Hybrid thoracoabdominal aortic aneurysm repair: is the future here?

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Abstract: Open surgical repair has been the gold standard for thoracoabdominal aortic aneurysm (TAAA) repair for more than 6 decades, but 2 additional options have emerged: total endovascular TAAA repair and a hybrid approach that combines open and endovascular repair. Despite the optimism for an endovascular approach, long-term results for these repairs are still lacking. Some of the issues with this emerging technology include the risk of paraplegia after extensive endovascular repair, the need for multiple reinterventions, continuous stent-graft surveillance, endograft branch stenosis, as well as the significant learning curve. Interest in a hybrid approach has resurged despite the non-superior results compared to open TAAA. Commonly, the focus of the hybrid approach is now on performing a less extensive open TAAA repair, which is then extended with a stent-graft or vice versa. Moreover, this approach is now often performed in two stages in an effort to decrease the associated spinal cord ischemia. Open surgical repair after endovascular aortic repair is increasingly being performed to address serious complications, such as infection or fistula, that cannot be repaired by further endovascular intervention. As with any new technology, there will be an increase in the number of procedure-related complications and a decrease in the number of surgeons who can perform the traditional open operation with good results.

Keywords: Thoracoabdominal aortic aneurysm (TAAA) repair; hybrid repair; endovascular aortic repair (EAR); vascular surgery; aortic surgery

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Introduction

Despite significant advances in surgical techniques, perioperative adjuncts, and critical care, open thoracoabdominal aortic aneurysm (TAAA) repair remains a surgical challenge. In our series of 3,309 TAAA repairs, we reported an overall operative mortality rate of 8% and a 30-day mortality rate of 5%; key complication rates ranged from 1% to 6% (1). The traditional morbidities associated with open TAAA repair include paraplegia, paraparesis, renal failure necessitating dialysis, stroke, and intestinal ischemia, most of which are related to distal aortic ischemia (2). The risk of postoperative death or complications is increased in the most extensive TAAA repair (Crawford extent II TAAA repair). This repair typically involves replacing the aorta from just distal to the left subclavian artery to the aortic bifurcation. The risk is also increased in certain patient populations, such as older patients and those with congestive heart failure, poor pulmonary function, or renal disease (3-7). Because of the added operative risk in patients with these comorbidities, less invasive techniques

Table 1 Summary of pooled outcomes for 528 hybrid thoracoabdominal aortic aneurysm repairs from 14 studies published between 2005 and 2012

Postoperative complication	Pooled outcome, mean (95% confidence interval)
Operative mortality	14.3% (9.3–20.2%)
Symptomatic spinal cord ischemia	7.0% (4.9–9.5%)
Permanent spinal cord ischemia	4.4% (2.7–6.3%)
Mesenteric ischemia	4.5% (2.3–7.3%)
Permanent renal failure necessitating dialysis	7.0% (2.4–13.8%)

Data are from Moulakakis *et al.* (24).

have been developed (8-11). These alternative techniques include either a total endovascular approach or a combined open and endovascular "hybrid" approach to TAAA repair. The decision on which approach to use for TAAA repair—conventional open, endovascular, or hybrid—should be based on a clear understanding of the risks of each one as well as the individual needs of the patient.

Unlike with coronary artery bypass graft procedures or abdominal aortic aneurysm repairs (12-14), no well-established risk models specifically address the risk reserved for "high-risk" patients, and the decision is commonly left to the clinician's discretion (15,16). Algorithms have been developed to assist with decision pathways for hybrid versus open aortic repair in some centers. Benrashid and colleagues (17) identified being frail or over 65 years old or having coronary artery disease, valvular heart disease, congestive heart failure, chronic obstructive pulmonary disease, renal insufficiency, or previous open distal aortic repair as markers for high-risk repair. At our center, we recently reviewed whether female sex or distal aortic reoperation affected postoperative outcomes after TAAA repair and found no significant effect of either variable on early outcomes (18,19). Further research is needed to identify preoperative characteristics that are predictive of increased risk.

Alternative approaches to open TAAA repair

Hybrid TAAA repair

Combined open and endovascular hybrid TAAA repair generally involves 1 or 2 stages. In this approach, the visceral and renal arteries (namely, the celiac axis, superior mesentery, left renal, and right renal arteries) are rerouted by "debranching" the vessels with 8- or 10-mm bypass grafts with aortic reattachment sites above or below the proposed endovascular zone; the repair is followed by endovascular exclusion of the aneurysm, which then covers the vessel origins (20). The hybrid procedure, originally introduced in 1999 by Quinones-Baldrich and colleagues (21), was intended to be an improvement over traditional open TAAA repair because its use avoided aortic cross-clamping, thoracotomy, single-lung ventilation, and prolonged ischemia. In theory, this approach was a better option for patients who were considered poor candidates for open surgical repair.

