81 Hybrid and Redo Strategies for Descending and Thoracoabdominal Aorta

Rana O. Afifi, Hazim J. Safi, and Anthony L. Estrera

81.1 Introduction

Aortic aneurysm is the 13th leading cause of death in the United States [1]. The prevalence of aortic aneurysms appears to be increasing, due in part to a higher level of awareness, an advancement in imaging modalities, and an aging population [2]. The incidence of thoracic aortic aneurysms is estimated to be around 10.4 cases per 100,000 person-years [3].

Open surgical repair has been the treatment of choice for degenerative thoracic aortic aneurysms since the 1950s. Thoracic endovascular aortic repair (TEVAR) was first used in 1987 [4], and since that time, many publications have reported a lower mortality and morbidity in TEVAR compared to open repair of thoracic aortic aneurysm [5–8]. Hence, TEVAR has become the predominant method of treatment for most thoracic aortic pathologies, including aneurysms, traumatic injury, penetrating aortic ulcers, and aortic dissection.

Despite the significant advances in perioperative critical care, open surgical techniques, and endovascular therapy, there are still challenging situations in which conventional endovascular therapy is not applicable and open surgical repair carries a high perioperative risk.

In this chapter, we will discuss strategies for redo operations and hybrid procedures for descending thoracic aorta (DTA) and thoracoabdominal aortic aneurysm (TAAA).

81.2 Redo Strategies for DTA and TAAA Surgeries

Redo surgery for DTA and TAAA is often dreaded by surgeons due to its higher risk for morbidity and mortality compared to the primary surgery. This is due to respiratory complications and a higher risk of bleeding [9–11]. Multiple aortic aneurysms is not an uncommon scenario. In fact, Crawford et al. [12] reported that 59.6% of patients originally presenting with ascending, transverse arch or descending aortic aneurysms developed multiple aortic aneurysms in other segments. Other publications have reported that the most common reason for redo DTA or TAAA repair was new aneurysms or extension of disease (70–90%) [11–13].

81.3 Outcomes of Redo DTA and TAAA Surgeries

Information regarding redo surgery for DTA and TAAA is limited in the literature as few publications have reported outcomes of such complicated

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O. H. Stanger et al. (eds.), *Surgical Management of Aortic Pathology*,
https://doi.org/10.1007/978-3-7091-4874-7_81

repairs. Earlier small series publications reported 25–28% early mortality rate [14–16]. More recent papers report a decrease in early mortality, 4.5–13.3% [10, 11, 17, 18].

Gloviczki and colleagues [9] reviewed the Mayo Clinic experience over two decades with 102 consecutive patients with multiple aortic aneurysms who underwent 201 aortic reconstructions. In 65 patients (63.7%), the initial operations involved the thoracic aorta; TAAA repair was performed as a subsequent procedure in 37 patients (36.3%). They found that overall operative mortality increased with the ordinal number of procedures: 4.4% for the first operation, 10.4% for the second, and 33.3% for the third.

Coselli et al. [18] reported their experience over 10 years, comparing patients who underwent TAAA repair with vs. without previous thoracic aortic aneurysm repair (PTAR). In all, 723 consecutive patients underwent TAAA repair, 179 of whom had PTAR. Although differences did not reach statistical significance, patients without PTAR tended toward increased in-hospital mortality (8.5% vs. 4.5%; $p = 0.078$) and postoperative paraplegia/paraparesis rates (6.5% vs. 2.8%; $p = 0.069$). More patients without PTAR had cardiac complications (11.3% vs. 5.6%; $p = 0.028$) and required chronic hemodialysis (5.9% vs. 1.1%; $p = 0.009$). In the PTAR, they reported pulmonary complications in 60/179 (33.5%), stroke in 5/179 (2.7%), and postoperative bleeding in 3/179 (1.6%) patients, and 37 (20.6%) underwent concurrent splenectomy. As a group, the patients with PTAR in this series were younger than those without PTAR and, consequently, had fewer comorbid factors. Rupture was also more common in the group without PTAR, likely explaining the better outcomes in the redo surgery group.

Kawaharada et al. [10] reported the experience in a single center in Japan, comparing a group of patients (70) who underwent elective TAAA repair without those with a history of previous DTA repair [30]. Major postoperative complications in the redo group included paraplegia (10%), renal failure requiring hemodialysis (20%), and respiratory failure (30%).

