer pulmonary complications
  - Fewer cardiac arrhythmias
  - Less pain
- Reduced hypothermia with subsequent reduction in
  - Coagulopathy
  - Cardiovascular instability
- Reduced rate of spinal cord ischaemia
- Reduced duration of mesenteric and visceral ischaemia with reduction in
  - Acidosis and associated problems
  - Gut bacteria translocation/sepsis
  - Renal failure/use of renal replacement therapy
- Less blood loss/reduced transfusion requirement
- Reduced hospital stay
  - ITU
  - Absolute
- More patients can be treated where comorbidity previously excluded them

CONCLUSION

The Future of Hybrid Repairs

The visceral hybrid repair of TAAA may be a bridging measure until branched EVSG technology matures to the point of established use.

Endovascular repair of juxtarenal and suprarenal abdominal aortic aneurysms with preservation of visceral perfusion by fenestrated[34,35] or branched[36] EVSG has been shown to be feasible, and using similar technology, several authors have described total endovascular repair of complex thoracic aortic disease.[37,38] Until recently, Chuter et al. were the only authors to report total endovascular repair of a TAAA with preservation of all four visceral vessels in a single patient.[39] Anderson et al. reported a series of four patients treated in this way: 12 of 13 target vessels were revascularized, with no endoleaks. Three of the patients required further procedures to correct bleeding from access vessels, and one patient died from multi-organ dysfunction syndrome after such a procedure. CT at 12 months confirmed antegrade perfusion in all 10 target vessels.[40]

Further improvement of, and access to, such devices, and correct patient selection (in light of the EVAR 2 trial results)[41] will see a reduction in the numbers of visceral hybrid procedures being performed for TAAA. In the meantime, and in cases unsuitable for fenestrated/branched EVSG, the visceral hybrid repair remains a robust and adaptable method of treating this complex and life-threatening disease process.

REFERENCES

1. Crawford ES, et al. Thoracoabdominal aortic aneurysms: preoperative and intraoperative factors determining immediate and long-term results of operations in 605 patients. *J Vasc Surg*. 1986;3(3):389–404.
2. Safi HJ, et al. Progress in the management of type I thoracoabdominal and descending thoracic aortic aneurysms. *Ann Vasc Surg*. 1999;13(5):457–462.
3. Svensson LG, et al. Dissection of the aorta and dissecting aortic aneurysms. Improving early and long-term surgical results. *Circulation*. 1990;82(5 Suppl):IV24–38.
4. Svensson LG, et al., Experience with 1509 patients undergoing thoracoabdominal aortic operations. *J Vasc Surg*. 1993;17(2):357–368; discussion 368–370.
5. Parodi JC, Palmaz JC, Barone H.D. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. *Ann Vasc Surg*. 1991;5(6):491–499.
6. Dake MD, et al. Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. *N Engl J Med.* 1994;331(26):1729–1734.
7. Quinones-Baldrich WJ, et al. Repair of type IV thoracoabdominal aneurysm with a combined endovascular and surgical approach. *J Vasc Surg*. 1999;30(3):555–560.
8. Rimmer J, Wolfe JH. Type III thoracoabdominal aortic aneurysm repair: a combined surgical and endovascular approach. *Eur J Vasc Endovasc Surg*. 2003;26(6):677–679.
9. Black SA, et al. Complex thoracoabdominal aortic aneurysms: endovascular exclusion with visceral revascularization. *J Vasc Surg*. 2006;43(6):1081–1089; discussion 1089.
10. Macierewicz JA, et al. Endovascular repair of perisplanchnic abdominal aortic aneurysm with visceral vessel transposition. *J Endovasc Ther*. 2000;7(5):410–414.
11. Juvonen T, et al. Combined surgical and endovascular treatment of pseudoaneurysms of the visceral arteries and of the left iliac arteries after thoracoabdominal aortic surgery. *Eur J Vasc Endovasc Surg*. 2001;22(3):275–277.
12. Agostinelli A, et al. Repair of coexistent infrarenal and thoracoabdominal aortic aneurysm: combined endovascular and open surgical procedure with visceral vessel relocation. *J Thorac Cardiovasc Surg*. 2002;124(1):184–185.
13. Saccani S, et al. Thoracic aortic stents: a combined solution for complex cases. *Eur J Vasc Endovasc Surg*. 2002; 24(5):423–427.
14. Watanabe Y, et al. Successful endografting with simultaneous visceral artery bypass grafting for severely calcified thoracoabdominal aortic aneurysm. *J Vasc Surg*. 2002;35(2):397–399.
15. Iguro Y, et al. Endovascular stent-graft repair for thoracoabdominal aneurysm after reconstruction of the superior mesenteric and celiac arteries. *J Thorac Cardiovasc Surg*. 2003;125(4):956–958.
16. Kotsis T, et al. Treatment of thoracoabdominal aortic aneurysms with a combined endovascular and surgical approach. *Int Angiol*. 2003;22(2):125–133.
17. Chiesa R, et al. Two-stage combined endovascular and surgical approach for recurrent thoracoabdominal aortic aneurysm. *J Endovasc Ther*. 2004;11(3):330–333.
18. Flye MW, et al. Retrograde visceral vessel revascularization followed by endovascular aneurysm exclusion as an alternative to open surgical repair of thoracoabdominal aortic aneurysm. *J Vasc Surg*. 2004;39(2):454–458.
19. Lundbom J, et al. Combined open and endovascular treatment of complex aortic disease. *Vascular*. 2004;12(2):93–98.
20. Bonardelli S, et al. Combined endovascular and surgical approach (hybrid treatment) for management of type IV thoracoabdominal aneurysm. *Vascular*. 2005;13(2):124–128.