However, in practice, the early hybrid TAAA experience was fraught with difficulty. The substantial morbidity and mortality after hybrid TAAA (6) repair led many centers to reserve it primarily for inoperable patients (22,23). In 2012, Moulakakis and colleagues (24) published a meta-analysis of outcomes of 528 hybrid TAAA repairs from 14 studies; they found a substantial mortality rate of 14.3% and a complication rate of 7.0% for spinal cord ischemia, 4.5% for mesenteric ischemia, and 7.0% for permanent renal failure (*Table 1*). Mesenteric ischemia after hybrid TAAA repair is a concern and may range from 17% to 40% (6,23). Chiesa and colleagues (25) reported that severe angulation of the superior mesenteric artery bypass graft is predictive of these ischemic complications.

Because of these findings, as well as an interest in "staged repair" concepts introduced by Griepp and others (26), newer hybrid techniques have been developed. Contemporary hybrid TAAA repairs often involve first performing a less extensive open TAAA repair (i.e., a Crawford extent III or IV TAAA repair) to reimplant the visceral arteries onto a short section of aortic replacement graft, rather than using a debranching approach with relatively long segments of bypass grafts; the repair is then extended with a stent graft or vice versa, in which at least one endovascular landing zone is a synthetic graft (27). This operation is completed in two stages (separated by days, weeks, or months), which appears to reduce major adverse effects (e.g., renal failure, spinal cord deficit, and operative death) as compared to

older methods of hybrid TAAA repair that necessitate debranching the visceral arteries (11,27,28). However, despite these preliminary positive outcomes, staged hybrid repairs are performed at an increased cost—nearly twice that of traditional open TAAA repair (7).

Total endovascular TAAA repair

As advancements in hybrid repair were being made, the development of total endovascular TAAA repair procedures progressed as well, and in recent years, the procedure has been simplified and delivered with high technical success (9). Entirely endovascular approaches to TAAA repair range from the use of bespoke devices with fenestrations or branches to accommodate the visceral arteries (most custom-made devices have a 6-week manufacturing delay) to the use of ad-hoc approaches incorporating a combination of available endovascular devices in an off-label fashion (e.g., parallel, snorkel, telescope, and chimney approaches). Each purely endovascular approach has a sharp learning curve, and early on in their development, many had considerable mortality and morbidity. A remaining concern is the potential for developing a spinal cord deficit after extensive (Crawford extent II) endovascular TAAA repair (29). However, in most contemporary series of endovascular TAAA repairs, few complications are reported (9,10,30,31). Nevertheless, the Achilles' heel of total endovascular approaches is the relatively frequent need for secondary reintervention (31), which necessitates continued postoperative surveillance. Additionally, it is unclear whether endovascular TAAA repair can be used in all patients, such as those with highly complex anatomy or those with mycotic aneurysm. For example, patients with advanced age, who in theory are the most likely to benefit from this approach, are also more likely to present emergently with aortic rupture, and until very recently, the need for emergent repair prohibited the use of custom-manufactured branched and fenestrated devices. However, Wolosker and colleagues (32) recently reported the successful emergent use of an off-the-shelf branched device to treat a patient with aortic rupture. *Table 2* shows the relative advantages and disadvantages of hybrid TAAA repair compared to endovascular TAAA repair.

Table 2 Overview of hybrid aortic repair versus total endovascular aortic repair of distal aorta

Hybrid aortic repair
Advantages
Option for high-risk patients
Ability to secure 1 or more landing zones in synthetic graft
Ability to stage procedures
Option for patients with complex anatomy
May avoid use of cardiopulmonary bypass
May avoid thoracotomy
May extend prior aortic repair (full salvage of prior EAR)
Disadvantages
Requires abdominal incision
Postoperative mesenteric ischemia often lethal
Visceral/renal branches may thrombose
Endoleak
Unknown durability
Cost
Total endovascular aortic repair
Advantages
Avoids thoracotomy
Improved outcomes in contemporary repair
Ability to use parallel grafts in an emergent repair
Disadvantages
Endoleak
Visceral/renal branches may collapse
Radiation
Often requires specialized facilities
Limited use in patients with complex anatomy

EAR, endovascular aortic repair.

Open repair after endovascular aortic repair (EAR)

Over the last 2 decades, while complex hybrid and endovascular approaches were being developed and refined, the rates of standard descending thoracic and abdominal EAR increased dramatically, despite related complications and unknown durability associated with this treatment. The decision to perform conventional open TAAA repair after endovascular treatment is not straightforward, and additional endovascular repair is typically performed first in an attempt to address complications. However, the conversion to open repair is often warranted in the case of serious complications, such as fistula, infection of the