Etz et al. [11] reported their experience over 20 years with TAAA repair in patients with previous thoracic aneurysm repair through left thoracotomy. Between 1988 and 2007, 60 patients underwent redo thoracotomy for DTA or TAAA. Hospital mortality was 13.3%. Respiratory complications occurred in 13 patients (21.6%), 5 of whom needed tracheotomy and 1 required extracorporeal membrane oxygenation (ECMO). Permanent dialysis was required in two (3.3%), with one patient suffering from postoperative paraplegia (1.7%), and three (5%) had bleeding that required reoperation. There were no strokes [11].

81.4 Technical Consideration in Redo Repair of DTA and TAAA

In our institution, the redo repair is carried out in similar fashion to our standard DTA and TAAA repair [19]. After induction of anesthesia and placement of double-lumen endotracheal tube, we use cerebrospinal fluid (CSF) drainage in the majority of the cases, unless the patient is hemodynamically unstable or there is a concomitant infection. The chest is entered through a left thoracoabdominal incision (sixth intercostal space). In redo surgery, additional precautions are needed. This part of surgery could be difficult, due to extensive adhesions, and it could take a few hours until the descending aorta is dissected with adequate proximal and distal control. Therefore, we limit division of adhesions to those essential for obtaining the necessary aortic exposure for the planned repair, minimizing pulmonary trauma and bleeding.

Etz et al. have described a 2-day procedure in a few patients to allow bleeding to subside and clearance of pulmonary secretions before institution of cardiopulmonary bypass. We usually use left heart bypass for distal aortic perfusion by accessing the inferior pulmonary vein or the proximal descending aortic graft from previous surgery (Fig. 81.1). We establish the arterial inflow through an 8-mm Dacron graft (DuPont,

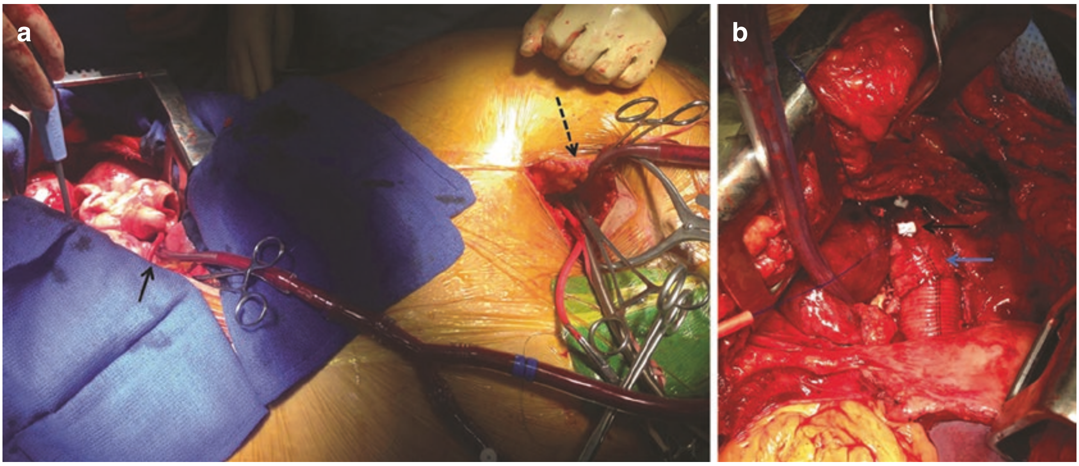

Fig. 81.1 (**a**) Left heart bypass for distal aortic perfusion by accessing the inferior pulmonary vein (arrow) and left femoral artery (dashed arrow). (**b**) Cannulation site for the left heart bypass (black arrow) in the descending aortic graft from previous surgery (blue arrow)