21. Fulton JJ, et al. Endovascular stent-graft repair of pararenal and type IV thoracoabdominal aortic aneurysms with adjunctive visceral reconstruction. *J Vasc Surg*. 2005;41(2): 191–198.
22. Gregoric ID, et al. Endovascular exclusion of a thoracoabdominal aortic aneurysm after retrograde visceral artery revascularization. *Tex Heart Inst J*. 2005;32(3):416–420.
23. Yoshida M, et al. Combined endovascular and surgical procedure for recurrent thoracoabdominal aortic aneurysm. *Ann Thorac Surg*. 2006;82(3):1099–101.
24. Ruppert V, et al. Endovascular repair of thoracoabdominal aortic aneurysm with multivisceral revascularization. *J Vasc Surg*. 2005;42(2):368.
25. Tachibana K, et al. Endovascular stent-grafting for thoracoabdominal aortic aneurysm following bypass grafting to superior mesenteric and celiac arteries: report of two cases. *Ann Thorac Cardiovasc Surg*. 2005;11(5):335–338.
26. Resch TA, et al. Combined staged procedures for the treatment of thoracoabdominal aneurysms. *J Endovasc Ther*. 2006;13(4):481–489.
27. Zhou W, et al. Hybrid approach to complex thoracic aortic aneurysms in high-risk patients: surgical challenges and clinical outcomes. *J Vasc Surg*. 2006;44(4):688–693.
28. Donas KP, et al. Hybrid Open-endovascular Repair for Thoracoabdominal Aortic Aneurysms: Current Status and Level of Evidence. *Eur J Vasc Endovasc Surg*. 2007.
29. Donas KP, et al. Combined endovascular stent-graft repair and adjunctive visceral vessel reconstruction for complex thoracoabdominal aortic aneurysms. *Int Angiol*. 2007;26(3):213–218.
30. Chiesa R, et al, Hybrid approach to thoracoabdominal aortic aneurysms in patients with prior aortic surgery. *J Vasc Surg*. 2007;45(6):1128–1135.
31. Lawrence-Brown M, et al. Hybrid open-endoluminal technique for repair of thoracoabdominal aneurysm involving the celiac axis. *J Endovasc Ther*. 2000;7(6):513–519.
32. Khoury M. Endovascular repair of recurrent thoracoabdominal aortic aneurysm. *J Endovasc Ther*. 2002;9 Suppl 2:II106–11.
33. Gawenda M, et al. Hybrid-procedures for the Treatment of Thoracoabdominal Aortic Aneurysms and Dissections. *Eur J Vasc Endovasc Surg*. 2007;33(1):71–77.
34. Greenberg RK, et al., Primary endovascular repair of juxtarenal aneurysms with fenestrated endovascular grafting. *Eur J Vasc Endovasc Surg*. 2004;27(5):484–491.
35. Verhoeven EL, et al. Treatment of short-necked infrarenal aortic aneurysms with fenestrated stent-grafts: short-term results. *Eur J Vasc Endovasc Surg*. 2004;27(5):477–483.
36. Hosokawa H, et al., Successful endovascular repair of juxtarenal and suprarenal aortic aneurysms with a branched stent graft. *J Vasc Surg*. 2001;33(5):1087–1092.
37. Inoue K, et al. Transluminal endovascular branched graft placement for a pseudoaneurysm: reconstruction of the descending thoracic aorta including the celiac axis. *J Thorac Cardiovasc Surg*. 1997;114(5):859–861.
38. Bleyn J, et al. Side-branched modular endograft system for thoracoabdominal aortic aneurysm repair. *J Endovasc Ther*. 2002;9(6):838–841.
39. Chuter TA, et al. An endovascular system for thoracoabdominal aortic aneurysm repair. *J Endovasc Ther*. 2001;8(1):25–33.
40. Anderson JL, et al. Repair of thoracoabdominal aortic aneurysms with fenestrated and branched endovascular stent grafts. *J Vasc Surg*. 2005;42(4):600–607.
41. Endovascular aneurysm repair and outcome in patients unfit for open repair of abdominal aortic aneurysm (EVAR trial 2): randomised controlled trial. *Lancet*. 2005;365(9478): p. 2187–2192.