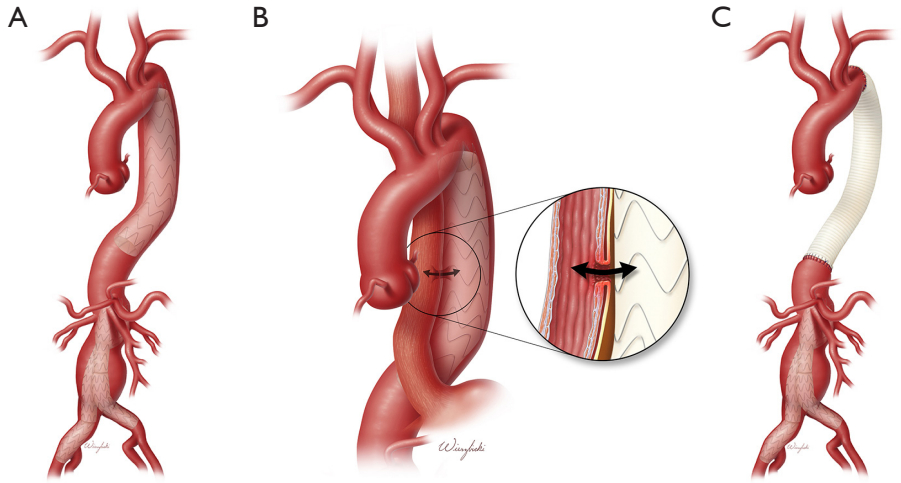

Figure 1 Illustrations demonstrating open aortic repair after emerging complications of endovascular aortic repair. (A) A 72-year-old man previously had both an endovascular abdominal and descending thoracic aortic repair; (B) over the course of a year, an aortoesophageal fistula developed and infection was present. Because of these complications, an open repair was necessary; (C) the stent-graft in the descending thoracic aorta was removed and replaced with a graft. Used with permission of Baylor College of Medicine.

stent-graft, retrograde type A dissection, device collapse or migration, and some types of endoleak (i.e., types Ia and Ib) or continued aneurysmal expansion (*Figure 1*) (33,34). As the number of patients treated with EAR increases, the number of patients that will need an open repair after endovascular repair is expected to also increase.

From 1996 through 2017, 159 patients with previous EAR underwent an open or endovascular reintervention at our major quaternary referral aortic center. Of these repairs, 22 (14%) involved the full salvage of the deployed stent-graft, which was incorporated into an adjacent open repair. Partial or complete extraction of the stent graft was performed in 90 patients, and for these patients, the rates of early operative death, permanent stroke, and renal failure were 8%, 1%, and 3%, respectively. However, the postoperative risk increases greatly in patients who undergo highly complex open conversion repairs, such as cases of infection or fistula. Melissano and colleagues (35) reported that the risk of early death may increase to as high as 17% when infection is present. Similarly, repair involving an aortic fistula is challenging and must additionally address the other injured organ or structure. *Figure 2* shows a case in which a patient developed an aortoesophageal fistula after endovascular repair and required complete extraction of the stent-graft via open descending thoracic aorta repair and resection of the esophagus.

The risk of late conversion after endovascular repair in patients with genetically triggered aortic disease (GTAD) is of particular interest; this type of repair is nearly universally considered an off-label approach, and results are generally unpredictable (37). In many centers, endovascular repair in patients with GTAD is performed only in cases in which the stent-graft can be landed within a previously placed surgical aortic graft or can be used as a bridge to definitive open repair. In the current era, the use of the endovascular technology has been extended to all types of aortic pathology because of its less invasive nature, ease of use, and lower associated morbidity; therefore, a certain number of associated failures is expected and may necessitate open repair at an experienced aortic center.

Conclusions

Hybrid and total endovascular approaches to TAAA repair are here to stay. These approaches are used most commonly in high-risk patients, such as octogenarians with multiple comorbidities or those who are considered frail. The determination of the best treatment approach for patients with complex aortic disease will likely be made based on the patient's health as well as the individual clinician's familiarity with the technology. Hybrid and total endovascular approaches show promising results but are associated with the risk of paraplegia and mesenteric ischemia in the early postoperative period and the risk of multiple reinterventions

Figure 2 Operative video demonstrating a case of stent-graft extraction after open repair (36). A 72-year old man with prior endovascular abdominal and descending thoracic aortic repair developed an aortoesophageal fistula, which was further complicated by infection. A redo thoracotomy was performed. The fistula was clearly seen. The stent-graft in the descending thoracic aorta was removed and replaced with a 28-mm Dacron graft. Pericardial fat tissue was used to protect the replacement graft, and the esophagus was resected. The patient continues to do well 6 months after the repair, and esophageal reconstruction is scheduled in the near future. Used with permission of Baylor College of Medicine.
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in the late postoperative period; additionally, a strict imaging surveillance protocol after repair must be followed. Furthermore, many clinicians will likely lack access to this advanced technology, and gaining sufficient experience to become proficient in its application remains problematic. Additionally, the use of hybrid and endovascular TAAA repair in emergency situations is limited, as both of these approaches are better suited to elective repair. Given the variety and difficulty of clinical scenarios combined with the continued development of novel approaches, evaluating these complex endovascular procedures is difficult. Lastly, the number of surgeons who can safely perform traditional open TAAA surgery is decreasing. It is safe to say the future is here and looms large, but challenges remain in deciding on the exact technique, the timing, and the optimal target population for endovascular repair.

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Footnote

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