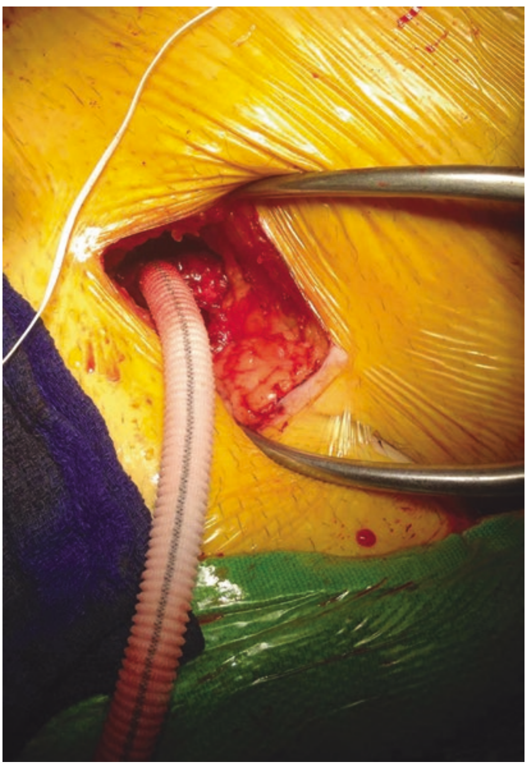

Fig. 81.2 A Dacron graft (DuPont, Wilmington, DE) sutured end to side to the common femoral artery as arterial inflow for the left heart bypass

Wilmington, DE) sutured end to side to the left common femoral artery (Fig. 81.2) or through the descending thoracic aorta if the distal anastomosis was completed first (distal-first approach) (Fig. 81.3). We use the distal-first approach in cases in which the left common femoral artery is not easily accessed for cannulation (i.e., previous aortobifemoral bypass, severely diseased vessel) [20, 21].

In redo cases due to visceral patch aneurysm (Fig. 81.4) in young patients and patients with genetic disorder (Marfan), we replace the graft with a side-branched thoracoabdominal aortic graft (STAG), which is a pre-sewn, multiple-branched woven Dacron graft that was designed by Dr. Hazim J. Safi in 1996 [22] (Fig. 81.5). For intercostal patch aneurysm, we reattach the intercostal arteries using a looped graft (Fig. 81.6).

Hypothermic circulatory arrest (HCA) can be used in cases where a placement of proximal aortic clamp is not feasible. Etz et al. reported the use of HCA in 30% of the redo repairs due to technical considerations. Lombardi and colleagues [17] utilized HCA in cases with visceral patch where they had to be converted from inclusion technique to separate bypasses to each vessel in the degenerated patch to provide additional visceral and renal protection during individual reconstruction of the visceral and renal vessels.

In the endovascular era, TEVAR is implemented in more complicated cases and with "off-label" use. This increases the risk for complications and a conversion to open repair at

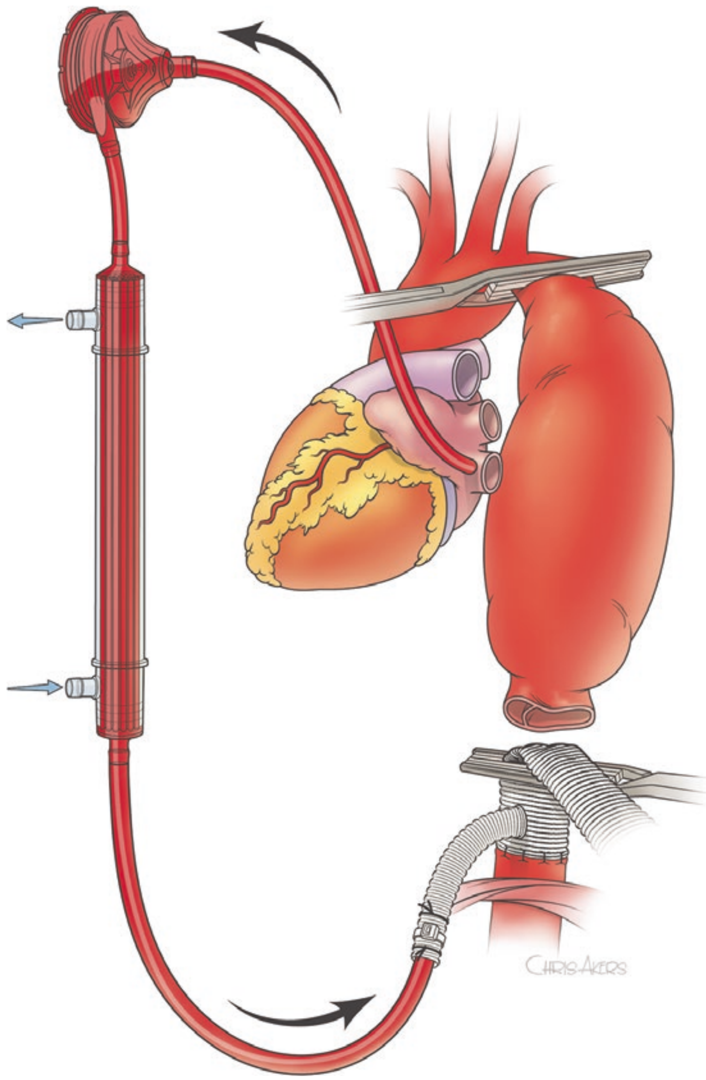

Fig. 81.3 Arterial inflow of left heart bypass through the descending thoracic aorta in "distal-first approach" (when the distal anastomosis completed first)

Fig. 81.4 Axial view of CT scan of visceral patch aneurysm (arrow)

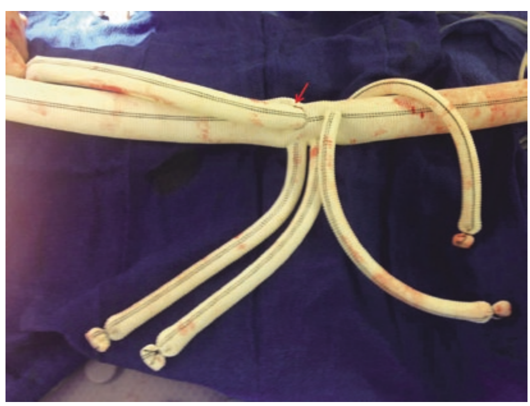

Fig. 81.5 A side-branched thoracoabdominal aortic graft (STAG). Four branches are pre-sewn for visceral/renal arteries. One additional branch (arrow) has been added for intercostal attachment

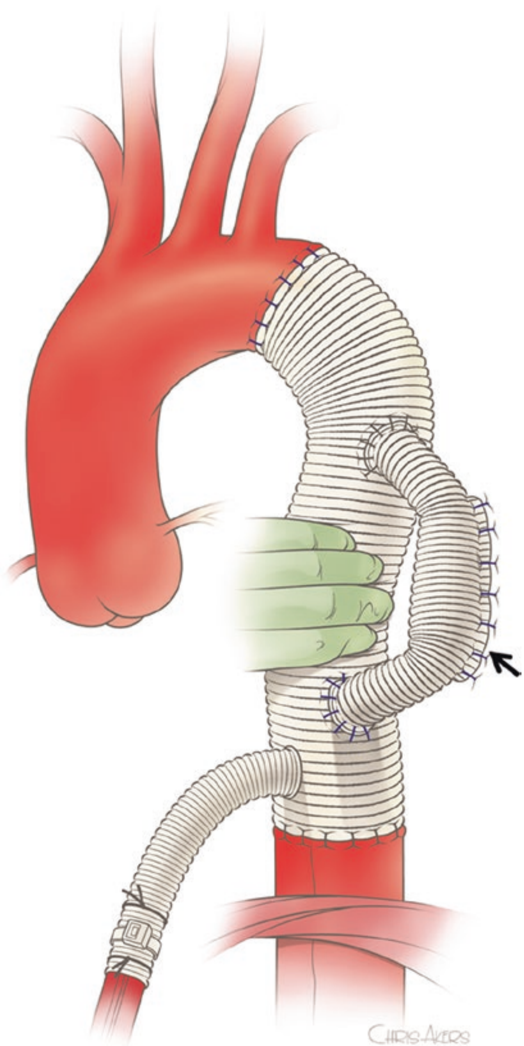

Fig. 81.6 A Dacron looped graft for intercostal arteries reattachment (arrow)

a later stage (Fig. 81.7) [23, 24]. Roselli et al. reported their experience from July 2001 to January 2012, with 50 patients who underwent TEVAR requiring additional open surgical repair, while HCA was required in 48%.

Redo repair of DTA and TAAA remains a challenge, with a higher risk for postoperative complications than the initial surgery. With increased expertise in endovascular surgery, more minimally invasive options, such as hybrid procedure, will likely become more appealing in treating those very complex cases.

81.5 Hybrid Procedures for DTA and TAAA

The conventional open repair for TAAA has evolved over the years, especially in the aspect of organ protection techniques, lowering the mortality and morbidity of this procedure in leading centers [19, 21, 22, 25–42]. However, it remains a great challenge for cardiothoracic and vascular surgeons, with significant rates of morbidity and mortality when performed in average centers.

Total endovascular repair of TAAA with fenestrated and branched stent graft has been described worldwide. Initial experience showed that this repair is safe and effective and reduces morbidity in patients with arch, thoracoabdominal, and pararenal aortic aneurysm [43–47]. The commercial devices for pararenal aortic aneurysms and TAAA extent II and III are with limited availability and still require 6–8 weeks for customization. There are "off-the-shelf" devices that allow treatment of more than 60–80% of patients with complex aneurysm. However, large series and long follow-up is lacking [48, 49]. These limitations have led a number of centers to come up with creative solutions for visceral artery bypasses using "chimney," "sandwich," "octopus," and "periscope" techniques, as well as physician-modified endografts [50–53]. Those approaches are limited by "off-label" indications and a lack of long-term follow-up.

Furthermore, total endovascular repair of TAAA, specifically four visceral endovascular bypasses, requires a high degree of expertise and capabilities that only few centers possess. The search for a third alternative for treatment complex aortic aneurysms led to the development of "hybrid" repair, which includes an extra-anatomic bypass for visceral vessels ("debranching"), followed by placement of an endograft for aneurysm exclusion. The hybrid procedure includes known surgical techniques and available commercial devices. It also minimizes the surgical stress by avoiding one-lung ventilation, the need for cardiopulmonary bypass, hypothermia, and aortic cross-clamping. Therefore, in many centers, it has become

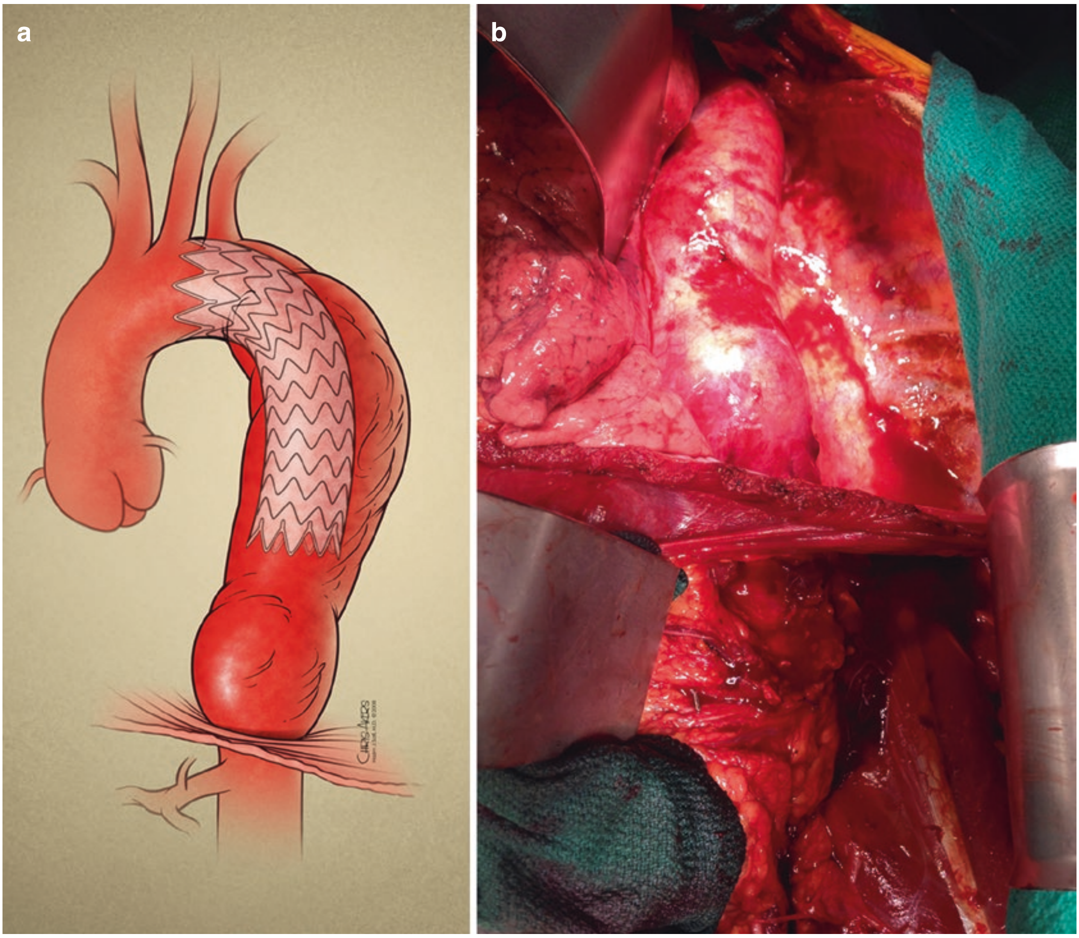

Fig. 81.7 DTA (extension of disease) following TEVAR. (**a**) Illustration. (**b**) Intraoperative picture

the treatment of choice for patients with TAAA and who are at high risk for conventional open repair [54, 55].

81.6 Outcomes of Hybrid Repair of TAAA

The outcomes of hybrid repair of TAAA remain with high morbidity and mortality in many centers. Oderich et al. [55] had reviewed many "single-center" experiences, with mortality ranging between 0 and 44% and morbidity between 3 and 69% [56–79]. Since this review, a few more centers have published results [54, 80–82]. The clinical outcomes of these published papers are summarized in Table 81.1.

There are few systematic reviews of the available literature that have been published on hybrid repair of TAAAs [83–85]. A recent review by Moulakakis et al. [85] included 528 patients and 14 reports published since 1999. There were 359 male (68%) and 169 female patients, with a mean age of 70.5 years. Aneurysm extent was classified as type I in 12.8%, type II in 23.2%, type III in 38%, type IV in 23.7%, and type V in 11.1%. A single-stage procedure was used in 47.5% and two-stage in 52.5%, with a mean period of 29.6 days between the two stages. Primary technical success, defined as completed visceral debranching and aneurysm exclusion by successful stent graft placement, was estimated as 95.4%. In all, 30-day or in-hospital mortality was 14.3%, and the most common causes of death were bowel

Table 81.1 Outcomes of hybrid thoracoabdominal aortic aneurysm repair

Author	Year	*N*	Mortality (%)[a]	Morbidity (%)	Spinal cord injury (%)[b]	Dialysis (%)	Endoleak (%)	Reintervention (%)	Mean follow-up (months)
Fulton et al. [1]	2005	10	0	50	0	0	10	10	8.7
Resch et al.[2]	2006	13	38	23	31	15	23	38	23
Black et al. [3]	2006	29	21	69	0	7	38	10	8
Donas et al. [4]	2007	8	12	37	0	12	0	25	21
Lee et al. [5]	2007	17	23	23	0	12	12	12	8
Gawenda et al. [6]	2007	6	0	0	0	0	17	0	12
Ballard et al. [7]	2008	4	25	50	25	25	0	0	12
Van de Mortel et al. [8]	2008	16	31	19	0	12	12	0	13
Quinones-Baldrich et al. [9]	2009	17	0	53	6	0	23	29	16.6
Biasi et al. [10]	2009	18	22	22	5	0	33	5	23
Da Rocha et al. [11]	2009	9	44	33	11	11	0	0	79.2
Donas et al. [12]	2009	58	26	[c]	3	0	12	7	22.1
Drinkwater et al. [13]	2009	107	15	3	12	26	31	[d]	[d]
Kabbani et al. [14]	2010	36	17	30	3	11	44	19	6
Patel et al. [15]	2010	29	3	3	3	17	34	7	30.5
Kuratani et al. [16]	2010	86	4	7	1	0	10	7	88.5
Chiesa et al. [17]	2010	41	17	15	7	0	10	2	23.3
Smith et al. [18]	2011	24	12	62	8	17[e]	8	37	11.7
Hurie et al. [19]	2011	39	35.9	[d]	5	12.8	43.5	35.9	24
Ham et al. [20]	2011	24	4.2[f]	25	4.2	12.5	4.2[f]	[d]	13.3
Lin et al. [21]	2012	58	24	52	[d]	10	3	3	27.3
Hughes et al. [22]	2012	58	13	[d]	3.5	12.1	3	3	26
Tshomba et al. [23]	2012	52	13.5[f]	28.8[f]	5.7	0	7.7	d	23.9

[a]Overall mortality
[b]Transient or permanent
[c]Nonspecified, only mortality group causes
[d]Nonspecified
[e]Nonspecified if dialytic or not
[f]Early (≤30 days)

ischemia, multisystem organ failure, respiratory complications, and aneurysm rupture prior to a second-stage procedure. Pooled rates of spinal cord injury were 7%, with irreversible paraplegia in 4.4%, and the pooled estimate of renal failure requiring dialysis was 7%. After a mean follow-up of 34.2 months, 21.1% of the patients had had endoleaks, and visceral graft patency was 96.5%.

The preliminary results of the North American Complex Abdominal Aortic Debranching (NACAAD) registry were presented at the 2011 Vascular Annual Meeting. Oderich et al. [55] summarized the results of this study. It included 208 patients treated for complex abdominal aortic aneurysms in 14 academic centers of North America. There were 118 male (57%) and 90 female (43%) patients with a mean age of 71 years. Aneurysm diameter averaged 6.6 ± 1.3 cm, and aneurysm extent included 163 TAAA (type I in 6%, type II in 25%, type III in 31%, and type IV) and 45 pararenal aneurysms. A single-stage debranching was performed in 92 patients (44%) and two-stage approach in 116 (56%). Arch debranching was needed in 22 patients (11%) to provide adequate proximal landing zone. The inflow for visceral reconstruction was based on the iliac arteries in 63%, aorta or aortic graft in 29%, or a hepatic/splenic artery in 8%.

Thirty-day or in-hospital mortality was 14% for all patients, 16% for TAAAs, and 9% for pararenal aneurysms. Morbidity occurred in 73% of the patients, most commonly pulmonary (22%), renal (19%), and gastrointestinal complications (14%). Spinal cord injury occurred in 21 patients (10%) and ischemic colitis in 13 (6%). After a median follow-up of 21 months, 70% of the patients had repeat aortic imaging. Endoleaks occurred in 23 patients (13%) and were classified as type I in 3%, type II in 8%, and type III in 1%. Primary visceral graft patency and freedom from reinterventions were 90 ± 2% and 85 ± 3% at 1 year, respectively.

81.7 Technical Considerations in Hybrid Repair of TAAA

The debranching procedure may be done through a midline incision, with transperitoneal or retroperitoneal approach. This is achieved in either a one- or two-stage fashion, with the aneurysm exclusion achieved by placement of the aortic stent graft. High-risk patients and those who have a difficult open reconstruction will benefit from the two-staged procedure. However, patients who don't require an extensive aortic coverage might be suitable for a one-stage repair, eliminating the risk of rupture while waiting for the second stage [55]. Hughes et al. [2] published their experience in TAAA hybrid repair in 47 patients. They performed the one-stage repair in the initial 33 patients and a two-stage repair in the same hospital in the recent 14 patients. Tshomba et al. [80] described their experience with hybrid repair of TAAA in 52 high-risk patients; 37 (71.2%) had a simultaneous repair and 15 (21.8%) a staged procedures.

The source of inflow to the extra-anatomic bypass is usually retrograde, originating of the distal common iliac artery or proximal external iliac artery. Other sources have been described, such as infrarenal aorta, aortic graft in patients with previous aortic repair, and renal or splenic arteries [55]. Tshomba et al. [80] have described an antegrade bypass originating of the ascending aorta through a median sternotomy extended into median laparotomy approach in three patients.

Many graft configurations have been described in the literature. Oderich et al. [55] at the Mayo Clinic prefer to use a trifurcated graft from one of the common iliac arteries, with an added limb, depending on the patient's anatomy. Lall et al. [1] have described using a bifurcated graft, which can be anastomosed with a short main body and graft limbs to the right renal and superior mesenteric arteries. To avoid kinks in prefashioned trifurcated grafts, separate graft limbs can be added for the celiac axis and left renal artery as needed. Hughes et al. [86] use a custom-designed, multibranched Dacron graft (Vascutek USA, Ann Arbor, Mich) with a 14-mm trunk, two 6-mm side limbs for the renal arteries, and two 8-mm side limbs for the visceral (celiac, SMA) arteries. In addition, there is a 10-mm side limb at the proximal end adjacent to the inflow anastomosis that is used as a conduit for the large sheaths during the delayed second endovascular stage.

Lachat et al. [58, 70] have described a modification of the technique, using VORTEC (Viabahn

Open Rebranching TEChnique). It allows for a suture-less anastomosis using Viabahn stent grafts (W.L. Gore & Associates, Flagstaff, AZ) for the visceral bypasses.

81.8 Conclusion

In the future, it is likely that hybrid repair will be replaced by total endovascular techniques in most centers. Future applications may be for patients who are high risk for open TAAA repair and those who fail total endovascular repair or in centers with no access or experience with fenestrated and branched endografts. Keys for successful outcomes include patient selection, case planning, and knowledge of the technical aspects of the procedure.

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